

# A Domestic Water Filter System to Defluoridation: Experience in Rural Brazilian Community

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## Abstract

High fluoride concentrations is found naturally worldwide in water. The purpose of this study was to verify if a domestic defluoridation filter system was an appropriate strategy to reduce high fluoride concentrations in an endemic dental fluorosis area. An experimental study was conducted during 22 weeks in four houses with 20 individuals in an endemic dental fluorosis rural area in Brazil, where drinking water concentration were 3.7 higher the optimum for the region. Through 15 weeks, samples of tap (control) and filtered water were collected 9 times, and total daily urine samples were collected 8 times. In the subsequent 7 weeks, samples of filtered water were collected 10 times and total daily urine samples 4 times. Fluoride concentration in water and urine were determined with specific ion electrode. Natural fluoride concentration found in the water was 2.56 ppm F (2.17-2.98) and was significantly reduced to less than 1.5 ppm F during 5-9 weeks of defluoridation ( $p < 0.001$ ). A correlation was found between the concentration of fluoride in urine and filtered water ( $r = 0.31$ ;  $p = 0.003$ ). The fluoride concentration in the urine of children did not differ significantly from an adolescent/adult. The system revealed to be effective and was considered an appropriate strategy to provide the appropriate water to a community in an endemic dental fluorosis area. More studies are needed to improve the system, as well as the longevity of usage so that the purpose of reducing severe dental fluorosis can be reached.

*Key Words: Endemic dental fluoride, Fluoride, Fluorosis*

## Introduction

Fluoride exposure is considered a method to prevent dental caries and the addition of fluoride in water supply is the best method to deliver it on a population basis [1]. However, the exposure to fluoride during the tooth formative period will disturb the normal mineralization pattern, creating dental fluorosis, a developmental defect of the tooth enamel which its severity is directly associated with the amount ingested, individual susceptibility, age and time of exposure. In an endemic dental fluorosis area, a significant portion of the local residents exhibits a moderate to severe degree of this condition, which is irreversible and considered a public health problem [1-6].

High fluoride concentration is found naturally worldwide in water [7] and in Brazil, endemic dental fluorosis has been reported in rural communities of seven states [8,9].

In the semi-arid northern region of the Minas Gerais state, the deficiency of water supply to the rural communities has created a demand of artesian wells. According to the Brazilian Institute of Geography and Statistics [10], in 2010, the city of São Francisco, located in this area, had about 53.828 inhabitants, and of these, 36,45% living in the rural area. With a total of 13.504 houses in this city, 19.73% had water supply from an artesian well, mainly in the rural area and, concentrations of fluoride ranging from 1.17 to 4.6 mg/L were found [5]. In an epidemiological study carried out in seven rural communities in this area with a population from 6 to 22 years old, it was identified an 80.4% prevalence of dental fluorosis and 48.9% of severe dental fluorosis (Thystrup & Fejerskov Index) [11]. This result was associated to the concentration of fluoride in the groundwater.

In cases where alternative sources of water are not available, the water defluoridation is the only method to prevent fluorosis. Several technologies and techniques, with different cost and criteria are reported in the literature for reducing exposure to fluoride, such as the use of alternative materials rich in calcium as the tamarind [12,13] and chemical treatment or absorption methods [6].

As a strategy to provide defluoridated water to a community in an endemic dental fluorosis area, a domestic Defluoridation Filter System (DDFS) was developed and the purpose of this study was to verify if this system is effective to reduce high fluoride concentrations.

## Materials and Methods

### Study design

An experimental study was conducted in an endemic dental fluorosis rural area in the municipality of São Francisco, located in the northern region of the Minas Gerais state, Brazil.

### The domestic Defluoridation Filter System (DDFS)

The Microspheres Gel Laboratory of the Center of Nuclear Technology Development of Minas Gerais (CDTN-Centro de Desenvolvimento da Tecnologia Nuclear de Minas Gerais) developed units of a DDFS, based on adsorbents microspheres of activated alumina-coal composite, sized for domestic use. Each filter was composed by three units: a container in the top for fluoridated water (approximately 30 liters or 8 gallons), and two containers below, which a smaller is inside a larger one. The adsorbents spheres are hold in the smallest container (approximately 8 liters or 2.1 gallons) and the filtered water is inside the larger container (approximately 55 liters or 14.5 gallons). Additionally, the filter has some advantages since it was designed for easily acceptance by the users, with a

filter element easy to exchange, that do not require energy consumption, constructed from conventional hydraulic parts and that do not require advanced skills to operate.

These DDFS were meant to provide an alternative where there are high concentrations of fluoride in the water consumed by the population. The process of defluoridation showed great ability to reduce fluoride in laboratory tests, which justified the need for an experimental study.

### Sampling

A previous field study was conducted to establish the inclusion/exclusion criteria of the houses in the sample and their intentional selection. It was established for house selection: with a total of 4 to 7 residents; that among these residents had varying ages (children, adolescents and adults); that used the same source of local supply (artesian well or tap water), and that the residents consented to participate in the research with the commitment to use for drinking and food preparation, only the filtered water by the DDFS.

The study protocol was approved by the Ethics Committee of the Universidade Federal de Minas Gerais (ETIC no.0568.0.203.000-10). Before data collection, one of the researchers contacted the residents of the houses that met the predetermined criteria and clarified the objectives of this study. All participants and their guardians who agreed to participate signed an informed consent.

Four houses (Houses 1, 2, 3 and 4) participated in the study, with a total of 20 individuals, belonging to the same rural community. For data collection 3 houses participated in the study (Houses 1, 2 and 3), distributed as 6 children (ages 2-13), 2 teenagers (ages 14-18) and 6 adults (ages 19-59). One of the houses (House 3) was replaced (House 4) after 15 weeks of the study due to the interruption of the water supply by the artesian well in that particular house. After a month interval, and in the subsequent 7 weeks, data collection was carried out in 3 houses (House 1, 2 and 4), with a total of 5 children (ages 2-13), 3 adolescents (ages 14-18) and 6 adults (ages 19-59).

Before the DDFS installation, the participants were instructed on its use and water samples were collected from the artesian well (tap water) to control possible fluctuations in the concentration of F, plus information on other ion sources. The DDFS were installed at the dining room, as near as possible to the kitchen, in a sheltered place and away from sunlight. Throughout the study, the participants were consulted by unnoticed visits or telephone calls about the use of the DDFS and if they had any doubts about the instructions given regarding the utilization of the DDFS.

### Water and urine collections

After the installation of the DDFS, samples of tap (control) and filtered water were collected 9 times during 15 weeks along with the participation of the Houses 1, 2 and 3. After the replacement of the House 3 and a month interval, filtered water samples were collected 10 times during 7 weeks, with the participation of the Houses 1, 2 and 4.

Once the urine is the major excretion route for ingested fluoride, monitoring concentrations and excretion in urine is a useful method to determine the exposure of fluoride in human populations [6,14-19]. Urine sampling were performed according to Zipkin et al. [20] and Marthaler [17],

in which over a period of 24 hours, urine was collected at pre-established times of the day (morning, evening and night). The samples were stored in plastic containers, previously encoded and stored in the refrigerator. At the end of the 24 hours collection, 10 ml from each of the three individual samples (morning, evening and night) were separated and combined in a container with a mean equivalent daily dose of 30 ml. The final samples were stored in plastic containers numbered and stored in a freezer with thymol crystals as a preservative, until laboratory analysis.

The urine collection was carried out with the participation of three houses and daily urine samples (morning, evening and night) were collected 8 times during 15 weeks from the participants of the House 1, 2 and 3. After the replacement of the House 3 and a month interval, urine samples were collected 4 times during 7 weeks, with the participation of the individuals from the Houses 1, 2 and 4.

Evaluation of the content of Fluoride (F) in water and urine were performed at the Laboratory of Oral Biochemistry in the Piracicaba School of Dentistry-UNICAMP, São Paulo, Brazil.

### Analysis of F content in water and urine samples

A standardized worldwide method [21] with ion specific electrode was used to analyze the F content in water and urine samples. For the solution preparation, plastic containers and disposable pipettes were used. In order to avoid interference from other ions, a solution equivalent to TISSAB II was mixed with each sample (1:1). The TISSAB II keeps ions stable, raises the pH value (pH = 0.5) and releases F ions that are attached to metal ions.

The sample was then mixed with the help of an agitator at a temperature of 25°C and after stabilization, the F ion-specific electrode Orion 9606 (Orion Research, USA) was used, permitting the reading of the result in microvolts (mV). Between the measurements, the electrodes were rinsed with deionized water and dried with paper towels. For the calibration of the electrode, curves were prepared from 0.250 to 4µg/ml. The F concentration in the samples was detected by comparison with the curve. The final values were transformed into ppm F using Microsoft Office Excel 2007®. For each day of analysis, the electrode was recalibrated and other curves were prepared.

Both urine and water samples were analyzed in duplicate and the final value was obtained from the arithmetic mean of the results.

### Data analysis

The collected data was stored in the Microsoft Office Excel 2007® (Microsoft Office 2008 Corporation) and statistically analyzed with the Statistical Package for the Social Sciences (SPSS for Windows, version 17.0, SPSS Inc, Chicago, IL, USA).

The Kolmogorov-Smirnov test was used to evaluate the distribution of the results of the water from an artesian well and the DDFS, but data normality was not observed. The Mann Whitney test was used for comparison between the concentration of F in water from the artesian well and DDFS in the 15-weeks period of the study. The correlation between the concentration of F in the water from the DDFS and in the urine was tested by the Spearman correlation coefficient.

The variation of the concentration of F in the urine and the water from the DDFS during the study was analyzed by the construction of the line chart, with a representation of the averages (95% IC) obtained in each of the evaluated periods (15 and 7 weeks). Considering the unit house, the cut-off of 1.5 ppm F [22] was adopted to determine the approximate length of the DDFS effect. For this, it was calculated the frequency of houses whose concentration of F in water of the DDFS was less than or greater/equal to 1.5 ppm F.

## Results

Natural fluoride concentration found in the artesian well or tap water (control) was 2.56 ppm F (SD=0.17; 2.17-2.98). The concentration of F in the filtered water from the DDFS was significantly lower than the concentration of F in the tap water at all times during the 15 weeks period of the sample collection ( $p < 0.001$ ; *Table 1*).

It was established, during the study, that the DDFS produced a reduction in the concentration of F less than 1.5

ppm for a period of 5 to 9 weeks. In the 15 weeks period, for 41 days the DDFS from three houses had a concentration of F in the water less than 1.5 ppm. After the spheres exchange, the system persisted for 30 more days. Following the house replacement and after 35 days, one house still had the DDFS working with concentrations of F less than 1.5 ppm. Within 42 days, all the DDFS had concentrations of F in the filtered water greater or equal to 1.5 ppm (*Table 2*).

The F concentration in the urine of the children did not differ significantly from the F concentration in the urine of an adolescent/adult. The concentration of F in urine and filtered water during the 22 weeks of the study showed a moderate correlation ( $r=0.31$ ;  $p=0.003$ ; *Figures 1 and 2*).

## Discussion

The rural area of São Francisco, had, in 2010 [9], around 19.624(36.45%) residents and a total of 333 families living in private properties. Of them, 155(46.54%) families had a monthly per capita income of up to  $\frac{1}{4}$  of the Brazilian

**Table 1.** Measures of central tendency and variability in the concentration of fluoride in the filtered and tap water (artesian well) and comparison of these measures during the 15-weeks period.

	Concentration of F in the tap water		Concentration of F in the filtered water		p value*
	Mean (SD)	Median (DI)	Mean (SD)	Median (DI)	
Baseline	2,71 (0,06)	2,77 (0,12)	0,10 (0,12)	0,03 (0,26)	<0,001
20 days	2,46 (0,19)	2,59 (0,04)	0,24 (0,18)	0,23 (0,42)	<0,001
40 days	2,58 (0,01)	2,55 (0,05)	0,59 (0,43)	0,85 (0,92)	<0,001
41 days (spheres exchange)	2,58 (0,01)	2,55 (0,05)	0,03 (0,005)	0,03 (0,01)	<0,001
56 days	2,62 (0,18)	2,68 (0,12)	0,54 (0,11)	0,53 (0,27)	<0,001
71 days	2,71 (0,19)	2,67 (0,31)	0,90 (0,08)	0,92 (0,19)	<0,001
86 days	2,37 (0,09)	2,43 (0,19)	1,84 (0,15)	1,83 (0,38)	<0,001
101 days	2,58 (0,01)	2,58 (0,01)	1,83 (0,10)	1,87 (0,23)	<0,001
102 days (spheres exchange)	2,58 (0,01)	2,58 (0,01)	0,05 (0,04)	0,02 (0,07)	<0,001

\*Mann Whitney Test results (median); SD = standard deviation; DI=Interquartile Distance

**Table 2.** Frequency of the houses with F concentration in the water of the DDFS less than or greater than or equal to 1.5 ppm F, during each period of the study.

	< 1,5 ppm	$\geq$ 1,5 ppm
<b>15-weeks period (Houses 1, 2 and 3)</b>		
Baseline	3 (100%)	0
20 days	3 (100%)	0
40 days	3 (100%)	0
41 days (Spheres exchange)	3 (100%)	0
56 days	3 (100%)	0
71 days	3 (100%)	0
86 days	0	3 (100%)
101 days	0	3 (100%)
102 days (Before spheres exchange)	0	3 (100%)
102 days (Spheres exchange)	3 (100%)	0
<b>7-weeks period (Houses 1, 2 and 4)</b>		
Baseline	0	3 (100%)
1 day (Spheres exchange)	3 (100%)	0
7 days	3 (100%)	0
14 days	3 (100%)	0
21 days	3 (100%)	0
27 days	3 (100%)	0
35 days	1 (33,3%)	2 (66,7%)
42 days	0	3 (100%)
49 days	0	3 (100%)
50 days (Spheres exchange)	3 (100%)	0

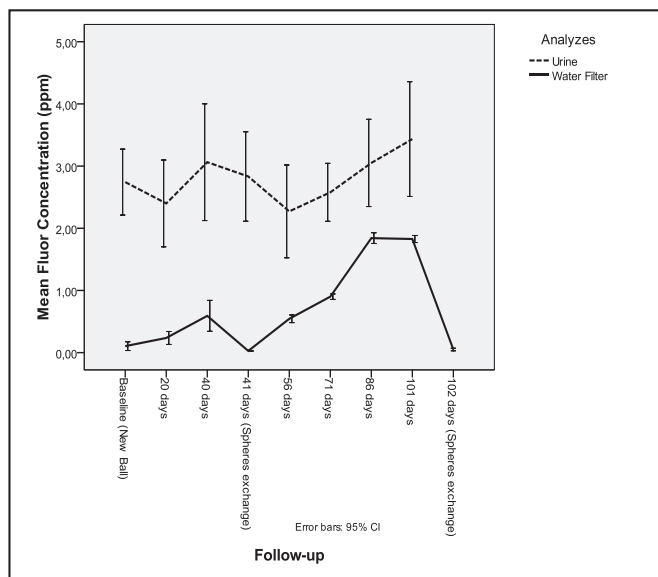


Figure 1. Average concentration of F (95% CI) in the filtered water and urine during the 15-weeks period (Houses 1, 2 and 3).

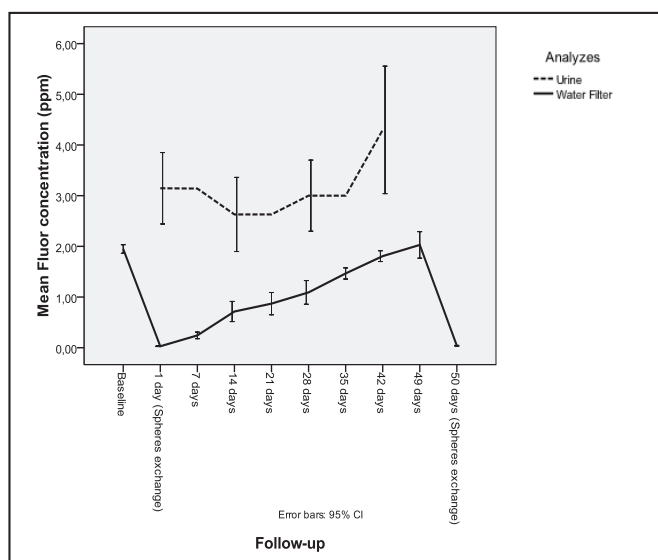


Figure 2. Average concentration of F (95% CI) in the filtered water and urine during the 7-weeks period (Houses 1, 2 and 4).

minimum wage (R\$545 or US\$309 was the total minimum wage per month in Brazil at the time) and 102 (30.63%) families were declared without any income. From the total population of the city (53.828 inhabitants), 14.20% (7.647) never attended daycare or school and 57.69% (31.058) were 10 years or older and never attended school [10], being the city considered with high poverty index and a compromised quality of living and health [9,23].

In a research carried out in seven rural communities in the northern Minas Gerais state, including São Francisco [5,11], identified a 48.9% prevalence of severe dental fluorosis (Thystrup & Fejerskov Index) in residents from 6 to 22 years of age and this condition was associated with high concentrations of F in the groundwater. In a qualitative study conducted in the area, multidisciplinary researchers [23] reported that the communities ingest high content of F in the water, and have a dramatic experience with dental fluorosis, with strong social impact. McDonagh et al. [24] state that the increasing prevalence of fluorosis of aesthetic concern is related with the increasing level of F in the water.

During the consultations made with the residents that were using the DDFS, it was a constant complain the fact that there were no possibilities of dental treatment in the area, and also due to their low economic status, they could not afford to go to the nearest city and pay for treatment (dental and medical) and also, to access other sources of water. Study performed in 2010, recognized that 66.7% of the population from 6 to 22 years of age, had no access to dental care [10]. Therefore, the utilization of the DDFS would be essential for the children so they could not develop an advanced degree of fluorosis and fluoride could be used in dental caries prevention.

The northern region of Minas Gerais has a semi-humid, warm, tropical climate, with mean annual temperature of 24°C (75°F) and mean maximal temperature of 32.3°C (90°F). Mean rainfall is 1,132.9 mm/year and rains are distributed among the four months of summer, followed by a long dry period, that increases the problem of water availability [9]. Due to the climate and the lack of surface water, artesian wells were constructed [5,23] in the rural communities of São Francisco, as an alternative to water supply and, in 2010, 2.665 houses(19.73%) presented water supply from artesian wells [10].

From previous researchers in the area [5,11,22] the community demonstrated that they were instructed about the high F content in the artesian well, and knew about the complications caused by the consumption of the tap water from an artesian well, mainly to drink. In this study, the families that were carefully chosen to use the DDFS were informed about the risks of using the tap water for drinking and preparing food, prior to the sample collection, and they committed to use for drinking and food preparation, only the filtered water by DDFS as this was one of the criterion of the selection of the participants.

Furthermore, the residents were drinking treated water provided by the government through a pipe truck; they did not know that cooking with the tap water was prejudicial. Since the typical Brazilian meal consists of rice and beans, study performed by Casarin et al. [25] found that F concentration in these grains was low but after cooking with fluoridated water, they increased 100 to 200-fold. The authors affirmed that the meal prepared with fluoridated water would be responsible for 29% of the threshold dose for F intake in terms of acceptable fluorosis; however, they used a concentration of 0.7 ppm F to prepare a meal. In the area of this study, the concentration of F found in the water was 2.56 ppm (SD=0.17; 2.17-2.98). In the 15 weeks period (p<0.001), the concentration of F in the filtered water from the DDFS was significantly lower than the concentration in the tap water at all times. After being verified, this result and minor fluctuations in the concentration of F in the tap water, the collection of tap water in the second period of the study was void and only the water from the DDFS was collected.

The water provided by the pipe truck would fill open plastic containers delivered nearby each house, as close as possible to the road, regardless of the size of the family and susceptible to contamination. Since it is a rural community, some houses are away from the road and near the crop area so the supply from the pipe truck would not arrive, leaving available only the water from the well. According to families

living in the area, the pipe truck also didn't have a regular schedule, therefore, this area was considered of not having a reliable source of water supply.

Another alternative source of water for the area is surface water or rainwater. The surface water is often contaminated with biological and chemical pollutants [22] and it cannot be used for drinking purposes without treatment and disinfection making it too expensive and complex for application in deprived communities like the area of this study. Rainwater is usually a much cleaner water source [22] and may provide a low-cost, simple solution, though, even if stored, would not last the 8 months of dryness during the year. Therefore, where alternative sources are not available, defluoridation of the water from an artesian well is the only practicable option to overcome the problem of F excess in the area of this study.

There are several different defluoridation methods and one can work in a community and do not work in another, meaning that what may be appropriate at a given time and stage of urbanization of a community, may not be at another [6]. Therefore, it is necessary to select the appropriate defluoridation method so a solution can be reached. This was a concern of the researchers and during the development and construction of the DDFS and, in the previous field survey conducted; an extensive discussion about the appropriate method was performed in order to find the appropriated method to this particular community. It was resolved that a domicile defluoridation system to be the most appropriate method due to the characteristics of the community, their low cultural and socioeconomic status [11,23], their work, mainly in plantation and crop areas, and lifestyle.

The optimum level of F is around 0.7 ppm F [26] and 1.5 ppm F [22], the maximum levels or the guideline value that represents the concentration that does not result in any significant risk to health over a lifetime of consumption. However, the World Health Organization also emphasizes that this value is not fixed, but should be considered in each context, since local adjustments to the daily water consumption value may be needed in setting local standards [27]. Brazil was one of the first Latin American countries to provide fluoridated water [14]. Since 1974, the Ministry of Health [28] has issued regulations and national standards for fluoridation. According to the National Health Foundation [29], access to treated and fluoridated water is crucial to the health of the population and enabling public policies that guarantee the implementation of water fluoridation is the most comprehensive and socially equitable access to F. Because dental fluorosis can also be a result of excess of natural F in the water, effective public health policies to detect occurrences of this excess are necessary and also, alternatives to water consumption are needed. In Brazil, the water with natural excess of F is sometimes, the only alternative for a community [11,23]. In the area of this study, it was found that the drinking water concentration was 3.7 higher the optimum for the region.

The DDFS produced a reduction in the concentration of F less than 1.5 ppm for a period of 5 to 9 weeks during the 22 weeks of the study. In the 15 weeks period, for 41 days the DDFS from the Houses 1, 2 and 3 had a concentration of F in the water less than 1.5 ppm. After the spheres exchange, it

lasted for 30 more days. In the 7 weeks period, after 35 days, one house still had the DDFS working with concentrations of F less than 1.5 ppm. Within 42 days, all the DDFS from Houses 1, 2 and 4 had concentrations of F in the filtered water greater or equal to 1.5 ppm (*Table 2*). This period range is due to the usage of the DDFS, based on spheres of activated alumina-coal composite, which saturates during the removal of F from the water.

Since the houses participating in this study did not have any sanitation or a facility and service for the safe disposal of human urine and faeces, the urine sample collections wasn't reported as a problem by the families. A concern about the House 3 was that only one participant of the family, with 8 years old, was capable of reading the labels of the plastic containers to retain the urine. After the period of 15 weeks, the family reported an interruption in the supply of tap water from an artesian well, being then, excluded from the study and replaced by the House 4. The spheres from the DDFS were removed, but the unit was left for the family, as to be used as a water container.

The main route of elimination of ingested F is the kidneys, and monitoring its concentration in urine excretion is a useful method for determining the exposure in human populations, being urine a strong biomarker [14-19]. In a study conducted with a population exposed to excessive fluoride in the water, authors have reported that higher levels of F in the urine of children from that population were associated with chronic exposure of F in the drinking water, and the concentration of F in the urine increases with increasing concentration F water [30]. The dentifrice with F was used by all participants in the study, but they stated that they usually brush their teeth just once a day, usually in the morning. Therefore, for this study, it was considered the source of F in the dentifrice insignificant for the urine analysis.

It is known that approximately 10-25% of the daily F intake is not absorbed and, of the F that is ingested, about 50% is excreted via the urine during the following 24 hours, and almost all of the remained will become associated with calcified tissues [17]. In a study that measured the urinary excretion of F following ingestion of the different types of waters (naturally fluoridated hard and soft waters, artificially fluoridated hard and soft waters and a reference water), reported that the metabolism of F seems to differ between children and adults and that, usually in an adult, between 40 and 60% of the dose ingested found in the urine, while, in children, there is a much higher absorption to the skeleton, and, consequently, a lower excretion [18].

In another study about the long term effects of water fluoridation on the human skeleton, affirmed that the analysis of samples at the tissue level, rather than the population level, reveals high levels of variability in response to water fluoridation [31]. Values of the fractional urinary excretion of F from the usual sources of F may differ under stable F intake conditions and have still not been determined for different age groups [32]. In this study evaluation, the F concentration in the urine of the children did not differ significantly from the concentration in the urine of an adolescent/adult. Although previous studies have suggested that a lower excretion of F be expected in children, when compared to adults, due to a

higher capacity of children to deposit F in hard tissues, this topic needs further studies, especially in endemic dental fluorosis areas.

The F concentration in the urine of the individuals decreased when they consumed the water from the defluoridation filter system, since urine data followed the water data from the system. A correlation ( $r=0.31$ ;  $p=0.003$ ; *Figures 1 and 2*) was found between the concentration of F in urine and the filtered water during the 22 weeks of the study. Although is a moderate correlation, it indicates that the fluctuation of the concentration of F in the filtered water was accompanied by the fluctuation in the concentration in the urine. This was expected, since as the results from the laboratory tests, the defluoridation filter system saturates over the period of approximately 5 to 9 weeks. The families of each house that were participating in had different numbers of individuals, having therefore, different consumption of water in the period of the research. That is observed in the second period, that after 35 days, one house still had the DDFS working with concentrations of F less than 1,5 ppm (*Table 2*).

For fluorosis, the total dose of F ingested is important determinate of risk not just the concentration [3]. It is obvious that the participants of this study had access to other sources of F, such as in soft drinks or even going to a relative house and be served a drink. It is a limitation of the study the fact that we rely in the understanding of the participants about the excess of F in the water and how the DDFS would work. During the consultations with the participants, they approved the DDFS and demonstrated commitment to the research; some of them reported that they took water from the DDFS in bottles to drink at work or in school, so that they would not drink different kind of water in case of thirst.

Due to particular proprieties of the water from the artesian well, the participants also reported that sometimes a delay happened in the filtering process, but they stated that when that happened, the person in the house responsible for the DDFS (usually the older women) would open the containers,

clean the inside of the water containers and stir the container with the adsorbents spheres. In this type of study, it is really important that the subjects participate as much as possible, so the results can really express the reality.

Moreover, it was stated that the population living in that area had knowledge about the excess of F in the water, but they continued consuming it. The understanding of the problem was not enough to resolve it, since they did not have another reliable source of water. That is the reason this specific area was chosen to participate in this study, being the DDFS an alternative to provide water with appropriate F content.

The domestic defluoridation system was intended to provide an alternative, in a location where there is naturally high concentrations of F in the water consumed by the population. This study demonstrates that the system is effective to reduce the high concentrations of F in the water for approximately 30 days, like the laboratorial preliminary tests. Although adaptation problems occurred, the subjects approved the use of the domestic filter system, being the system an appropriate strategy to provide defluoridated water to a community in an endemic dental fluorosis area. More studies are needed to improve the system, as well as the longevity of usage so that the purpose of reducing severe dental fluorosis can be reached.

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