IMPACT OF FLUORIDE CONTENT IN DRINKING WATER

2 authors:

Khaled Abu-Zeid
Centre for Environment and Development for the Arab Region and Europe
38 PUBLICATIONS 232 CITATIONS

Lama El Hatow
Erasmus University Rotterdam
8 PUBLICATIONS 20 CITATIONS

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Dr Khaled AbuZeid [1]
Eng Lama El Hatow [2]

ABSTRACT

Fluoride is a chemical element that has shown to cause significant effects on human health through drinking water. Different forms of fluoride exposure are of importance and have shown to affect the body's fluoride content and thus increasing the risks of fluoride-prone diseases. Fluoride has beneficial effects on teeth at low concentrations of 1 mg/L by preventing and reducing the risk of tooth decay. Concentrations lower than 0.5 mg/L of fluoride however have shown to intensify the risk of tooth decay. Fluoride can also be quite detrimental at higher concentrations exceeding 1.5 – 2 mg/L of water. High concentrations of fluoride pose a risk of dental fluorosis as well as skeletal fluorosis and osteoporosis. Skeletal fluorosis is a significant cause of morbidity in certain regions of the world. This of course depends on the level and period of exposure of fluoride by any given individual. Fluoride has been known to be found most frequently in groundwater at higher concentrations, depending on the nature of rocks and natural fluoride-carrying minerals at certain depths. Thus high fluoride concentrations generally can be expected from calcium-poor aquifers and where cation exchange of sodium for calcium occurs. In hotter climates where water consumption is much more frequent, the dosage of fluoride within the drinking water needs to be modified based on average daily intake. Thus diet and exercise also play a large role on the quantity of body's fluoride intake within a day. There has also been a direct correlation which shows that high altitudes can increase fluoride retention within the body and can thus have an effect on dental and skeletal appearance and structure, independent of fluoride intake and exposure. International standards for drinking water have been placed by organizations such as the World Health Organization (WHO), however local conditions determine the nature of the standards that are to be legislated by different countries, and thus fluoride limits in drinking water Standards may differ from one country to another. This paper investigates the potential health risks involved with both lower and higher concentrations of fluoride in drinking water, as well as posing possible measures of mitigation to eliminate such harmful threats. It also provides a survey of fluoride content in several bottled water samples around the World.

I. INTRODUCTION

A country's ability to collect, clean, and distribute water to its users reflects the health of a country's people. According to the World Health Organization (WHO), 1.1 billion people in low and middle-income countries lack access to safe water for drinking, personal hygiene and domestic use (WHO, Nov. 2004). This numbers represents more than 20% of the world's population. Of this 1.1 billion people, nearly two-thirds live in Asia. In sub-Saharan Africa, 42% of the population is still without improved water. In order to meet the water supply MDG target for 2015, an additional 260,000 people per day should gain access to improved water sources. It is noteworthy here to mention that by 2015, the world's population is expected to increase every year by 74.8 million people (WHO, Nov. 2004).

[1] Khaled AbuZeid, Ph.D, P.E, PMP, Water Resources Programme Manager (CEDARE)
Address: 2 ElHegaz Street, Heliopolis, Cairo, Egypt. Tel: 224513921, Ext 665, Fax: 224513918, kabuzeid@cedare.org

[2] Lama El Hatow, M.Sc, Program Assistant, Water Resources Management Programme (CEDARE)
Address: 2 ElHegaz Street, Heliopolis, Cairo, Egypt. Tel : 224513921, Ext 662, Fax : 224513918, lelhatow@cedare.org

A. Fluoride

The Fluoride element is found in the environment and constitutes 0.06 – 0.09 % of the earth's crust. It is present in water, foods and air. Fluoride is commonly associated with volcanic activity and gases emitted from the earth's crust. Thermal waters, especially those of high pH, are also rich in fluoride. Fluoride has various uses in many industries including toothpaste, ceramics, tiles, bricks, etc. Fluoride is not found naturally in the air in large quantities. Average concentrations of fluoride found in the air are in the magnitude of 0.5 ng/m^3 (WHO, 2004). Fluoride is found more frequently in different sources of water, with higher concentrations found in groundwater due to the presence of fluoride-bearing minerals. Average fluoride concentrations in seawater are approximately 1.3 mg/L. As for foods it has been shown that vegetables and fruits have low levels of fluoride with ranges of 0.1 – 0.4 mg/kg (WHO, 2004). Foods with higher levels of fluoride consist of barley and rice with about 2 mg/kg of fluoride. Fish can contain fluoride levels of ranges 2-5 mg/kg, however canned fish and fish protein concentrations may contain fluoride levels up to 370 mg/kg (IPCS, 2002). Dry tea leaves also have significantly high levels of fluoride of up to 400 mg/kg, however due to the ingestion of tea the fluoride exposure ends up ranging from 0.04 to 2.7 mg/person/day (Murray, 1986). In one study that was done, it was shown that 34% of the fluoride in black tea remains in the oral cavity ((Simpson *et al*., 2001). Toothpaste contains very high concentrations of fluoride up to 1000-1500 mg/kg of toothpaste, however what is accidentally swallowed and ingested may range up to 3.5 mg/day. It has been shown, that with all the human exposure to fluoride that varies from region to region, drinking-water is generally on average the largest single contributor to daily fluoride intake (Murray, 1986). Due to this fact, daily fluoride intakes (mg/kg of body weight) are based on fluoride levels in the water and water consumption per day per liter.

II. Drinking Water Standards

There are maximum guiding values for fluoride in drinking water. There are no minimum imposed limits, however there are recommended values to ensure no potential health risks from lack of fluoride within the drinking water. World Health Organization (WHO) places international standards on drinking water that should be adhered to for health purposes, however is not enforceable and each individual nation may place its own standards and conditions on drinking water. This can be seen in the United States, where the Environmental Protection Agency (EPA), the regulatory body for drinking water, places more lenient drinking water standards than that of the WHO. This can be seen in the Table I.

Table I: Drinking Water Standards Internationally and Nationally

Fluoride Guideline Value Drinking Water Standards	Recommended Minimum Value (mg/L)	Maximum Value (mg/L)	Reference
WHO	0.5	1.5	WHO (1993)
USA - Primary Secondary	0.5 0.5	4.0 2.0	US EPA (1985)
Egypt	-	0.8	Egypt – Decree 108 and 301/1995 (1995)
Jordan	-	2.0	Jordan (2001)
Morocco	-	0.7	Morocco (1991)

Kuwait	0.5	1.5	WHO guidelines applied without modifications
Palestine	0.6	1.0	Palestine (1997)
Saudi Arabia	0.7	1.2	Saudi Arabia (2000)
Lebanon (at 8-12ºC) (at 25-30ºC)	- -	1.5 0.7	Lebanon (1996)
Iraq	-	1.0	Iraq (2001)

Primary Drinking water standards are those that must be enforced. Secondary Drinking water standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water (US EPA, 1985). EPA recommends secondary standards to water systems but does not require systems to comply, however states may choose to adopt them as enforceable standards. In a temperate climate, the recommended level to help reduce tooth decay is one milligram of fluoride to every liter of water (1 mg/L), while the minimum recommended value is 0.5 mg/L (WHO, 2004). The WHO maximum guideline value of 1.5 mg/L is higher than the recommended value for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/L (WHO, 2004).

These values vary according to local conditions including climate and altitude. In hotter climates where water consumption is much more frequent, the dosage of fluoride within the drinking water needs to be modified based on average daily intake. The majority of fluoride is consumed through drinking water and food with lesser consumptions contributed from toothpaste (IPCS, 1984). Thus diet and exercise also play a large role on the quantity of bodily fluoride intake within a day. There has also been a direct correlation that shows that high altitudes can increase fluoride retention within the body and thus can have an effect on dental and skeletal appearance and structure, independent of fluoride intake and exposure (IPCS, 2002).

III. Drinking Water from around the World

Fluoride content in drinking water varies around the world depending on the geographical location. Many factors affect the fluoride content such as volcanic rocks, granitic and gneissic rocks, and sediments of marine origin in mountainous areas. These rocks, high in fluoride content, are often found underground affecting groundwater. Thus high concentrations of fluoride in water are generally found in groundwaters (WHO, 2000). Dangerous levels of fluoride that are increasingly found in groundwater in South and South-eastern Asia are of growing concern, along with infectious or other toxic substances (WHO, 2000). An example from around the world with volcanic activity leading to high fluoride concentration in the waters is Tanzania and the area surrounding the East African Rift system. Many of the lakes in this area have fluoride concentrations reaching up to 1640 mg/L and 2800 mg/L (IPCS, 2002).

Table II: Bottled Water values from around the world

ARAB REGION (mg/L)

EGYPT

Baraka	0
Delta	0.12
Nestle	0.08
Sabile	0.05
Aquafina	0
Mineral	0.6
Siwa	0.45
Safi	0.6
Aqua	0
Hayat	0.5
Dasani	0
Schweppes	0
Sabeel	0.05

JORDAN

Ghadeer	0

SYRIA

Boukein	0.2

LEBANON

Tannourine	0.25
Sohat	0.01
Sabil	0.6

ALGREIA

Sidi El Kebir	0

SAUDI ARABIA

Fayha al-qassim	0.9
Safa	0.7
Masafi	0.02
Alwadi	0.8
Hada Water	0.8

KUWAIT

Al-grain	0
ABC	0.02
Rawdatain	0

TUNISIA

Fourat	0
Safia	0

UAE

Gulf	0
Oasis	0
Pure Natural Spring	0.2
Crystal	0.2

BAHRAIN

Tylos	0.68
Arwa	0.45

MOROCCO

Sidi Ali	0

AFRICA (mg/L)

SOUTH AFRICA

Valpre	0.2

KENYA

Block Hotels	0.9
Keringet	1.7
Aquamist	0.1

GHANA

Voltic	0

ETHIOPIA

Highland Springs	0
Ambo	0
Aquaddis	0

BURUNDI

Kinju	0

UGANDA

Blue Wave	0
Summit	0.55
Rwenzori	0.6

OTHER (mg/L)

IRAN

Polur	0.07

CHINA

Nine Dragon	0
Limpid	0
Hilton Water	0

MEXICO

Sta. Maria	0
E'pura	0
Bonafont	0

TURKEY

Hayat	0
Pinar	0
Yildiz	0
Sultan	0.17
Ref Alps	0

USA

Deep Rock	64
Bling H2O	0
Mount Olympus	0
Trinity	3.6
Avita	0.1

EUROPE (mg/L)

SPAIN

Font Vella	0
Zambra	0
Lanjaron	0

FRANCE

Evian	0
Dax	1.4
Pierval	0

GREECE

Loutraki	0

CYPRUS

Agros	0
Saint Nicholas	0

PORTUGAL

Fastio	0.2
Carvalhelhos	0

ITALY

S.Pellegrino	0
Agua de Mondariz	0.4
Fabia	0
Spa	0
Lilia	1.05
San Benedetto	0.06
Acqua Panna	0.1
Santa Croce	0
Levissima	0
Guizza	0.06

GERMANY

Gerolsteiner	0

NORWAY

Voss	0.1

UNITED KINGDOM

Hildon	0.02

DENMARK

Aquador	0

NETHERLANDS

Brasserie Aquarium	0

As can be seen from Table II, the majority of fluoride concentrations in bottled water around the world are below the WHO international standard for drinking water of 1.5 mg/L. Very few bottled water companies exceed this limit. The two companies of Deep Rock and Trinity in the USA contain concentrations of 64 and 3.6 mg/L respectively. It can be inferred from the name of the company 'Deep Rock' that the high fluoride concentration is due to the depth of the water coming from groundwater with a high possibility of fluoride-bearing minerals. Even though Trinity's concentration is fairly high and exceeds the WHO limit, it does not however exceed the US EPA's primary limit for drinking water of 4.0 mg/L.

It can also be observed from Table II that values of fluoride concentrations in the Arab Region are quite low and do not exceed 0.9 mg/L with an average value of 0.23 mg/L. This can be attributed to the hotter climates in the Arab Region and increased water consumption. Fluoride concentrations were modified to factor in the rate of consumption in this desert climate.

A. Egypt Case Study

BOTTLED WATER

All fluoride concentrations for bottled water in Egypt are below the Egyptian Guideline for Drinking Water (Decree 108 and 301/1995) of 0.8 mg/L (Egypt 1995). The drinking water limit under Egyptian guidelines is considerably lower than the WHO drinking water limit of 1.5 mg/L. This is due to the fact that Egypt lies in a region of desert climate and heated temperatures and thus water consumption is increased to avoid dehydration. Due to this increased water consumption, the fluoride content is inevitably increased in the body, and thus limits for fluoride concentrations in water must be lowered to eliminate health risks associated with high fluoride consumption. From Table II it can be seen that the average value for bottled drinking water is 0.188 mg/L. The bottled water companies with fluoride concentrations that come close to the Egyptian drinking water limit are Mineral, Safi, Hayat and Siwa with values of 0.6, 0.6, 0.5, and 0.45 mg/L respectively.

TAP WATER

The source of tap water in Egypt is mainly the River Nile. Out of samples taken from ten governorates around Egypt (Cairo, Giza, Kaliobia, Fayoum, Menia, Mansoura, Alexandria and Ismailia), the range of fluoride content in the tap water was 0.330-0.377 mg/L with an average of 0.36 mg/L (Hassan et.al, 2004). This value is suitable for the hot climate in Egypt. The source of drinking water in the two governorates of Marsa Matrouh and Arish however, is groundwater coming from artesian wells. This water contained higher levels of fluoride with an average of 0.761 and 0.926 mg/L for Marsa Matrouh and Arish respectively (Hassan et. al, 2004). These values need to be modified and the water requires de-fluoridation if it is to be used as drinking water.

B. National Surveys from around the world

The quantity of fluoride that is naturally occurring within the environment and is not fluoridated in any way, varies depending on the geological environment of the region and the naturally occurs rocks and fluoride-bearing minerals in the region. The highest reported level occurring naturally is 2800 mg/L (IPCS, 2003). Table III shows a summary of certain national surveys produced for specific countries.

Table III: National Surveys of Drinking Water from around the World

Location	Fluoride concentration (mg/litre)	Comment	References
Canada	0.73–1.25	Range of mean concentrations in fluoridated[b] samples collected between 1986 and 1989 from 320 communities in 8 provinces	Health Canada (1993)
Czech Republic	0.05–3.0	Range of concentrations in more than 4000 samples of drinking-water collected between 1994 and 1996 from 36 districts within the Czech Republic	NIPH (1996)
Finland	<0.1–3.0	Range of concentrations in 5900 groundwater samples	Lahermo et al. (1990)
Germany	0.02–0.17	Range of concentrations of drinking-water collected from various facilities in Germany between 1975 and 1986	Bergmann (1995)
The Netherlands	0.04–0.23	Public drinking-water samples collected in 1985 from water treatment plants in 12 provinces	Sloof et al. (1989)
Poland	0.02–3.0	Range of mean concentrations in samples of drinking-water collected from 94 localities in central and northern Poland between 1993 and 1995	Czarnowski et al. (1996)
USA	<0.1–1.0	Fluoride levels in drinking-water of approximately 62% of the US population served by public supplies range from <0.1 to 1.2 mg/litre; levels of fluoride in drinking-water of approximately 14% of the US population served by public supplies range from 1 to 2 mg/litre	US EPA (1985); US DHHS (1991)

Source: CEHA, 2006
a: Drinking-water in which inorganic fluoride was not intentionally added for the prevention of dental caries
b: Drinking-water in which inorganic fluoride was intentionally added for the prevention of dental caries.

IV. Potential Health Impacts

As mentioned before there are both recommended minimum and maximum values of fluoride needed in drinking water. If there is not enough fluoride content within the water, then this may result in tooth decay and dental caries (Fawell et al., 2006). However, if there are high concentrations of fluoride within the water, this may result in dental and skeletal fluorosis (Fawell et al., 2006). The severity depends upon the amount ingested and the duration of intake. Dental fluorosis is a condition where excessive fluoride can cause yellowing of teeth, white spots, and pitting or mottling of enamel. Consequently, the teeth become unsightly. Dental fluorosis occurs more frequently in children under the age of 6 due to the fact that the enamel formation has not yet developed. Dental fluorosis occurs more often where teeth are forming under the gums. Skeletal fluorosis is a bone disease exclusively caused by excessive consumption of fluoride, which depending on the degree of fluorosis can cause increase in bone mass, stiffness in joints, and osteoporosis (Fawell et al, 2006). This is more frequent in the later stages in life with ingestion of high levels of fluoride.

At drinking water concentrations between 0.9-1.2 mg/L, fluoride may give rise to mild dental fluorosis. Values of 1.5-2 mg/L of fluoride in drinking water gives rise to higher chances of dental fluorosis, while values exceeding 2 mg/L may have very high chances of dental and skeletal fluorosis (WHO, 1994). Total fluoride intakes above 6 mg/day have been shown to increase the effects on the skeleton, while fluoride intakes above 14 mg/day pose serious threats of severe skeletal effects (WHO, 1994).

Fluoride can have serious effects on skeletal tissues as well, with adverse changes in bone structure. Drinking water containing 3-6 mg/L of fluoride has been shown to cause such deficiencies (Fawell et al., 2006). Crippling skeletal fluorosis and osteoporosis develops when drinking water contains over 10 mg/L of fluoride. Table IV shows the health effects at varying quantities of fluoride intake.

Table IV: Fluoride Intake of Drinking Water and Health Effects

Drinking Water Fluoride Concentration (mg/L)	**Health Effect**	**Population Affected (%)**
1	Dental Fluorosis	1-2
2	Dental Fluorosis	10
2.4 - 4.1	Dental Fluorosis	33
8	Osteoporosis	Unknown data

Source: Kaminsky, 1990

A recommended fluoride intake of 0.05 mg/kg/day for a 60 kg individual is deemed acceptable. A daily intake of fluoride of 1-3 mg/day of body weight prevents tooth decay and dental caries, however for children under the age of 6 its is recommended that the optimal dose of fluoride ingested daily, range from 0.5 – 1.0 mg/day of body weight (IPCS 1984). However long term exposure to higher amounts of fluoride, may have health effects on teeth and bones. Doses of 5-10 mg/day body weight could cause acute toxic effect. Death was reported following ingestion of 16 mg/day however the usual lethal range is from 70 – 140 mg/day body weight daily (IPCS 1984, and CCIS 1994).

In China, it has been reported that over 26 million people suffer from dental fluorosis due to the high concentrations of fluoride in drinking water (WHO, Nov. 2004). In addition to this, over 1 million cases of skeletal fluorosis are associated to the drinking water. Possible mitigations strategies were proposed which include using the river water, reservoir construction and de-fluoridation (WHO, Nov. 2004).

As for the Arab Region, it has been observed in Saudi Arabia in the Hail Region that over 90% of 2355 rural children examined and aged 12-15 years, were reported to have dental fluorosis. This was associated to the high levels of fluoride of 0.5 – 2.8 mg/L found in well water used for drinking in this area (Akpata et al. 1997). The city of Mecca with fluoride concentrations of up to 2.5 mg/L, was also reported to have cases of endemic fluorosis (Al-Khateeb et al, 1991).

V. EXAMPLE OF DAILY FLUORIDE INTAKE IN EGYPT

If certain assumptions are made for daily fluoride intakes coming from the two biggest contributors of fluoride (food and water), specific values may be estimated to determine the range an individual should fall in to ensure his/her safety against the health impacts associated with excess and lack of fluoride on the human body. Table V shows the values of daily fluoride intake for an average adult weighing 60 kg, and an average child weighing 30 kg. These assumptions are made for Egypt, where the climate is hotter and thus water consumption in a day is much more frequent than in temperate climates. Other factors need to be noted when taking a case study as Egypt, such as the fact that a vast majority of Egyptians drink large quantities of tea in a day. Tea holds one of the largest fluoride contents known in foods. Thus it plays a large role in assuming average fluoride daily intakes for adults and children in Egypt.

Table V: Average Fluoride Daily Intakes for Adults and Children in Egypt.

Adult (60 kg)	Child (30 kg)
0.25 kg Rice = 0.5 mg / day 0.25 kg Fish x 2/7 [1] = 0.142 mg / day 0.25 kg Fruits = 0.075 mg / day 0.25 kg Veg. = 0.075 mg / day Tea[2] = 1.0 mg / day	0.125 kg Rice = 0.25 mg / day 0.1 kg Fish x 2/7 = 0.057 mg / day 0.125 kg Fruits = 0.0375 mg / day 0.125 kg Veg. = 0.0375 mg / day Tea [7] = 0 mg / day
Total Fluoride from Food = 1.792 mg/day	**Total Fluoride from Food = 0.382 mg/day**
2L Tap water x [3] 0.36 mg/L = 0.72 mg/day	1L Tap water x 0.36 mg/L = 0.36 mg/day
Total fluoride with tap water = 2.512	**Total fluoride with tap water = 0.742**
2L Bottled water x [4] 0 mg/L = 0 mg/day	1L Bottled water x 0 mg/L = 0 mg/day
Total fluoride with bottled water (0) = 1.792 mg/day	**Total fluoride with bottled water (0) = 0.382 mg/day**
2L Bottled water x [5] 0.6 mg/L = 1.2 mg/day	1L Bottled water x 0.6 mg/L = 0.6 mg/day
Total fluoride with bottled water (0.6) = 2.99 mg/day	**Total fluoride with bottled water (0.6)= 0.982mg/day**
Recommended Daily Intake [6] = 3 mg /day	**Recommended Daily Intake [6] = 0.5 – 1.0 mg /day**

1: Fish consumed 2 days out of the 7-day week
2: Tea consumed in large quantities by adults in Egypt – assumption of 1.0 mg/day
3: Average value of tap water with source from Nile (Cairo, Giza governorates) is 0.36 mg/L
4: Least fluoride content in bottled water in Egypt is 0 mg/L
5: Most fluoride content in bottled water in Egypt is 0.6 mg/L
6: WHO Vales for recommended daily intake (WHO, 2004)
7: Assumption that children do not drink tea.

As seen from table V, total fluoride values in a day for both adults and children with tap water, bottled water with least fluoride content, and bottled water with most fluoride content in Egypt, are all within the standard range of daily intakes recommended by WHO. It can be seen that as for adults, drinking either tap water, or bottled water with the most fluoride content (0.6 mg/L) is most suitable for adults.

This however does still depend on the individual's weight, and intake of fluoride from different kinds of foods and beverages, but on average the scenarios above might be most suited for adults in Egypt. As for children, it can be seen that the same holds true. The usage of either tap water or bottled water with the highest fluoride content (0.6 mg/L) appears to be the most suitable situation for children in order to fit within the WHO recommended range of daily fluoride intake. The same holds true with children, as did with adults, in that these values may vary with respect to the child's body weight, and fluoride consumption from various foods and beverages, and should not be viewed as generalizations, rather than mere assumptions and guidelines to follow.

VI. Treatment of High Concentrations of Fluoride

In drinking waters with high concentrations of fluoride, treatment of these waters is necessary in order to eliminate any negative effects on the mass population. Three specific treatments have been deemed successful in the removal of fluoride from drinking water. These processes are shown in Table VI.

Table VI: Treatment of Excessive fluoride concentrations in water.

	Coagulation	Activated alumina	Membranes
Fluoride removal	50% or more	80% or more (<1 mg/L)	80% or more (<1 mg/L)

Source: Fawell et al., 2006

A. Coagulation

Chemical coagulation is a treatment process commonly used for surface waters. In this process, the chemical coagulant which is usually aluminum or iron salts, are placed in the raw water under specific dosages and conditions to form a solid flocculent or flakes that may be easily filtered from the water (Fawell et al., 2006). The precipitated floc removes the dissolved fluoride contaminant by charge neutralization, adsorption and entrapment. This process is also known as the Nalgonda process that was developed for low-income African households (Fawell et al., 2006). This process will remove fluoride up to 50% and possibly more depending on the nature and degree of the fluoride content in the water (Fawell et al, 2006).

B. Activated Alumina

Activated alumina is used in a treatment process to filter fluoride in drinking water. It is made of aluminum oxide and has a very high surface area to weight ratio allowing it to have many small pores that run through it (Fawell et al, 2006). This process will have a success rate of up to 80% removal of fluoride with less that 1 mg/L of fluoride content left in the water (Fawell et al, 2006).

C. Membrane Process

The most significant processes in water treatment for membrane processes include reverse osmosis, ultra-filtration, micro-filtration, and nano-filtration (Fawell et al., 2006). These processes are now recently being applied to the treatment of drinking water. Membrane operations generally utilize artificial membranes to separate the mixtures and capture the undesired material. This process is successful in fluoride removal from drinking water up to 80% or more, leaving the water with a fluoride content of less than 1 mg/L (Fawell et al., 2006).

D. Other De-fluoridation Technologies

Other forms of de-fluoridation include calcined clay and bone charcoal. Calcined clay includes clay powder and fired clay which is capable of sorption of fluoride along with other contaminants in water. Clay has the ability to clear the turbidity of water, which is a quality that is believed to have been used in domestic households in ancient Egypt (Fawell et al, 2006). Even though clay soaks up fluoride in the form of sorption, however it may also be utilized as a flocculent powder causing precipitate that may later be filtered out (Fawell et al, 2006). As for bone charcoal the process entails a material (bone charcoal) which is a blackish, granular material composed of calcium phosphate, calcium carbonate, and activated carbon. When in water, the bone charcoal is capable of absorbing a wide range of pollutants including fluoride (Fawell et al, 2006). However bone charcoal in some cultures may prove to be an unacceptable for use due to the fact that bone charcoal originates from pigs, and thus may be questioned by Muslims, as well as Hindus and Jews (Fawell et al, 2006). Some villages in North Thailand oppose the charring of bones, and thus may also have stipulations with respect to this de-fluoridation process. When considering different methods and technologies of de-fluoridation, it is important to consider these cultural and religious factors, as well as considering cost, material availability locally, and feasibility of technology in that region of the world.

E. Wastewater Use

Several methods were explained and are quite simple and feasible for many countries. In other countries such treatment to the water may prove to be costly and unfeasible. In these circumstances, other solutions including using the water for other purposes such as irrigation are possible. This may be used for the drinking water that can not be used, or wastewater that has been treated. For irrigation purposes, countries place standards for reclaimed water for reuse in irrigation. This may be seen in Table VII.

Table VII: Reclaimed water standards and required level of treatment for reuse in irrigation (mg/L)

	Saudi Arabia	**Tunisia**	**United States - EPA**	
Fluoride	2	3	1 (long term)	15 (short term)

Source: Abu-Zeid, 1998.

As can be observed from the table, limits for reclaimed water for use in irrigation are considerably higher than the limits imposed for drinking water. This may be a possible potential use for water that is not deemed fit for drinking. In order to ensure safe and potable water reaching the end users, rigorous evaluation of the source is imperative at every juncture.

VII. Treatment of Low Concentrations of Fluoride

A. Water fluoridation

Water fluoridation is a process of adding fluoride to the drinking water in order to eliminate or reduce the chances of tooth decay in the population. Minimum recommended values of fluoride within the drinking water to reduce tooth decay, have been deemed by both WHO and EPA to be 0.5 mg/L. The addition of fluoride typically occurs within the range of 0.7 – 1.2 mg/L in the form of sodium hexa-fluorosilicate or hexa-fluorosilicic acid, however the recommended value for artificial fluoridation is 0.5–1.0 mg/L by WHO (Murray, 1986).

There has been widespread controversy however to public water fluoridation of drinking water. Critics oppose this for reasons that water fluoridation can have harmful health effects such as dental and skeletal fluorosis, bone cancer, and osteoporosis (IPCS, 1984). The process of public water fluoridation has been criticized in that it takes away an individuals right to choose and limit the amount of fluoride intake depending on food and medical intake. Many strong opponents include members of the Medical community, notably Arvid Carlsson, Nobel Prize Winner (Murray, 1986).

VIII. CONCLUSIONS

While establishing national standards for drinking water it is essential to put in mind the possible health risks associated with fluoride exposure. Factors such as intake of water by the population in a designated environment, as well as intakes from sources such as food, air, and dental products, all contribute to the total consumption and ingestion of fluoride in a given environment. In countries where the daily intake of fluoride exceeds 6 mg/day, it would be advisable and recommended to place a national drinking water standard less than the WHO limit of 1.5 mg/L to compensate the factors incorporated in the environment.

It can be seen that fluoride concentrations at both lower and higher levels within the drinking water, may pose health risks to humans. There is more of a threat however to the higher concentrations due to the severity of the diseases posed by such levels within the water. There are many potential problems that may rise from elevated concentrations of fluoride in water however there are several options that may be considered to prevent these risks from occuring. One option includes the process of de-fluoridation or treatment of the water. Several methods were explained and are quite simple and feasible for many countries, but in some nations they may prove to be costly. In these instances, options such as using the water for other purposes such as irrigation are possible. This may be used for the drinking water that can not be used, or wastewater that has been treated. For irrigation purposes, countries place standards for reclaimed water for reuse in irrigation that is considerably higher than those imposed on drinking water. At this point, it may prove to be useful to utilize the water for other purposes of beneficial use.

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