WWCH 2018 PROBLEM DESCRIPTION

Problem Title
Problems Pertinent to Prevalence of Excessive Fluoride in Different Water Sources

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1. Basic information

Fluoride is the most reactive, most electronegative and harmful nonmetallic inorganic substance affecting the human health when it′s consumed above the standard. Fluorine is a yellow gas having strong odour, strong oxidative and corrosive properties (Katarzyna et al., 2015). A human being can ingest fluoride in to its body through food, water, breathing air, drugs and cosmetics (Meenakshi et al., 2004). Significant amount of fluoride can be found in foods such as tea (112 mg/kg), rice (6 mg/kg), tobacco(up to 38m g/kg), fish/beef (6.5 mg/kg), apple (5.7 mg/kg) and lettuce(5.7 mg/kg) (Meenakshi and Maheshwari, 2006). Considering this substantial amount of fluoride consumed through food plus the smaller amount from the air, drugs, cosmetics etc, the world health organization (WHO) has set a standard for the maximum contaminant level (MCL) of fluoride in the drinking water to be 1.5 mg/L (WHO, 2006) as it causes different environmental and health hazard.

Fluoride in any water source is believed to emanate either from the natural rocks (up to 2,800 mg/L), mainly as sellaite (MgF_2), as fluorspar in sedimentary rocks (CaF_2), as cryolite in igneous rock (Na_3AlF_6) and fluorapatite [$3Ca_3(PO_4)_2$ $Ca(F,Cl_2)$] (Mohapatra et al., 2009) or from different anthropogenic effects, mainly release of industrial wastewater from aluminium manufacturers (emits cryalite of boxite ore Na_3AlF_6), phosphate fertilizer (release SiF), semiconductor industry, electronics, ceramics, glass, metallurgical production (up to 3,000 mg/L) (Min et al., 1984; Ndiaye et al., 2005). From all the natural water sources, ground water mainly contains the largest fluoride amount. The fluoride concentrations in groundwater range from 1.0 mg/l to more than 35.0 mg/l this value mainly depends on the geology, the chemical and physical behavior of the aquifer, and its interaction with the environment (Keri et al., 2011). Surface water resources normally do not have concentration bigger than 0.3 mg/L of fluoride except polluted from other external special cases (Arda et al., 2009). In most developing communities with decentralized water supply system the extensive use of ground water as their main source is exposing them to fluoride harm. So far higher amount of fluoride has been recorded in Australia, Middle East, South America, North Africa, Ethiopia, Kenya, Thailand, China and India (Sehn, 2008). Nowadays, more than 200

million people from more than 35 nations across world suffer from face issues of excess fluoride (Ayoob et al., 2008) see **Fig. 1.** A typical fluoride rich water is soft having high pH and big amount of silica (Keri et al., 2011).

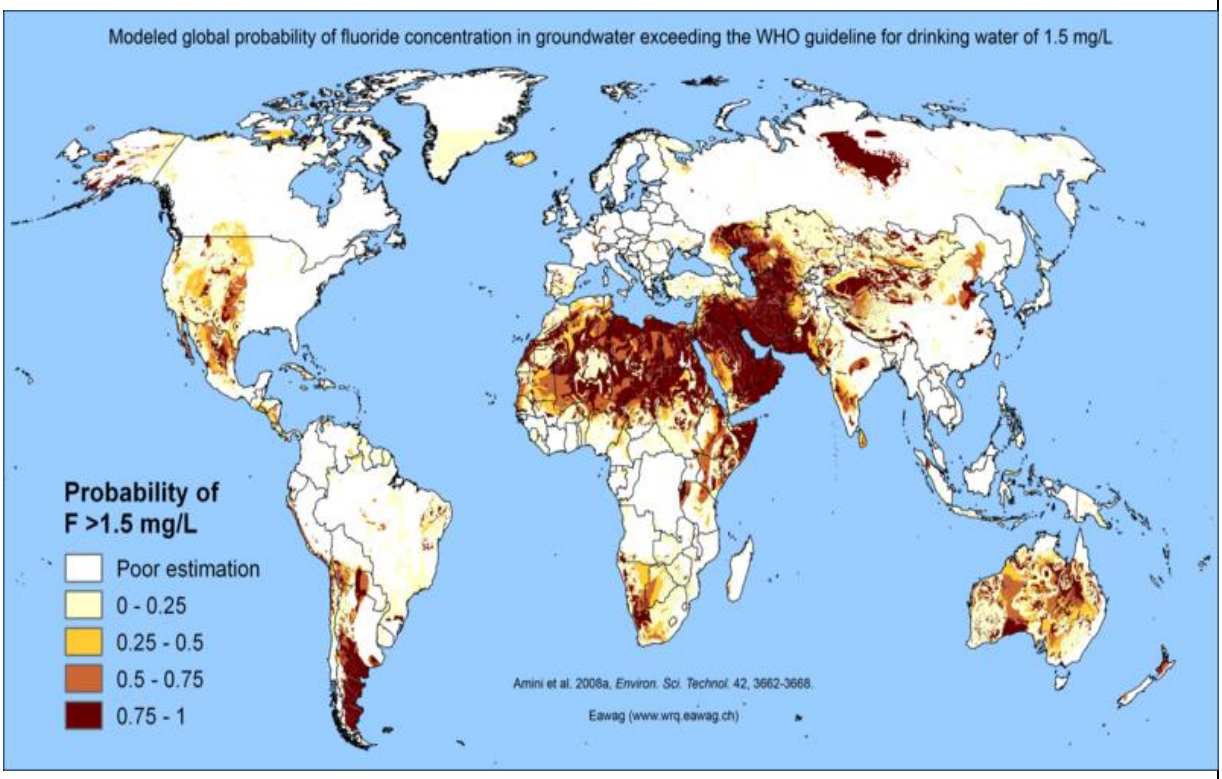


Fig. 1 Global fluoride distribution in ground water (Amini et al., 2008)

3. Problem description

Problem Statement (challenges)

The existence of fluoride has negative effect both on the aquatic life and to the human well beingness. Most countries′ local government has a environmental standard for disposal of waste water effluents to the municipal sewer line and marine coastal area. For example, the EPA effluent limitation for fluoride for the hand pressed and blown glass manufacturing industry is 13 mg/L (US EPA, 2015); The Japanese national effluent standard of fluoridated wastewater to the coastal areas is 15 mg/L and for non-coastal areas is 8 mg/L (JNES, 2015). When it comes to the drinking water standards, more stringent regulations (1.5 mg/L) apply to the fluoride level in water (WHO, 2006). If complying with this standard is not successful, the nearby aquatic life will be critically in danger specially those living in the fresh water.

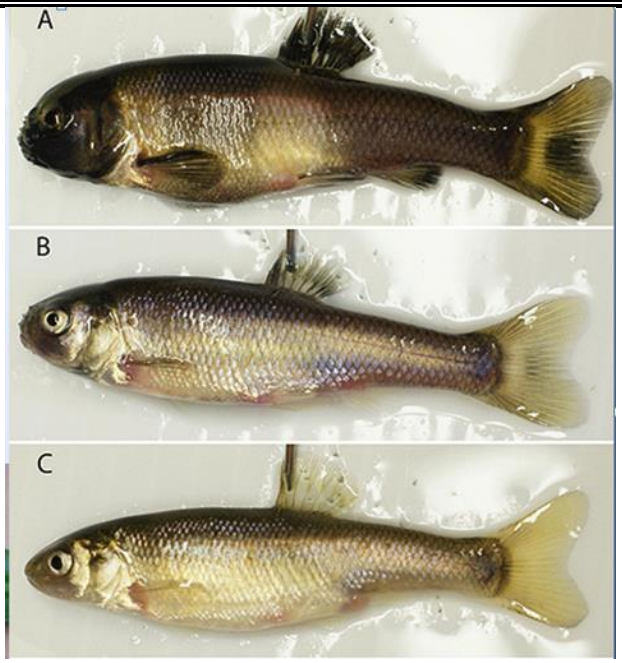
a) Health impact on aquatic life

A fluoride concentration as low as 0.5 mg/L can adversely affect freshwater invertebrates and

fishes, especially caddisfly and salmons. In aquatic animals, fluoride is accumulated in tissues and inhibit the entire metabolic processes (Camargo, 2003). An aquatic invertebrate is basically a bug (don′t have spines). But these are the basis of the food chain for fish, which in turn feed higher predators (See **table 1**). These bugs eat plants and decaying matter in the aquatic ecosystems and without them there will be severe collapse of entire ecosystems. This collapse would destroy fish, and fish preying bird populations (Edminsten, 2016), as such the effect of fluoride ion in the entire biosphere is significant enough to touch all the aquatic and terrestrial animals (see Fig. 2). A study (Edminsten, 2016) stated that these bug can only sustain in an acceptable fluoride level of 1.94 mg/L in the water. On the other hand, The effect of fluoride on the aquatic flora and algae depends on various factors hence sometimes inhabits and sometimes favors their growth. It also worth to mention that aquatic plants also have positive impact toward removing the excess fluoride from the polluted media (El-Said and El-Sikaily, 2013; Hekman et al., 1984; Oliveira et al., 1978).

Table 1 Health impact of fluoride ion on aquatic flura and fauna

SN	Victim species type	Fluoride attacked species in the ecosystem
1	Daphnia Magna	

2	Fishes	
3	Aquatic plants	

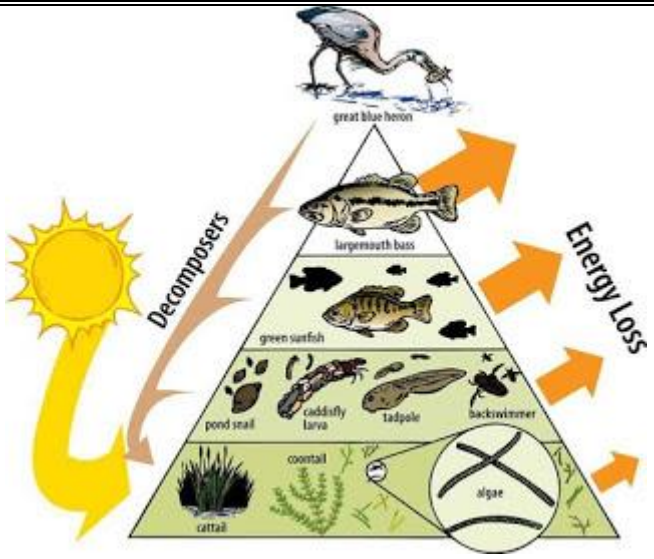


Fig. 2 Health impact of fluoride ion in the ecosystem pyramid (Edminsten, 2016)

b) Health impact on human health

The effect of fluoride on the human health is enormous but it mainly affects the bone and teeth. This is because the fluoride ion displaces hydroxide ions from hydroxyapatite of the teeth and form tougher fluoroapatite which consequently increase the brittlity of the teeth (Mohapatra et al., 2009). Fluoride less than 1.5 mg/L (WHO, 2006) is often required for our dental and skeletal health, but any amount over these limit have its own negative impact. For instance fluoride amount 1.5–4.0 mg/L causes dental fluorosis, 4.0–10mg/L cause dental and skeletal fluorosis and greater than 10.0mg/L cause paralysis, crippling fluorosis (Meenakshi and Maheshwari, 2006). Moreover, long term exposure to excess fluoride ion above the required limit also have additional complications (see **table 2**) such as failure on foetus, low haemoglobin, inhabiting enzymes, distributed pain and weakness on joints, cancer, Gastro intestinal problems, depression, urinary tract malfunctioning, sterility, malfunctioning of liver, kidney, and respiratory system. (Heikens et al., 2005; Ozsvath, 2009). Its mental effects and brain cell damage also indicated in that, children in high-fluoride areas are found to have significantly lower IQ scores than those who lived in low-fluoride areas. (Choi et al., 2012)

Table 2. Various complications of excessive fluoride on the human health

SN	Fluoride level in drinking water	Type of health impact
1	< 1.5 mg/L	Essential to the human teeth and skeletal health

2	1.5 - 4.0 mg/L	Cause dental fluorosis   
3	4.0 - 10.0 mg/L	Cause skeletal fluorosis  

		
4	Extended long term use above 1.5 mg/L	Cause other health impacts stated on **Fig. 3** 

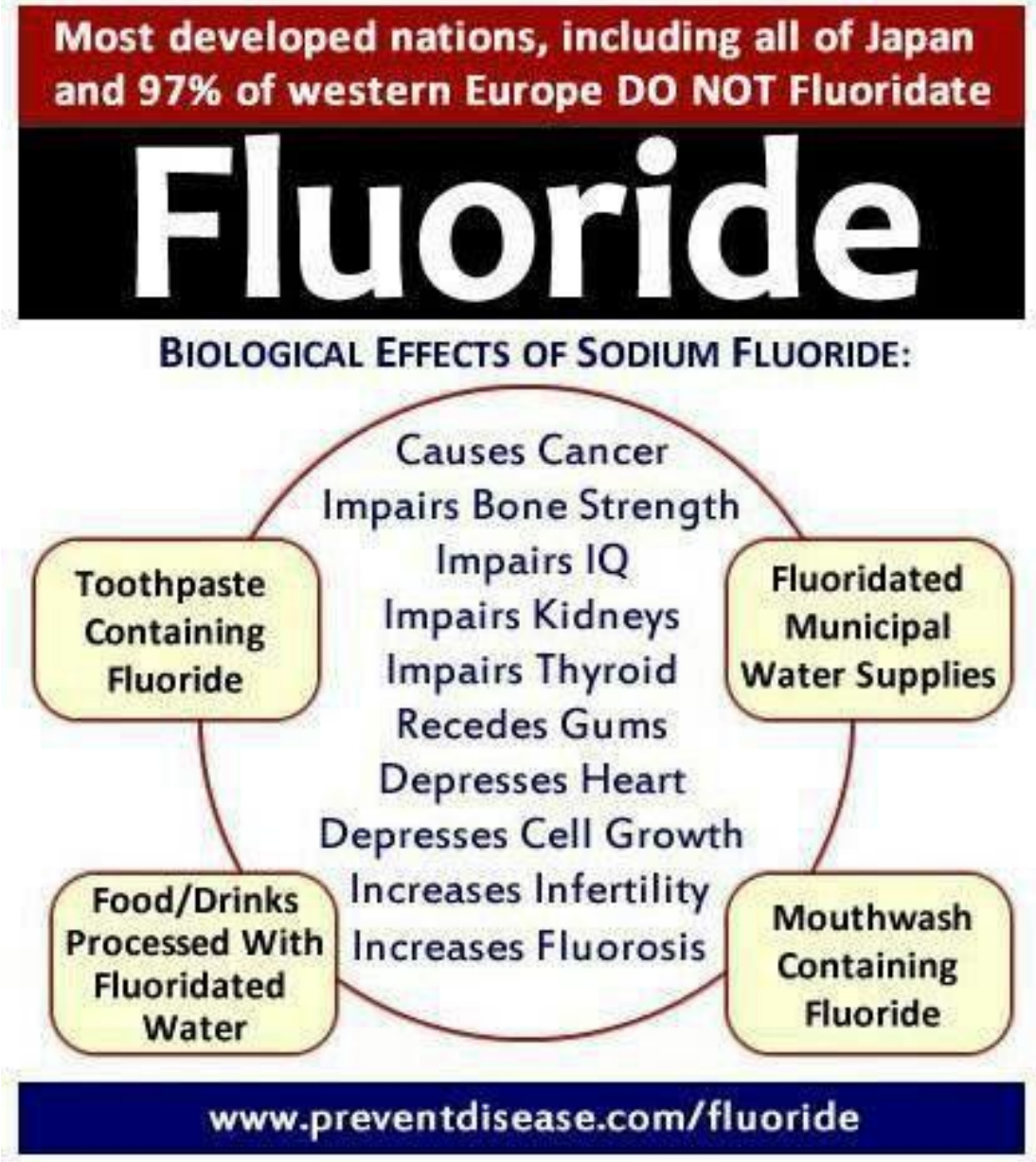


Fig. 3 List of various health effects of excessive fluoride on the human health

Hypothesis (technology options)

To avoid this environmental health impact of fluoride, water has to be treated before drinking (so as to avoid its effect on the human health) and should be adequately defluoridated before releasing industrial wastewater to the water bodies (to control its effect on the life of aquatic and terrestrial ecosystem). Fluoride removal from different water sources has drawn big attention for extended period of time for the reason that it′s complete removal is very difficult to be attained by the conventional methods such as precipitation, ion exchange, adsorption and coagulation (Katarzyna et al., 2015). This difficulty is mainly because of its ionic size (atomic number 9) and high reactivity to forms so many more soluble compounds.

Publication and research attention is now being increasing on the fluoride related discipline toward easily controlling its environmental and human health effects. This research team in Korean Institute of Civil Engineering and Building Technology is now working toward forwarding different advanced innovative technologies. Various cost effective treatment mechanisms fitting the decentralized system in rural setting has been suggested based on real laboratory experimental data analysis. In addition to this the research group has also conducted alternative best options for defluoridating extremely polluted, high fluoride containing industrial wastewater. All these solutions and treatment technologies will be organized and presented during the second phase of this world water challenge 2018 contest.