AN INVESTIGATION OF FLUORIDE CONCENTRATION IN DRINKING WATER OF SANGANER TEHSIL, JAIPUR DISTRICT, RAJASTHAN, INDIA AND DEFLUORIDATION FROM PLANT MATERIAL

UNE ÉTUDE DE LA CONCENTRATION DE FLUORURE DANS L'EAU POTABLE DE SANGANER TEHSIL, DISTRICT DE JAIPUR, RAJASTHAN, INDE ET DÉFLUORURATION PAR MATIÈRE VÉGÉTALE

UNO STUDIO SULLA CONCENTRAZIONE DI FLUORURO NELL'ACQUA POTABILE DI SANGANER TEHSIL, DISTRETTO DI JAIPUR, RAJASTHAN, INDIA E DEFLUORIZZAZIONE MEDIANTE MATERIALE VEGETALE

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Abstract

Forty water samples of 20 villages of Sanganer tehsil, Jaipur district were analyzed for determining fluoride ion concentrations. High fluoride containing regions were identified on the basis of fluoride levels of the water samples and also on the prevalence rate of dental and skeletal fluorosis of the study area. Fluoride maps, which distinguish the regions containing the water sources of different ranges of fluoride ion concentrations, were also prepared by isopleth's technique, a statistical method. Water samples containing high fluoride levels were defluoridated with low-cost materials prepared from plant byproducts. These materials successfully decrease the fluoride ions concentration to an acceptable limit (from 0.5 to 1.5 mg/L) without disturbing drinking water quality standards.
Keywords: S*anganer tehsil; defluoridation; plant by products; carbon adsorbents*

Résumé

Quarante échantillons d'eau de 20 villages de Sanganer Tehsil, district de Jaipur ont été analysés pour déterminer les concentrations d'ions fluorure. Les territoires avec élevées concentrations de fluorure ont été identifiés sur la base des niveaux de fluorure des échantillons d'eau ainsi que sur la fréquence de fluorose dentaire et osseuse dans la zone d'étude. Des cartes de fluorure, distinguent les régions contenant les sources d'eau avec les différents concentrations des ions fluorure, ont été préparées par isoplèthes, une méthode statistique. Les échantillons d'eau contenant des niveaux élevés de fluorure ont été défluorés par des matériaux à prix très bas préparés à partir des sous-produits d'origine végétale. Ces matériaux ont étés capable de réduire la concentration des ions fluorure à une limite acceptable (de 0.5 à 1.5 mg / L) sans altérer les standards de qualité d'eau potable.

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Mots clés: *Sanganer tehsils; défluoration; produits végétaux; adsorbants carbonés*

Riassunto
Sono stati analizzati chimicamente 40 campioni di acqua di 20 villaggi di Sanganer Tehsil, quartiere di Jaipur, per la determinazione delle concentrazioni di ioni di fluoro. Sono state individuate aree che presentano alte concentrazioni di fluoro sulla base dei livelli di fluoruro nei campioni di acqua potabile ed anche sul tasso di prevalenza di fluorosi dentale e scheletrica relativa all'area di studio. Sono state predisposte mediante metodo statistico mappe relative alla distribuzione del fluoro, con la classificazione delle regioni in funzione della diversa concentrazione dei fluoruri nelle sorgenti d'acqua. Campioni di acqua contenente alti livelli di fluoro sono stati sottoposti a defluorizzazione mediante sottoprodotti a basso costo di origine vegetale. Questi materiali sono in grado di abbassare la concentrazione di ioni fluoruro a limiti ammissibili (da 0.5 a 1.5 mg/L) senza alterare gli standard di qualità dell'acqua potabile.
Parole chiave: *Sanganer tehsil; defluorizzazione; prodotti vegetali; carbonio adsorbenti*

Introduction

Fluorides is widely distributed in nature and it has been estimated that the element fluorine in the form of fluoride constituents 0.32% of the earth's crust (WHO, 1984). Fluoride could be found in a number of minerals, of which fluorspar, cryolyte and fluorapatite are the most common (WHO, 1993). Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking water have clearly indicated that fluoride primarily produces effects on skeletal tissues (bones and teeth) (Somboon & Chinpitak, 2005). Skeletal fluorosis is observed when drinking water contains 3-6 mg/L. Crippling skeletal fluorosis develops where drinking water contains over 10 mg/L of fluoride (WHO, 1996). In India totally 25 states have been reported as fluoride affected areas but severe problem occurred in the states of Andhra Pradesh, Tamilnadu, Rajasthan and Madhya Pradesh (Susheela, 1999, Handa, 1975, UNICHEF, 1999, Sarma & Rao, 1997, Suthar et al., 2008). Rajasthan is known as a desert state with acute water crisis. Since many pockets were identified as fluoride affected belts (Arif et al., 2011, 2012a, b, 2013a, b, Husain et al, 2012, 2013).
Several methods are in vogue to remove fluoride from drinking water (Sarma & Rao, 1997). These includes use of alumina, bone char, plant byproducts, ion exchange resins and reverse osmosis (Suthar et al., 2008), but the literature survey clearly indicates the materials used in the present studied not reported any where.
There are number of viable techniques for defluoridation of drinking water, but they are economically rich and non-applicability on mass scale. The current study present the use and applicability of adsorbent carbon materials prepared from the dry fruits of various plant materials and the obtained results were compared with the commercially activated carbon (CAC).

Materials and Methods

Totally 40 samples were collected from all Villages in the Sanganer tehsil. Samples were collected in pre-cleaned polythene bottles with necessary precautions (Brown et al., 1974). The samples were collected from manually operated public hand pumps and public walls in residential localities of studied habitations. The fluoride concentration in water was determined electrochemically, using fluoride in selective electrode (APHA 2012). This method is applicable to the measurement of fluoride in drinking water in the concentration range of 0.01–1,000 mg/l. The electrode used was an Orion fluoride electrode, coupled to an Orion Ion meter. Standards fluoride solutions (0.1–10 mg/l) were prepared from a stock solution (100 mg/l) of sodium fluoride. As per experimental requirement, 1 ml of Total Ionic strength Adjusting Buffer Grade III (TISAB III) was added in 10 ml of sample. The ion meter was calibrated for a slope of −59.2 ±2 (APHA 2012). The composition of TISAB solution was 385.4 g ammonium acetate, 17.3 g of cyclohexylene diamine tetracetic acid and 234 ml of concentrate hydrochloric acid per liter. All the experiments were carried out in triplicate, and the results were found reproducible with ±2% error. Defluoridating materials were prepared from the dry fruits, collected from the plants *Enterolobium saman* (ESC), *Acasia arabica* (AAC), *Prosopis juliflora* (PJC) belongs to Mimosideae family and *Citrus limon* (CLC) belongs to Rutaceae family in the plant kingdom. These materials are available as agricultural wastes and carbonized at 400 °C to 500 °C in muffle furnace. The prepared carbons were chemically treated with 0.5 M HNO_3 solution and then washed with distilled water and finally sieved in to 75 µm particles size. CAC was used to compare with other material and the procedure to prepared CAC was below: 0.5 g of adsorbent carbon was mixed with 100 ml of water samples and stirred at 100 rounds/minute speed on Remi shaker for 30 minutes. Solution was filtered through Whatman no 42 filter paper and the filtrate were examined for further ion selective electrode. Experimental conditions were obtained with the above prepared carbon adsorbents in batch mode study as 40 minutes agitation time, 5 g/L adsorbent concentration; optimum pH range is 6.9-9.0. The same conditions were applied in defluoridation of drinking water samples in batch mode study.

For water samples, which contain fluoride range between 3.0 and 6.0 mg/L, the dose of adsorbent is 5 g/L and for those water samples, which contain fluoride, ranging from 1.5 to 3.0 mg/L, the dose adsorbent is 4.0 g/L.

Ground water is the only source of potable water for majority of people in the study area. However, the inhabitants here are average to drink bore well water or water from public water system. They say that water drawn from great depths is not tasty, hence their preference to open well water or hand pump water. A survey of residents of the selected villages in the study area on the impact of water used for drinking on health of the users revealed that, most of the residents suffer from dental discoloration, early tooth decay and bone deformations. The practicing physicians of the study area also confirmed our observations.

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Study area

The area is located approximately 20km away from the capital of Sanganer tehsil, Jaipur, Rajasthan falls in the survey of Sanganer toposheet no.56 P/10. The Jaipur is located from 26°46' to 27°01' North (latitude) and from 75°31' to 76°57' East (longitude). It is bounded by Sikar in North, Tonk in South, Alwar, Sawaimadhopur and Dausa districts in the East and Nagaur district in the West. The area fall in semiarid region. The diurnal temperature range of Jaipur will be recorded to be 45°C to 8°C, usually overall rainfall range from 500 mm in the West to 700 mm in South East of the zone. The soils are sierozem in the Eastern part of Jaipur district.

Results

The results are shown in tables 1-3. The concentration of fluoride in all samples of study area varied from 1.1 to 6.45 mg/L, 1.3 to 6.45 mg/L and 1.1 to 5.40 mg/L, in hand pump, bore well and open well water samples respectively. From chemical analysis the study area was broadly classified into five categories depending upon the concentration (Table 4) of fluoride ion. Fifteen water samples from bore well, 20 from hand pump, 5 samples from open well water was fallen within the range of 1.1 to 6.45 mg/L concentration of fluoride ion, but only 9 from hand pump, 4 from bore well, 2 from open well water samples having less than 1.5 mg/L concentration.

Defluoridation studies of potable water samples

Water samples collected from various villages of Sanganer tahsil (Tables 1 to 3) indicate that 11 samples from hand pump, 11 samples form bore well water and 3 samples from open well water contain excess of fluoride beyond the permissible world health organization limit 1.5 mg/L (WHO, 1996). Hence the defluoridation studies have been carried out on these particular samples using prepared bio adsorbents from ESC, AAC, PJC and CLC. The results were compared with those of CAC.

The optimum contact time is 40 minutes with constant stirring at 200 rpm speed. The concentrations of fluoride ion in these samples after defluoridation have also been reported in the same tables.

A comparative study of the results of some physico-chemical analysis of water from bore well, hand pump and open well before defluoridation and after defluoridation, indicate that water quality parameters like pH, EC, TDS, PO_4^{3-}, SO_4^{2-}, Cl^-, K^+ etc. values were increased slightly, but negligible in many water samples when the adsorbents ESC, AAC, PJC, CLC and CAC are used for the Defluoridation process (Kishore & Hanumantharo, 2010).

Among the adsorbents, ESC, AAC and PJC decrease the fluoride content in potable water samples to a considerable extent without affecting the permissible limits of other water quality parameters. The order of adsorption capacity in the removal of fluoride by these adsorbents is ESC > AAC > PJC > CLC > CAC**.**

Table 1

Fluoride ion concentration (before and after defluoridation) of hand pump water samples

S. No	Villages	Ci	Cf				
			ESC	AAC	PJC	CLC	CAC
1	Sanganer	2.50	0.65	0.70	0.72	0.76	1.65
2	Mohanpura	1.30	No need to Defluoridation process				
3	Jaichandpura	1.50					
4	Shrirampura	1.20					
5	Sukhalpura	1.10					
6	Mangyawas	1.40					
7	Ramsinghpura	1.20					
8	Singarpura	1.50					
9	Muhana	1.20					
10	Ramjipura	1.30					
11	Vatika	3.24	0.72	0.76	0.81	0.86	1.96
12	Ashawalla	6.20	0.86	0.90	0.92	0.96	2.20
13	Chak vatika	3.35	0.70	0.76	0.83	0.86	1.98
14	Tellawalla	4.49	0.72	0.80	0.89	0.92	2.0
15	Lilya ka bas	6.45	0.89	0.92	0.96	1.02	2.35
16	Badvoki dhani	3.20	0.68	0.70	0.75	0.79	1.92
17	Sitapura riico	3.82	0.69	0.72	0.79	0.82	1.98
18	Goner	1.70	0.56	0.58	0.62	0.68	1.45
19	Vidhani	1.90	0.59	0.62	0.68	0.72	1.62
20	Surajpura	2.90	0.67	0.69	0.73	0.78	1.70

Ci (mg/L) = initial concentration
Cf (mg/L) = final concentration of fluoride ion

Table 2

Fluoride ion concentration (before and after defluoridation) of bore well water samples

S. No	Villages	Ci	Cf				
			ESC	AAC	PJC	CLC	CAC
1	Sanganer	2.70	0.68	0.78	0.82	0.92	1.75
2	Ramsinghpura	1.30	No need to Defluoridation process				
3	Singarpura	1.50					
4	Muhana	1.30					
5	Ramjipura	1.42					
6	Vatika	3.34	0.78	0.89	0.95	1.03	1.98
7	Ashawalla	6.30	0.92	1.02	1.15	1.25	3.20
8	Chak vatika	3.45	0.78	0.90	0.96	1.21	2.00
9	Tellawalla	4.60	0.79	0.95	1.05	1.30	2.20
10	Lilya ka bas	6.45	0.92	1.20	1.26	1.34	3.35
11	Badvoki dhani	3.32	0.74	0.78	0.82	0.92	1.92
12	Sitapura riico	4.20	0.75	0.79	0.86	0.98	2.35
13	Goner	2.10	0.68	0.62	0.70	0.78	1.55
14	Vidhani	2.20	0.71	0.70	0.78	0.82	1.72
15	Surajpura	2.90	0.78	0.76	0.83	0.88	1.80

Ci (mg/L) = initial concentration
Cf (mg/L) = final concentration of fluoride ion

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Table 3

Fluoride ion concentration (before and after defluoridation) of open well water samples

S. No	Villages	Ci	Cf				
			ESC	**AAC**	**PJC**	**CLC**	**CAC**
1	Ashawalla	5.40	0.82	0.98	1.02	1.34	2.45
2	Mohanpura	1.10	No need to Defluoridation process				
3	Jaichandpura	1.40					
4	Vatika	2.89	0.72	0.76	0.88	0.96	1.99
5	Surajpura	2.32	0.68	0.70	0.82	0.96	1.20

Ci (mg/L) = initial concentration
Cf (mg/L) = final concentration of fluoride ion

Table 4

Classification of fluorotic areas basing on the concentration limit

Concentration range (mg/L)	Water sample category		
	Hand pump	Bore well	Open well
0.5-1.5	8	4	2
1.5-2.0	2	--	--
2.0-2.5	1	2	1
2.5-3.0	1	2	1
3.0-3.5	3	3	--
3.5-4.0	1	--	--
4.0-4.5	1	1	--
4.5-5.0	1	1	--
5.0-5.5	--	--	1
5.5-6.0	--	--	--
6.0-6.5	2	2	--

Discussion

The results of the study indicate that the area under study is fully affected by endemic fluorosis, and the concentration of fluoride ion in all water sources varies from place to place. All of these results may arise due to the nature of rock and soil formation. Especially higher concentrations were observed in bore well and hand pump water. The low cost adsorbents ESC, AAC and PJC remove fluoride content from potable water to a larger extent compared with the other adsorbent CLC. Hence the adsorbents ESC, AAC and PJC can be used for the defluoridation of potable water at house hold level. Finally the results also suggest that the area is fully contaminated with fluoride and not suitable for drinking purpose and proper care must be taken by the people.

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