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Exploring Fluoride safe water drinking habits in the African Rift Valley.

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1. INTRODUCTION

The consequences of groundwater Fluoride contamination on plants, animals and humans have been expressed widely based on studies by scientific institutions, international organizations and communities with the World Health Organization (WHO) setting the standards for accepted levels of Fluoride (F) intake. The globally accepted safe Fluoride intake standard is (1mg/L), although WHO, estimated that more than 260 million individuals across the globe utilize Fluoride contaminated water above the prescribed average of (1mg/L) (WHO, World Health Organisation, 1984). Fluorine, a naturally occurring element, is widely distributed; exist in air, soils and water (Stephen and Niyi., 2014). While Fluoride intake has both valuable and adverse effects on life, the adverse impacts of excess Fluoride intake is directly determined by the concentration of Fluoride in a place to the exposure relationships. The known adverse problems emanating from high Fluoride intake are Dental and Skeletal Fluorosis, bone fracture, visible leaf injury, damage to crops as well as decline of quality of farm yields (Rajesh et al., 2012).

Even though groundwater fluoridation is still a debatable public health topic, in major instances, groundwater sources have been rendered unsafe. Other purposes such as irrigation and consumption of yield produced utilizing contaminated water have not received the same attention. Fluorine is a naturally existing element and easily soluble in ground and surface water, soils and air. Fluorine being one of the most reactive of all chemical elements do not exist as Fluorine in the natural environment, but rather, as Fluoride. Fluorides are found at significant levels in a wide variety of minerals, including fluorspar, rock phosphate, cryolite, apatite, mica, hornblende that are associated with igneous and metamorphic rocks such as granites and gneisses (WHO, World Health Organization, Geneva., 1986). According to (WHO, World Health Organisation, 1984), approximately 260 million people in nearly 29 countries utilized Fluoride contaminated water above the prescribed intake levels of (1mg/L). In (Brindha, 2011), human and livestock requires Fluoride intake of between (0.6 to 1mg/L) for the development of stronger teeth and bones. On the other hand, ingestion of excessive Fluoride (> 1.5 mg/L) can result in a disease known as Fluorosis (Bhupinder and Garg., 2012). Exuberant Fluoride concentration in the groundwater across the globe is responsible for widespread Fluorosis. Fluorosis is a slow, progressive, crippling condition that affects body organs, tissue and cells resulting in health complications with overlapping manifestations in several other diseases (Gopalan et al., 2008). Fluoride accumulates in body tissues of plants and animals and, it's excessive intake exposes these tissues to risks of developing Fluorosis and damage to produce thereby reducing their health, quality and endangering consumers (Dhar and Bhatnagar., 2009). In human and animals, Fluorosis is the key indicator through bone and dental defects. It also causes paralysis, respiratory complications, low blood pressure (Andezhath., 1999), and in chronic phase, experiences such as weight loss, anorexia, anemia and cochexia are very common (Ibrahim M, Effects of Fluoride Content in Ground Water: Acritical Review, 2011). Higher Fluoride levels of (>10 ppm) in pregnant women has also been proven to be able to cross the placental barrier, affect the primary dentition for the unborn and lead to permanent inhibition of growth in children

(Ibrahim M, Effects of Fluoride Content in Ground Water: Acritical Review, 2011; Bronckers et al., 2009).

Naturally, groundwater Fluoride concentrations are associated with diverse geological conditions, mineral reactions, rock formation processes and climate change-temperature and precipitation- in specific contexts across the globe. The current excessive extraction of groundwater to meet growing human population demands and the alteration of precipitation patterns, negatively affects the groundwater balance capability. This scenario has not only diminished fresh water resources but also influences the water quality through higher dissolution of fluorites from bedrocks leading to high Fluoride content in most groundwater sources (Bhupinder and Garg., 2012). The presence of a large number of variables facilitating Fluoride contamination in diverse contexts implies that the average accepted Fluoride concentrations in groundwater could vary from region to region and country to country. Variables such as climatic conditions especially high air temperatures, volcanic activity, fumarolic gases, calcium-deficient aquifers and the presence of high sodium in ground rocks-that has an influence on Fluoride solubility and ingestion-influences the quantity of Fluoride solubility in water and subsequently to the end users (Edmunds and Smedley., 1996). Nevertheless, Fluoride intake prescription is expected to conform to the mean of (1mg/L) (USA, US Government Printing, 1962).

Although global distribution of Fluoride depends on a combination of variety of sources, this study focused specifically on contamination from natural sources. In approximately 29 countries, both developing and developed, excessive Fluoride concentrations, prevalence of Fluorosis and it's impacts have been reported (Meenakshi, 2006). Countries in Africa such as Algeria records between (0.4 to 2.3 mg/L; (Messaïtfa, Fluoride contents in groundwaters and the main consumed foods (dates and tea) in Southern Algeria region, 2008), Ethiopia (0.01 to 13mg/L; (Tekle-Haimanot, 2006), Ghana up to 142.35 mg/L; (Yidana, Analysis of groundwater quality using multivariate and spatial analyses in the Keta basin, Ghana., 2010; Apambire, Geochemistry, genesis, and health implications of fluoriferous groundwater in the upper regions of Ghana., 1997), Malawi (1.65 to 7.5 mg/L; (Sajidu, Groundwater fluoride levels in villages of Southern Malawi and removal studies using bauxite, 2008), Kenya (0.1 to 25 mg/L; (Gaciri and Davies., 1993), Tanzania (15 to 63 mg/L; (Nanyaro, A geochemical model for the abnormal fluoride concentrations in waters in parts of northern Tanzania, 1984) all exhibit higher than accepted Fluoride concentrations. Other regions e.g. Australia (0.69 to 9 mg/L, (Petrides, The hydrogeology and hydrogeochemistry of the Barwon Downs Graben aquifer,, 2006) from a large survey of boreholes in central Australia where 1.5% registered (>9mg/L (Fitzgerald, 2000).

In Asia, many countries led by India and China have large Fluoride deposits. India's range of (0.6 to >43 mg/L; (Brindha, 2011) spans 17 states with a national mean Fluoride concentration at (22.1 mg/L) with the highest being Rajastan and the lowest being Madhya Pradesh (2.18). All of the 17 states being way above the internationally prescribed standards. China presents a (> 8 mg/L; (Fuhong, Distribution and formation of high-fluorine groundwater in China, 1988; Li et al., Fluoride in drinking water, brick tea infusion and human urine in two counties in inner Mongolia, China., 2009; Genxu, Fluoride distribution in water and the governing factors of environment in arid north-west China., 2001; Zheng, High fluoride groundwater with high salinity and fluorite in aquifer sediments in Inner Mongolia,, 2006; Guo, Geochemical processes controlling the elevated fluoride concentrations in groundwaters of the Taiyuan Basin, 2007), for groundwater contamination and (20 to 500 mg/KG) for coal (air) indoor Fluoride concentrations (Swaine, Trace Elements in Coal, 1990). South Korea has a margin of between (0 to 48.8mg/L; (Kim, 2005), Sri-Lanka at (0.01 to 5mg/L; (Dissanayake, Environmental management and health., 1991), Iran >12.08; (Looie, 2010; Moghaddam, Distribution of fluoride in groundwater of Maku area, northwest of Iran., 2008), and Jordan with a much lower Fluoride levels of (0.009 to 0.055mg/L; (Moghaddam, Distribution of fluoride in groundwater of Maku area, northwest of Iran., 2008). Pakistan represents another large groundwater contamination to the tune of (0.11 to 22.8 mg/L; (Farooqi, 2007) and Saudi Arabia at (0.42 to 1.8 mg/L; (Alabduláaly, Fluoride content in drinking water supplies of Riyadh, Saudi Arabia, 1997). High levels of Fluoride have also been recorded in the Americas where in Brazil the concentration levels ranges between (0.1 to 4.79 mg/L; (Mirlean, 2007), Mexico (0.53 to 7.59 mg/L; (Valenzuela-Va´squez, The origin of fluoride in groundwater supply to Hermosillo City, Sonora, Mexico, 2006), USA (0.3 to 6.26; (Hudak, 2003). In fact, data from (EPA, USA., 1985) found that 0.5% of USA and Canada population were constantly exposed to (>2.0 mg/L), Canada stands at (> 15.1 mg/L; (Desbarats, On elevated fluoride and boron concentrations in groundwaters associated with the Lake Saint-Martin impact structure,, 2009). European countries recording elevated Fluoride level include; Norway (> 8.26mg/L; (Banks, The distribution of radon, major and minor elements in 1604 crystalline bedrock groundwaters, 1998), Turkey (1.5 to 13.7mg/L; (Oruc, Occurrence and problems of high fluoride waters in Turkey: An overview., 2008), Poland (0.3 to 2.45 mg/L; (Czarnowski, Fluoride in drinking water and human urine in northern and central Poland, 1996), and Estonia (0.01 to 7.2 mg/L; (Indermitte, Exposure to high fluoride drinking water and risk of dental fluorosis in Estonia, 2009).

Daily exposure to Fluoride is highly dependent on geographical regions and countries, climate, local practices and a number of different sources such as natural, industry and agriculture. While some studies have shown that daily Fluoride exposures are influenced by the relationship between maximum temperatures and water intake, community practices such as utilization of Fluoride rich coal for house heating, drying and cooking food has significant effects (IPCS, 2002). Much higher intake of water normally occurs in hot and dry regions and this has a direct relationship to the amount Fluoride intake. Consumption of Fluoride rich food and beverages like brick tea and farm products irrigated with Fluoride contaminated water and soils increase this effect-exposure relationship (Meenakshi, 2006). In hotter climate zones where much higher consumption of contaminated water occur increases the Fluoride intake by (3.6 to 5.4 mg/day) with more severe impacts (Galagan D. J., 1957). Dental Fluorosis is identified to be prevalent in drier regions with elevated Fluoride concentrations as compared to cooler environments (Dissanayake, Environmental management and health., 1991).

While the global prescribed maximum Fluoride contaminated water intake range remains (0.6 to 1.5 mg/L), (WHO, World Health Organisation, 1984; WHO, World Health Organisation, 1993), Fluoride contamination through air increasingly predispose a large number of communities across the globe. Fluorine elements can easily be transported by air from sources such as burning Fluoride rich coal, anthropogenic emissions and contaminated dust/loose soils during wind erosion. The worldwide air Fluoride concentration from natural sources stands at (0.5 ng/m3), while those from anthropogenic emissions stands at (3 ng/m3) (Slooff, 1988). Research by (WHO, World Health Organisation, 1996) indicates that in the Netherlands, Fluoride air concentration was (70 ng/m3) in Fluoride rich regions and (40 ng/m3) in non-rich regions, where the total daily Fluoride intake through air remains between the dosage of (1.4 to 6.0 mg) (Slooff, 1988). China's main source of Fluorosis derives from Coal burning. As the largest producer and consumer of coal, with 84% of energy derived from coal, people in 27 provinces, autonomous regions and municipalities are highly exposed to ingested effects of Fluorine and other related ailments. Mainly, combustion of Fluoride rich coal for heating, cooking, drying food, implies that indoor air concentrations of Fluoride in China ranges from (20 to 500 mg/KG) providing an average daily ingestion of Fluoride between (0.3 to 13mg) per person (Cao SR, 1992). The USA and Canada indoor air Fluoride concentration ranged between (0.02 to 2.0 ng/m3) (IPCS., 1984). This figures intentionally excludes outdoor and industrial Fluoride emissions that has a direct effect in increasing exposure.

For decades Fluorosis has been associated with drinking high Fluoride content water. But, current research is showing that Fluoride and Fluorosis can be acquired from food and agro-animal products. Crops and livestock fodder from contaminated soils and water accumulate Fluoride in their tissues and thereby exposing the end users. Food represents a high percentage of Fluoride intake which is propositional to body weight (Slooff, 1988). Fluoride contaminated diet in many communities and the health of such population determines the extent to which an exposed individual contracts Fluorosis. In children, total Fluoride intake through food is thought could be lower than adults due to their lower consumption rates. Curiously, (Ibrahim, 1995) realized that 91% of children living in regions of Sudan with low Fluoride water content (0.25 mg/L) still acquired Fluorosis. Same results were found by (Venkateswara R, 1990) in Indian regions with accepted levels of Fluoride in drinking water experiencing a high rate of Fluorosis. In Ethiopia (Olsson, 1978) presented mild Dental Fluorosis in 18% of people utilizing (0.3 mg/L) range all of which still fall bellow the accepted levels of (1mg/L). These results from regions with lower than accepted Fluoride level presenting Fluorosis and not the expected dental carriers and weak bones confirm that Fluorosis is not only acquired through water, air but from food. Food could present other two options whereby a possibility of influence from 'market goods' like tea or fish from other contaminated regions accessing such communities.

Research on different irrigated crops in Fluoride rich soils and water exhibited elevated levels of Fluoride. Scholars, (Rajesh et al., 2012), performed field tests in India on selected crops. Fluoride was found to have affinity to vegetable leaves and tubers thereby negatively affecting growth and yield. Fluoride levels have been detected up to (40 mg/KG) in curly kale (highest) and (25.70 mg/KG) in Spinach (fresh weight) in Nagaur District of India (Gautam R., 2010). In Spinach from Mwanza region of Tanzania, a trace of up to (7.7 mg/KG) was detected. Other foods have also been detected in the African Rift Valley. With many lakes, soil and mountains with elevated Fluoride levels, African Rift Valley is one of the major zones where Fluorosis is prevalent. Fluoride test on typical dish/ staple food in Africa Rift Valley have confirmed Fluoride high concentration in cereals and meat. In a survey by (Marian, 1997) in Mwanza region of Tanzania, Cassava accumulated (2.5mg/KG), Maize flour (1.2 mg/KG), Sweet potato (1.0mg/KG) and Groundnuts (4.3mg/KG). Tilapia fish from Lake Tanganyika (11.6mg/KG), Tilapia fish from Lake Awasa in Ethiopia had (17.5mg/KG), Tilapia from Lake Victoria in Kenya presented (3.7mg/KG) and African Cat fish from L. Tanganyika accumulated (8.2mg/KG) in their fillet tissues only. Fluoride accumulation in bones and skin recorded higher figures. Given that these foods are always served together during a meal e.g. maize meal with meat/fish and vegetables in these regions, (Reynolds, 1993) and (Marian, 1997) believes that this has a reinforced increase of food-exposure relationship to Fluorosis prevalence. Tea, carrots, cabbage and wheat have also produced evidence of elevated Fluoride results in India, Kenya and China (Bhargava D., 2009). Specifically, (Opinya, 1991) reported a (249mg/KG) Fluoride elevation in Kenyan tea. In this backdrop, (Venkateswara R, 1990), contends that tea is one of the main source of Fluorosis in regions with low Fluoride drinking water. In essence, (Slooff, 1988) confirms that dried tea Fluoride accumulation ranges between (3 to 300 mg/KG), which translates to (0.4 to 0.8mg) per 3rd cup of tea taken. This elevated concentration in tea could be as a result of tea plant absorption of Fluoride from natural sources (water and soils), fertilizers or during manufacturing. This intake can be exacerbated if Fluoride contaminated water is further utilized in preparing the tea or other beverages and food (IPCS., 1984).

Traditionally, water has been identified as the main source of Fluorine and Fluorosis. Elevated Fluoride concentrations in water are associated with diverse sources. Ground waters have tended to possess higher Fluorine than surface flowing waters. As noted earlier, types of rocks and other elements determines the quantity of contamination. Surface water studies by (Slooff, 1988) reported a total of (1.3 mg/L) for seawater, while other sources such as boreholes, wells, springs, lakes and rivers have varying degrees depending on their geographical locations. A level of (2800mg/L) in Lake Nakuru in Kenya remains the highest ever tested from surface water sources. Water and beverages therefore contributes 50% of the total daily Fluoride intake (Ershow, 1989). In the African Rift Valley, which extends from Jordan to Tanzania, high Fluoride concentrations are a common issue. Lake Elementaita (1,640 mg/L) and Lake Nakuru (2,800 mg/L) both of Kenya as well as Lake Momella (690 mg/L) of Tanzania are just but a few elevated examples (Thole, 2012). Random national Fluoride survey in Kenya indicates that 40% of the 1000 groundwater samples returned (5mg/L to >8mg/L), Malawi (>1.9), Tanzania (>8 mg/L), South Africa (>1.3mg/L), Canada (3.3 mg/L), Australia (3 to >9 mg/L) (Thole, 2012; Fitzgerald, 2000). Tests from China's selected villages, Fluoride concentrations were consistently (>8 mg/L) (Fuhong, Distribution and formation of high-fluorine groundwater in China, 1988). Although Fluorides can also enter water sources through industrial discharge, this study focused on natural Fluoride sources. Importantly, a recommendation for setting a different standard for tropical regions to a mandatory limit of (0.6 mg/L) for Fluoride in portable water has been proposed (Lesan, 1987) and the general average daily safe Fluoride intake to be between (1.5 to 4.0 mg/day) per adult followed by a much lower percentage for children (National Research Council , 1989). This observation corresponds to the Fluoride-Temperature relationship. These internationally researched and recommended ranges have been potentially altered depending on local situations and national legislations where for instance Tanzania Government recommended Fluoride intake is (4mg/L) instead of (1mg/L).

The most common health problem associated with Fluorine is Fluorosis. Fluorosis is a slow, progressive, crippling condition that affects body organs, tissue and cells creating diverse negative health conditions (Gopalan et al., 2008). Fluoride intake itself is not a bad phenomenon but excess intake can be fatal. Fluoride ingestion up-to (1mg/L) is very important in developing strong bones and teeth and to avoid dental carries (Bhupinder and Garg., 2012). But, (WHO, World Health Organisation, 1984) warns that Fluoride intake in excess of (> 1.5 mg/L) leads to a condition known as Fluorosis. Fluorides accumulates in body tissues of plants and animals and exposes these tissues to risks such as bone fracture, visible leaf injury in plants and vegetable and damage to quality of farm produce (Dhar and Bhatnagar., 2009). Apart from bone and dental defects in human and animals, excess Fluoride ingestion causes paralysis, respiratory complications, low blood pressure, abortion, reduced immunity, still births, prevalence of depression, gastrointestinal problems, urinary tract malfunction, muscle fiber degradation, male sterility, memory lapse, (Andezhath., 1999), and weight loss, anorexia, anemia and cochexia are very common in chronic phase (Ibrahim M, Effects of

Fluoride Content in Ground Water: Acritical Review, 2011). A higher Fluoride level accumulation of (>10 ppm) could be able to cross the placental barrier, affect the primary dentition for the unborn and lead to permanent inhibition of growth in children (Ibrahim M, Effects of Fluoride Content in Ground Water: Acritical Review, 2011). It is estimated that a continuous dosage of (20 to 120 mg/day) over a period of 10 to 15 years leads to crippling of the victims (Bronckers, 2009).

1.1. Stages of Fluoride effects

Fluoride Concentration (mg/L)	Effects of Fluoride
<0.5	Dental carriers and weak bones
0.5-1.5	Strong bones and teeth
1.5-4.0	Dental Fluorosis
4.0-10	Dental and Skeletal Fluorosis
>10	Crippling Skeletal Fluorosis, Cancer and other ailments, Death.

Source: (Indira D., 2014).

In India, research on Fluorosis started in 1937 and so far groundwater from 17 States have been confirmed to possess high levels of Fluoride. This excessive presence of Fluoride in groundwater spans over 177 districts. High presence of Fluorosis, deformed limbs and spine, joint and neck pains in adults, calcified ligaments and exostosis are common in these states (Chakraborti D. D. B., 2016). More than 65 million are at risk of dental and skeletal Fluorosis in these 17 states while 6 million children are already suffering Fluorosis (Ibrahim, 2011). On the other hand, even though the data of specific prevalence remains elusive in regions of Africa Rift Valley, the daily exposure in Tanzania is thought to be up to (30 mg/Day) for adults mainly from drinking water. Utilizing Fluoride rich coal in house heating, cooking and preserving food led to registered Dental Fluorosis cases to the tune of 18.1 million persons and a further 1.6 million skeletal

Fluorosis in China. This presents it as one of the most grave health challenge in China (Daishe, 2004). In China the content of Fluorine in coal ranges between (25 to 1230mg/KG) in 27 provinces, autonomous regions and municipalities. The national mean for Fluoride indoor air concentration is (190mg/KG) while food and beverages other than water provide (1.8 to 8.9 mg) (Cao SR, 1992). In Kenya, Fluorosis has been considered endemic and a major public health problem for decades. The identified major source was drinking water although dust/soils, food and beverages have a significant contribution. In Lake Nakuru basin, dust particles contains between (2800 to 5600ppm) of Fluoride particles (Williamson, 1953). During drought, which is a common phenomena, volcanic dust particles as well as wind erosion along the Rift Valley spread significant Fluoride content. This directly affects poor households such as those working in long distance grazing of animals, quarry, manual labor, construction workers, domestic chores and farming. In his research (Davis, 2008) also add that since most road network in these developing countries are not tarmacked, coupled with heavy traffic, the air is dust-filled for most parts of the year leading to inhalation of more Fluoride contaminated dust. This continuous inhalation of Fluoride rich dust is capable to accumulate in the lungs of the population and lead to the high prevalence of diseases such as silicocis, tuberculosis, lung cancer and asthma. Along the African Rift Valley according to (Nair K. R. and Manji, 1984), large presence of volcanic rocks, hot springs and Rift Valley Lakes has led to this high prevalence of Fluorosis. Nevertheless, (Chakraborti D. D. B., 2016), believes that nutritional and health status of individuals when compared to the amount and period of ingesting Fluoride determines how one transitions to crippling Fluorosis.

Health is a very key component in human capital while human capital remains a very key component of development and wealth creation across the globe. In many instances, it has not been well appreciated the relationship between a working population and their health status. Fluorosis effects on population have a notable degree of impacting negatively on social lifestyle as well as on economic advancements. Although political, cultural, social, economic and even environmental factors have an influence on health systems, economically stable people are able to make choices on the quality of water and food they consume. Majority who are deprived in general face basic problems on livelihood and health. In major instances, such people do not possess the awareness of the adverse effects of Fluoride on their lives apart from perception and myths. According to (Indira D., 2014), poor households faces a lack of accessibility to clean safe piped water driving them into digging boreholes and wells. It is also a well-known fact that developing countries have very weak to non-existing control of quality and type of water their citizenry could utilize in rural areas, let alone regulation in digging and extracting ground water. Some of these ground water sources contains unknown amount of Fluorides and other elements that leads to Fluorosis (Chakraborti D. D. B., 2016). Recognizing that 80% of rural inhabitants are peasants and small-scale farmers in developing countries, and if this is coupled with high population growth and increased demands, presence of Fluoride in water both for drinking and agriculture has a direct effect on their socio-economic status.

Education, income and occupation defines individual's socio-economic position and living standards within a community (Graham, 2004). It is possible to note that due to the negative effects of Fluoride such as diseases and crippling conditions has the potential to negatively affect socio-economic advancements of underprivileged. Large decrease in the ability to work and be productive due to Fluorosis has a direct negative correlation to the socio-economic status of households (Indira D., 2014). Not only do underprivileged households face economic poverty, but also social segregation and deteriorating health due to poor diet occasioned by inability to work. Further, due to inability to labor, individual victims become a financial burden to their families who must be able to support them both medically and socially. This further reduces collective working hours of able family members to the detriment to social status of the victim. Sick family members are constrained in employing labor intensive approaches in any kind of work which is the most common method in rural poor households agriculture (Indira D., 2014).

In situation where the Fluorosis victim is also the sole household head, multiple effects on affording children education, health and livelihood is negatively affected. Depletion of family and community savings due to medical expenses deprives such families and regions the much needed capital that could be utilized to improve other sectors such as education, shelter, nutrition and health systems (Graham, 2004). It is possible that crippling Fluorosis effects on sole household heads could contribute to child labor where children are engaged in income wage employment at an early age to bridge the family income gap. When able members of families are unwell or sick, abandonment of farms or failure to improve farming practices tend to occur and farmers are unable to remain at pace with modern climate adaptation strategies, hence reducing output. This reduced agricultural output can have a direct impact on the total amount of food produced, quality, malnutrition, savings and buying power. Fluorosis victims attract fewer wages due to perceived less hours of work or non-perfection in discharging their duties. High exposure to Fluorine therefore has the potential to expend a relentless physical, health and subjective burden that has direct correlation to nose diving economic and other social advancements (Graham, 2004).

This study focused on Fluoride water contamination and Fluorosis in the African Rift Valley countries of Kenya and Tanzania where Fluorosis is prevalent. Since the African Rift Valley is still an active volcano zone, coupled with large inland lakes containing elevated loads of Fluoride, countries such as Ethiopia, Kenya, Tanzania and Uganda's population along this Rift faces diverse kinds exposure to elevated levels of Fluoride. In essence (Brindha, 2011), found that of the Ethiopia's 11 million African Rift Valley inhabitants, 9 million were severely exposed to higher than normal concentration of Fluoride from water, food and air.

This study also focused on naturally fluoridated drinking water and its impacts on the people of Kenya and Tanzania. This thesis is organized as follows; it explored through a ten year Systematic Review the factors that influence the relationship between Fluoride in drinking water and Dental Fluorosis, which was followed by a ten year statistical/Meta-Analysis on the factors influencing the relationship between Fluoride in drinking water and Dental Fluorosis. In the last chapter, the study conducted qualitative research in the field in Kenya and Tanzania to explore drinking Fluoride safe water habits using Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) approach. This section was aimed at understanding behavioral, socio-economic and habits hindering the uptake and use of filtering equipment before introducing a prototype filtration machine. The thesis ends with discussion and recommendations.

To explore these topics, the general questions proposed were as follows;

1. What are the global analytical and statistical prevalence and impact of Fluoride contaminated ground water and Fluorosis on poor population?
2. What are the ingrained habits on consumption of naturally Fluoridated drinking water and its impacts on the poor people of Kenya and Tanzania?
3. What are the attitudes and believes towards water defluorination technology among the Fluorosis affected population in Kenya and Tanzania?

2. CHAPTER 1

FACTORS INFLUENCING THE RELATIONSHIP BETWEEN FLUORIDE IN DRINKING WATER AND DENTAL FLUOROSIS: A TEN-YEAR SYSTEMATIC REVIEW

2.1. Background

Among elements, Fluorine ranks 13th in the world for abundance and constitutes the 0.08% of the earth's crust (Sananda D., 2016). Fluorine is easily soluble in water, soil and air, and being one of the most reactive among all chemical elements does not exist on its own in the natural environment but rather as Fluoride. Surface water is normally low in Fluoride, with values lower than (1.5 mg/L), while groundwater may contain elevated quantities of Fluoride depending on geological condition (Sananda D., 2016). Starting from the first water Fluoridation schemes in the USA in the late 1940s, Fluoride has had a tremendous impact on the oral health of millions of adults and children (Blinkhorn A., ,2013). The reduction in dental caries in Fluoridated communities in the USA ranges from 20% to 40%, which is a lower value than before its introduction (Downer, 2007). However, Fluoride over-exposition may cause Fluorosis, and epidemiological evidence suggests that Fluoride concentrations in drinking water above (1.5 mg/L) can carry an increasing risk of Dental Fluorosis, while progressively higher concentrations lead to increased risks of skeletal Fluorosis (WHO, World Health Organisation, 2011). Specifically, Dental Fluorosis is a problem that occurs during tooth formation and it influences Dental enamel structure by altering its shape

(Blinkhorn A., ,2013). It results in aesthetic and functional problems depending on the severity of the lesions (Sananda D., 2016).

Fluorosis has now become a global problem, with more than 200 million individuals in nearly 25 countries seemingly affected (WHO, World Health Organisation, 2011). Fluorosis as well as being influenced by climate conditions, is also caused by beverage, eating and livelihood habits (e.g. brick tea, tobacco, '*magadi also known as Trona'* use in the African Rift Valley and burning coal) (UNICEF, 1999; Rango et al., 2012; Kaseva, 2006; Mandinic et al., 2009; Malde et al., 2011; Galagan D. J., 1957; DMO'Mullane et al., 2016) . However, drinking water seems to be the main source (WHO, World Health Organisation, 2011).

In this chapter, we are interested in evaluating the impact of Dental Fluorosis caused by water that is naturally contaminated with Fluoride, while controlling for other possible factors related to this disease. Thus, epidemiologic studies which analyze the relationship between water fluoridation (i.e. the addition Fluoride to public water supplies for reducing dental caries) and Dental Fluorosis are not the focus of this chapter. We think that it is useful to keep these two phenomena apart because they have different causes and require diverse policies to reduce the risk of Dental Fluorosis.

As regards other reasons behind Dental Fluorosis, we are interested in investigating the influence of age on the severity of Dental Fluorosis in children exposed to drinking water, and other factors such as local temperature, rainfall and altitude, which have been sometime cited as important factors in determining the total amount of Fluoride in water. Excessive temperature may influence the level of water intake above that usually required (Galagan D. J., 1957; Firempong et al., 2013) and, in reverse, the use of harvested safer rain water may reduce the use of unsafe groundwater (Edmunds WM, 2005; Susheela AK., 1999). Furthermore, the effect of altitude on the prevalence and severity of Dental Fluorosis has been reported in (Manji et al., 1986; Rwenyonyi et al., 1999) as a possible cause of worsening Fluorosis disease.

To summarize the main research queries, we are interested in answering the following questions:

- What is the relationship between natural Fluoride water contamination and the prevalence of Dental Fluorosis?
- Is this relationship the same in different geographic areas of the world?
- What is the impact of other factors, such as age, climate condition, and altitude on the prevalence of Dental Fluorosis?
- What tools could policy makers adopt to tackle Dental Fluorosis?

The remainder of the next two chapters is organized as follows. The methodology section will explain both the criteria used to select papers for the Systematic Review and the statistical approach used to perform a Meta-Analysis. The results section will discuss the qualitative and the quantitative findings of the Systematic Review and Meta-Analysis respectively. Finally, in the conclusions we will discuss possible policy implications that emerged from the study.

2.2. Methods

It is widely recognized that Systematic Reviews and Meta-Analysis have become more important in many disciplines because they allow researchers and practitioners to be up to date on advances in the field, to identify research questions based on results obtained in different contexts and to justify that grants for further research in a specific area are needed (Cooper HM., 1998; Littell J H., 2006). To answer the research questions presented above and to achieve the stated objective of this study we conducted both a Systematic Review and a Meta-Analysis. A Systematic Review is a process that uses systematic and explicit methods to identify, select, and critically appraise relevant research and to collect and analyze data from the studies that are included in the review (Moher et al., 2009; Gough et al., 2012; Mallett et al., 2012). The well-defined process of inclusion and exclusion of suitable articles is based on the identification of ad-hoc criteria and promotes a confident approach to analyzing data not only qualitatively but also quantitatively bringing to fore empirically robust results via Meta-Analysis.

Search strategy and identification criteria

We searched the Web of Science (www.webofknowledge.com), PubMed (www.ncbi.nlm.nih.gov/pubmed), Google Scholar (scholar.google.it) and Scopus (www.scopus.com) databases for publications dated between 2007 and 2017. The following terms were searched using Boolean operators: “Dental Fluorosis”, “Fluorosis”, "Dean Index", “Thylstrup and Fejerskov Index” "drinking water". This search focused only on human beings with restriction on English language. The motive to include Dean and Thylstrup-Fejerskov indexes in the Boolean search is linked to the fact that many studies reporting information of Fluorosis widely utilize them. The choice of the proposed time span was motivated by the fact that Fluoride concentration and variation can be related to climate, rainfall and temperature, and thus enlarging the time-period can introduce not only additional heterogeneity, but also information that does not reflect the current situation due to climate changes. Table 1 shows the criteria that were used to select studies included in this Systematic Review and Meta-Analysis. One of the most important criteria for initial selection of studies was the evaluation of the relationship between natural Fluoride content in drinking water and prevalence of Dental Fluorosis.

Table 1. Inclusion and exclusion criteria

Inclusion criteria of studies	Exclusion criteria of studies
● Articles in English language. ● Empirical, theoretical, review, clinical, academic papers and reports providing information from all countries around the world. ● Articles that focused on strong connections between natural Fluoride content in drinking water and prevalence of Dental Fluorosis. ● Articles that focused on population that are long-term inhabitants. ● Articles focusing on humans. ● Articles providing information on Fluoride content ● Articles providing information on the sample size. ● Articles providing information on the number of people affected by Fluorosis ● Articles providing information on the age of participants ● Articles published between April 2007 and May 2017	● Duplicated articles ● Misclassified articles ● Articles in other languages ● Articles on piped water fluoridation ● Articles on water de-fluoridation technologies ● Articles that focused on animal Fluorosis both livestock and laboratory research animals ● Articles providing information on Fluorosis caused by Fluoride from soil and air ● Articles providing information on Fluorosis caused by industrial pollution ● Articles providing information on Fluorosis caused by food stuff and goods including toothpaste ● Articles providing information on Fluorosis linked to other health issues e.g. children IQ, cancer etc.

Sampling of international studies and data extraction

Figure 1 shows that initially a total of 2,580 articles were identified from the four databases as follows: Web of Science (970), Scopus (883), Pub Med (577), Google Scholar (149) and one paper was obtained from authors' request. Information gathered at this stage on all articles was stored in Endnote. The first major elimination of duplicated copies was carried out on Endnote, where 796 studies were eliminated. For the residual stages, two reviewers (MA and LG) analyzed the remaining 1,784 and independently applied the inclusion and exclusion criteria as indicated in Table 1. Disagreements were resolved through discussion and consensus with a third author (GN). At the end of the screening stage, 39 articles were eligible for this study. The 39 articles underwent content check where all of them qualified for Systematic Review while only 21 qualified for Meta-Analysis Table 2, due to 18 articles not containing information on key variables such as the Fluoride level in drinking water or the number of people affected by Dental Fluorosis. For the 21 articles selected for Meta-Analysis we also collected data of maximum and average annual temperature, annual rainfall, and local altitude. Where not included in the studies, the data were collected from https://www.weather2visit.com/.

Fig 1. Flow diagram of identification of eligible studies to final inclusion

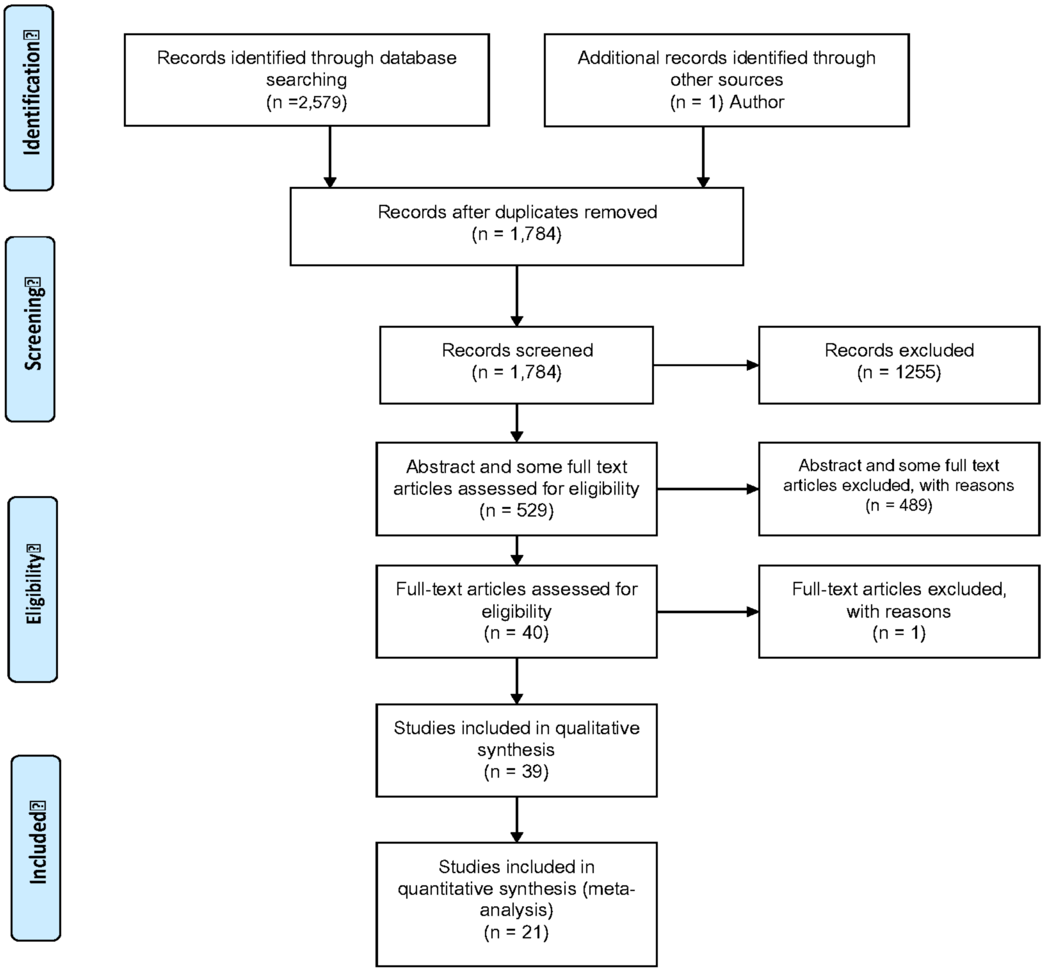


Fig 1. Flow chart of identification of eligible studies to final inclusion

Table 2 Characteristics on studies included in the Meta-Analysis

N	Author	Continent	Country	Zone	No of Subjects	No of people affected by Fluorosis	Avg. Prevalence rate	Avg. Age (years)	Avg. Fluoride Content (mg/L)	H-index Journal	Citations per year	Excessive Temperature ratio	Altitude (m)	Rainfall (mm)
1	Almerich-Silla et al. (2008)	Africa	Algeria	Tindouf, South Algeria, Refugee camp	572	206	36.01%	8.5	1.905	77	3.778	1.4005	400	55.0
2	Arif et al. (2013)	Asia	India	Didwana Tehsil, Nagaur district	1136	788	69.37%	28.o	3.608	11	4.250	1.2483	342	434.0
3	Bagh et al. (2012)	Asia	India	Birbhum district	54546	5468	10.02%	26.0	2.900	5	0.000	1.2496	60	373.0
4	Bhalla et al. (2015)	Asia	India	Kampur city, Uttar Pradesh	1343	243	18.09%	12.0	2.250	0	0.500	1.2041	48	886.0
5	Firempong et al. (2013)	Africa	Ghana	Bongo district	200	126	63.00%	15.0	1.543	11	4.750	1.1178	0	1118.0
6	Vilasrao et al. (2014)	Asia	India	Chhattisgarh State	3390	725	21.39%	12.0	2.000	0	2.000	1.2756	330	1319.0
7	Ruan et al. (2007)	Asia	China	Haoping, Shaanxi Province	596	419	70.30%	10.0	1.017	53	1.200	1.6768	103	591.0
8	Isaac et al.(2009)	Asia	India	Kaiwara, Karnataka State	416	100	24.04%	10.0	2.082	12	1.250	1.1698	919	582.0
9	Asawa et al. (2015)	Asia	India	Dad, Bokersal & Deotalab villages, Dungarpur District	750	395	52.67%	40.0	2.750	12	5.000	1.2235	100	701.0
10	Keçeci et al. (2014)	Asia	Turkey	Deregümü, Isparta	293	276	94.20%	40.0	1.830	37	0.667	1.6580	1035	555.0
11	Kotecha et al. (2012)	Asia	India	Vadodara district, Gujarat	6093	2960	48.58%	29.0	1.601	68	11.400	1.1870	129	1044.0
12	Garg et al. (2013)	Asia	India	Gurgaon district, Haryana State	650	517	79.54%	10.0	2.366	11	1.000	1.2732	229	634.0
13	Malde et al. (2011)	Africa	Ethiopi a	Wonji Shoa Sugar Estate Nazareth, (Adama)	28	28	100.00%	3.5	6.100	227	6.167	1.0968	1540	1654.0
14	Marya et al. (2010)	Asia	India	Gurgaon and Hisar districts, Haryana State	3007	1636	54.41%	14.0	1.510	5	1.286	1.2682	215	734.0
15	Medina-Solis et al. (2008)	America	Mexico	Tula de Allende, Hidalgo State	1538	1184	76.98%	13.6	1.957	52	3.111	1.1244	2020	648.0
16	Sebastian et al. (2016)	Asia	India	Mysore district, Karnataka	405	169	41.73%	11.0	1.200	28	8.000	1.1564	758	567.0
17	Shitumbanuma et al. (2007)	Africa	Zambia	Choma district	37	37	100.00%	3.5	6.986	53	2.400	1.1710	1208	804.0
18	Rango et al. (2012)	Africa	Ethiopi a	Central Main Ethiopian Rift	200	200	100.00%	13.5	10.338	137	17.600	1.0889	1600	1422.0
19	Vuhahula et al. (2009)	Africa	Tanzani a	Rift Valley in Nothern Tanzania	2912	2804	96.29%	14.7	4.600	128	2.125	1.0931	1400	837.0
20	Yadav et al. (2009)	Asia	India	Jhajjar District, Haryana State	9667	5052	52.26%	11.0	1.809	53	6.250	1.2720	220	600.0
21	Akosu et al. (2008)	Africa	Nigeria	Central Plateau	1022	124	12.13%	13.5	0.6812	82	1.778	1.1178	1280	1177.0

2.3. Systematic Review Results

All the studies included in this Systematic Review confirmed increase of Dental Fluorosis with long-term consumption of elevated Fluoride levels (>1.5mg/L) in drinking water. Natural Fluoride contamination constitutes the main driver of Fluoride water contamination. One article also confirms decrease in Fluorosis prevalence rate with decrease of Fluoride in drinking water (Malde et al., 2011). Fluoride level in drinking water (> 6 mg/L) seem to drastically increase all three forms of Fluorosis i.e. dental, skeletal and non-skeletal Fluorosis among populations under observation. On the other hand, concentration of Fluoride (<6 mg/L) finds Dental Fluorosis to be more prevalent than skeletal and non-skeletal Fluorosis. Other studies compared confounding factors such as climate, altitude, age, gender and dental caries on prevalence of Dental Fluorosis. These studies focused on consumption of naturally fluoridated water to explore the link between high Fluoride content in water and prevalence of Dental Fluorosis. (Bagh et al., 2012; Goodarzi et al., 2016; Akosu J., 2008; Yadav et al. L. K., 2009; Sudhir et al., 200).

Besides the impact of Fluoride contamination on Dental Fluorosis, the analysis of these studies shows that this disease is influenced by several factors that have been categorized into the following five relationships:

1. Age and prevalence of Dental Fluorosis;
2. Gender and prevalence of Dental Fluorosis;
3. Temperature, rainfall and altitude and prevalence of Dental Fluorosis;
4. Dental caries and prevalence of Dental Fluorosis and
5. Other dietary intake and prevalence of Dental Fluorosis.

2.3.1 Age and prevalence of Dental Fluorosis

In 37 out of 39 papers selected for this Systematic Review, age is considered to be a key variable that potentially influences susceptibility to Dental Fluorosis. Literature shows that water-born Fluorosis is the most endemic where the majority of school children under observation present different stages of Dental Fluorosis and high levels of Fluoride in urine. Prevalence of Dental Fluorosis, in most studies, seems to display a linear relationship with the increase in age. Most of these studies were conducted in schools and age of children does not necessarily refer explicitly to a defined age, but rather to diverse age brackets ranging from three to eighteen years of age.

Children in the teeth and body tissue growth stage are more exposed to Dental Fluorosis due to tissue, bone and teeth mineralization. This situation increases the susceptibility of the enamel to many forms of attack leading to discolored or mottled teeth. Literature shows that most of the affected teeth seemed to have long growing period interval confirming the character of slow manifestation of Fluorosis over time. This longer duration of exposure to elevated Fluoride is also said to be responsible for higher prevalence rate of Dental Fluorosis and less skeletal Fluorosis in children. Dental Fluorosis in children also seems to be more prevalent and evident in permanent teeth than in primary teeth further suggesting that in children over ten years of age, Dental Fluorosis is more visible and prevalent than those below the age of eight (Rango et al., 2012; Firempong et al., 2013; Bagh et al., 2012; Goodarzi et al., 2016; Isaac et al., 2009; Kotecha et al., 2012; Garg VK., 2013; Keçeci et al., 2014 ; Yadav et al. G. R., 2012; Marya et al., 2010) (Sebastian et al., 2016; Chauhan et al., 2012; Vuhahula et al., 2009; Almerich-Silla et al. M.-C. J.-M., 2008; Medina-Solis et al., 2008; Shitumbanuma et al., 2007; Bhalla et al., 2015; Vilasrao et al., 2014). On the other hand, one study focused on

Dental Fluorosis reversal by eliminating Fluoride in drinking and cooking water for children. It highlights that a complete removal of Fluoride from water could reduce incidence of Dental Fluorosis in children by 50% (Malde et al., 2011). This study further recommends investigation of other potential sources of Fluoride such as food and beverage pathways. Interestingly, another study shows that Dental Fluorosis has a minimum correlation with age (Sudhir et al., 200).

For people above 18 years, both dental and skeletal Fluorosis is present accompanied by other non-skeletal diseases. In this age bracket, skeletal Fluorosis is more pronounced leading to health deterioration with time, while Dental Fluorosis appears to stagnate. Literature shows that those under observation between the age of eighteen and thirty-four exhibit higher skeletal Fluorosis when compared to Dental Fluorosis than to those below eighteen. This group also presents less Fluoride levels in urine samples when compared to those above thirty-five, although their urine Fluoride levels is still higher than those below eighteen years of age. Although the importance of the prevalence and severity of Fluorosis is widely noted to increase with age, health deterioration in over thirty-fives tends to be faster towards skeletal Fluorosis. In fact, several studies find that over thirty-fives start to present partial or total loss of teeth due to Dental Fluorosis. This group also returns the highest Fluoride level in tested urine samples. In the oldest group of individuals, even though Dental Fluorosis appears to stagnate, problems such as difficulty in eating or chewing, gastrointestinal Fluorosis or even death are experienced. For these people nutritional deficiencies, bad lifestyle habits and environmental factors appear to be common phenomena among those highly affected (Mandinic et al., 2009; Malde et al., 2011; Bagh et al., 2012; Yadav et al.

L. K., 2009; Garg VK., 2013; Keçeci et al., 2014 ; Yadav et al. G. R., 2012; Maura et al., 2009; Marya et al., 2010; Chauhan et al., 2012) (Asawa et al., 2015, 9,; Tahir M.A., 2013; Li et al., Fluoride in drinking water, brick tea infusion and human urine in two counties in inner Mongolia, China., 2009; Kotoky P, 2008 .)

2.3.2. Gender and prevalence of Dental Fluorosis

As regards gender, while some studies show that this factor does not have any relationship with Dental Fluorosis, other studies indicate significant statistical differences between males and females but without a clear direction. For example, some studies show that the prevalence of Dental Fluorosis is higher in females than males and this might be due to poor nutrition among girls in many communities (Keçeci et al., 2014 ; Chauhan et al., 2012; Asawa et al., 2015, 9,; Arvind et al., 2012,). On the other hand, other studies find that males are more affected by Dental Fluorosis than females. In males, literature indicates that highest prevalence of Dental Fluorosis is exhibited between the age of twelve and twenty-four. Furthermore, males over thirty-five seem to be more affected where their condition deteriorates more rapidly than that of females. In the oldest groups, male Fluorosis prevalence rate is also found to be consistently higher than that of females, but these differences are not significant both for Dental Fluorosis and for urine samples tested in the observed population (Firempong et al., 2013; Kotecha et al., 2012; Garg VK., 2013; Yadav et al. G. R., 2012; Marya et al., 2010; Bhalla et al., 2015; Vilasrao et al., 2014; Asawa et al., 2015, 9,; Arif et al., 2013).

The higher prevalence rate of Fluorosis observed for males could be explained by the fact that males might be away from homes and involved in activities that require them to consume more and different types of water. Fluoride retention as well as being influenced by different types of water could also be affected by nutritional and climatic conditions away from home. Finally, these differences could also be explained by different biological reactions to Fluoride and individual susceptibility to the duration of exposure (Sudhir et al., 200; Chauhan et al., 2012; Li et al., Fluoride in drinking water, brick tea infusion and human urine in two counties in inner Mongolia, China., 2009).

2.3.3. Temperature, rainfall, altitude and prevalence of Dental Fluorosis

Part of the difficulty and complexity of dealing with exposure to Fluoride contamination arise from the action of factors such as temperature, altitude and rainfall because they can influence the dissolution of Fluoride into water, consumption of Fluoride contaminated water and body retention of Fluoride. In 1984, WHO advised that in regions with warm weather, a concentration of Fluoride in drinking water should be below <1 mg/L, while in cooler climates it could be up to 1.2 mg/L (WHO, World Health Organisation, 2011; Yadav et al. L. K., 2009; Sebastian et al., 2016).

Studies show that general temperature, average annual temperature, average maximum daily temperature, rainfall, altitude, and the depth of wells are confounding factors that can influence the prevalence rate of Dental Fluorosis. These factors are not conclusive but represent a major challenge to efforts of mitigating Dental Fluorosis. Literature indicates that Fluoride intake varies with the variation in temperatures i.e. the higher the temperature the higher the Fluoride intake because hot conditions might trigger higher consumption of water creating higher risk of contracting water-borne Fluorosis. This pattern has been confirmed in high temperature zones, which show highest prevalence rates of Dental Fluorosis even when Fluoride levels were under optimal suggested, by WHO. On the contrary, in cold temperature zones Fluorosis seems to originate from people utilizing contaminated coal for heating their homes and cooking which predispose many people to effects of airborne Fluorosis (Firempong et al., 2013; Sudhir et al., 200; Garg VK., 2013; Sebastian et al., 2016; Chauhan et al., 2012; Almerich-Silla et al. M.-C. J.-M., 2008; Vuhahula et al., 2009; Vilasrao et al., 2014; Tahir M.A., 2013; Tellez et al., 2012) (Suthar et al., 2008)

Altitude is increasingly scrutinized in literature to define its role in prevalence rate of Dental Fluorosis, but its direction is not clear. Some studies on higher altitudes have shown that urine becomes acidic influencing Fluoride ions to last longer in the body and thus altitude stimulates faster absorption and spread of Fluoride ions in the intestine. These conditions are known to quicken Fluoride storage in the bones and muscles that have been proved to influence Fluoride mineralization in tissues causing Dental Fluorosis (Keçeci et al., 2014 ; Vuhahula et al., 2009; Shitumbanuma et al., 2007; Kotoky P, 2008 .; Ruan et al., 2007; Taghipour et al., 2016; Liu, 2015; Fan et al., 2016). In contrast, another study finds that both lower and higher altitudes have similar effects on prevalence rates of Fluorosis (Akosu J., 2008).

Rainfall seems to influence Fluoride and Fluorosis in that industrial contaminated coal emission coupled with soot could contaminate rainwater that is collected by people for domestic usage. The depth and age of water wells utilized by communities indicate that deeper wells could contain elevated Fluoride concentrations and that lack of rainfall may influence ground water recharge capability leading to higher concentration dissolution of Fluorides into ground water (Tahir M.A., 2013; Ruan et al., 2007; Suthar et al., 2008; Fan et al., 2016).

2.3.4. Dental caries and prevalence of Dental Fluorosis

Even though adequate levels of Fluoride ions (≤ 0.6mg/L) are needed to inhibit dental caries and develop stronger bone mass and teeth, when Fluoride is above this limit it is not clear how Fluorosis influences dental caries. Some studies agree that higher dosage of Fluoride reduces dental caries because they find that in regions with high prevalence of Dental Fluorosis there is lower prevalence of dental caries. These results suggest the role of Fluoride as protective element against dental caries (Firempong et al., 2013; Mandinic et al., 2009; Bagh et al., 2012; Kotecha et al., 2012; Sebastian et al., 2016; Vuhahula et al., 2009; Li et al., Fluoride in drinking water, brick tea infusion and human urine in two counties in inner Mongolia, China., 2009; Tellez et al., 2012; Fan et al., 2016).

An interesting concern is that some severe Dental Fluorosis patients also exhibit higher levels of caries, which may be explained by the fact that Dental Fluorosis is characterized by the evidence of hypo-mineralization of the enamel tissue. Finally, a few studies show no relationship between Dental Fluorosis and dental caries. However, further research should be conducted to understand how several factors (caries developing resistance to Fluorides, effect of amount of Fluoride dosage, personal oral hygiene, prevalence of cariogenic bacterial strains in the mouth and socio-economic status of individuals) influence the relationship between dental caries and Dental Fluorosis (Fan et al., 2016; Sudhir et al., 200; Keçeci et al., 2014 ; Almerich-Silla et al. M.-C. J.-M., 2008; Taghipour et al., 2016).

2.3.5. Other dietary intake and prevalence of Dental Fluorosis

Also, for dietary intake, findings show that the direction of the relationship is not clear. Several studies indicate that dietary intake positively influences Dental Fluorosis. Food, beverages (brick tea, tea, butter tea) baby formula, fish, beans, potatoes, wheat, animal and plant proteins and '*magadi*' popularly utilized as tuber softener, have questionable Fluoride content and thus impacting on Fluorosis prevalence rates (Malde et al., 2011; Kotecha et al., 2012; Yadav et al. G. R., 2012; Vuhahula et al., 2009; Almerich-Silla et al. M.-C. J.-M., 2008; Li et al., Fluoride in drinking water, brick tea infusion and human urine in two counties in inner Mongolia, China., 2009; Fan et al., 2016; Abuhaloob L., 2013). However, other studies that also focused on tea, animal and plant proteins found no difference on Fluorosis prevalence rates from the products (Firempong et al., 2013; Abuhaloob L., 2013).

2.4. Discussion and Conclusion

In this study we presented the results of a Systematic Review aimed at understanding how environmental, socio-demographic and economic factors influence the prevalence of Dental Fluorosis caused by Fluoride contained mainly in groundwater. The Systematic Review is based on 39 studies identified in selected scientific databases using key words and Boolean operators. Our findings indicate that while Dental Fluorosis affect all age brackets, for other factors such as gender, temperature, altitude, rainfall, dietary intakes and dental caries the direction of this association is not clear. As regards age, Dental Fluorosis affects all groups of children, but the most vulnerable are those below 11 with a rate of prevalence very close to 100%. There is a need to conduct more research on children younger than 11 and especially those living in small villages where there is a lack of alternatives to groundwater sources that are rich in

Fluoride (Edmunds WM, 2005). Children affected by Fluorosis are perceived not to be intelligent, unattractive, unhappy and unsmiling, with poor hygiene, and lack interactive social skills. All these beliefs greatly harm children's development and call for high urgency in information sharing, training and health education programs addressing causes and negative impacts of Dental Fluorosis (Firempong et al., 2013; Akosu J., 2008; Yadav et al. L. K., 2009; Isaac et al., 2009; Kotecha et al., 2012).

For individuals older than 18 years of age, Dental Fluorosis is also associated with skeletal and non-skeletal Fluorosis and for those older than 35 also with loss of teeth, nutritional deficiencies and bad lifestyle habits. In this case, policy makers could devise information on nutritional campaigns aimed at both increasing the consumption of fruit, vitamins A and C, thiamine, folic acid, milk, longer period of breast-feeding, calcium and promoting remedies such as boiling drinking water, proper storage of water in ceramic tanks, clay pots for storing water and elimination of tea in children diet. Evidence based nutritional interventions are strongly recommended in different contexts especially for children (Kotecha et al., 2012; Rango et al., 2012; Yadav et al. G. R., 2012; Almerich-Silla et al. M.-C. J.-M., 2008; Arif et al., 2013; Liu, 2015; Taghipour et al., 2016). However, for the other confounding factors more research should be conducted to understand how they interact with age and Dental Fluorosis.

3. CHAPTER 2

FACTORS INFLUENCING THE RELATIONSHIP BETWEEN FLUORIDE IN DRINKING WATER AND DENTAL FLUOROSIS: A TEN-YEAR META-ANALYSIS

3.1. Background

Defined as "the statistical analysis of a large collection of analyzed results from individual studies for the purpose of integrating the findings", Meta-Analysis has also attracted controversy among different researchers and scholars across board (Glass., 1976; Lelorier J., 1997; Liberati A., 1995). During the last 30 years, the application of Meta-Analysis has increased remarkably when quantitatively and statistically merging the results from different studies but of the same outcomes (Glass GV., 1981). Meta-Analysis achieve results by systematically combining studies that goes beyond normal literature review where specific results from various studies are not only discussed but are compared and tabulated, scrutinized and results synthesized into a new result (Nancy GB., 2002). Whether a fixed or random-effects model is utilized, scholars using Meta-Analysis are always focused towards the total results. It does this by summarizing the collected data or by elucidation of variability between different studies. In the case of summarizing studies, all the studies included should all have similar characteristics and consistency (Glass GV., 1981). It is widely recognized that Meta-Analysis has become more important in many disciplines because it allow researchers and practitioners to be up to date on advances in their field, to identify research questions based on results obtained in different contexts and to justify. In Meta-Analysis, large number of articles, published and un-published can be analyzed to produce robust results in almost every single sector such as medicine, population studies and other fields (Cooper HM., 1998; Littell J H., 2006).

3.2. Statistical Analysis

Meta-Analysis refers to the use of statistical techniques in a Systematic Review to integrate the results of included studies. As data from the 21 studies selected for the quantitative analysis showed Fluorosis heterogeneity, we focused on random effects Meta-Analysis of the Fluorosis prevalence rate defined as the proportion of people affected by Dental Fluorosis. Binomial exact confidence intervals were used to contrast and summarize results. The use of the random effect model is justified by the expectation that observed differences among the prevalence rates cannot be entirely attributed to sampling error, but also to other factors such as differences in the population under observation, publication bias etc. (Egger et al., 2001). Heterogeneity is quantified using the I^2 statistic that represents the percentage of total variation across all studies due to between-study heterogeneity (Higgins JP., 2002) . Usually, an I^2 value greater than 50% indicates significant heterogeneity. We also performed an independent meta-regression analysis to estimate the contribution of different study characteristics to heterogeneity within the selected sample of international studies. A p-value < 0.05 was considered statistically significant, unless otherwise specified. Statistical analysis was conducted using Stata 15.0 employing the metaprop (Nyaga et al., 2014) and metareg (Harbord RM., 2008) packages.

The prevalence rate of Dental Fluorosis was investigated by pooling the sample of studies in subgroups given by the level of Fluoride in drinking water and the age of people surveyed in the studies. With respect to the level of Fluoride, the prevalence rates were sub-grouped as follows: one group for studies with values of Fluoride in drinking water (<1.5 mg/L), a 2nd group for values which range between (1.5 and 3.0

mg/L), which is the limit allowed in some countries such as Tanzania, and one final group for values (> 3.0 mg/L). Data categorization was also conducted by subgrouping the prevalence rate for age, i.e. splitting the sample of people surveyed into those below the age of 10, those with ages ranging from 10 to 15 and the final group with age >15. The forest plots were produced for the two categorical variables of Fluoride level in drinking water and age.

Finally, following (Murtaugh PA., 2002), we proposed a simple analysis for detecting possible publication bias in our Meta-Analysis. This method is based on the relationship between the strength of the results in published studies and different indexes representing the quality of the studies. The idea is that if the magnitude of an estimated effect influences the likelihood that a study's results will be published, papers describing studies which report a low effect-size may find it difficult to submit and be accepted by high-quality ranking journals, and/or to receive relevance in the literature.

To examine this hypothesis, we regressed the prevalence rate of Dental Fluorosis reported in our studies both over the h-index of each journal and over the yearly average number of citations of the study. These two measures were chosen because they allowed us to explore possible bias in the review process (h-index) and within the scientific community (yearly average citation number of the study). The h-index values were obtained from SCIMAGO (https://www.scimagojr.com/), while the average number of citations per year from Google Scholar (https://scholar.google.it/).

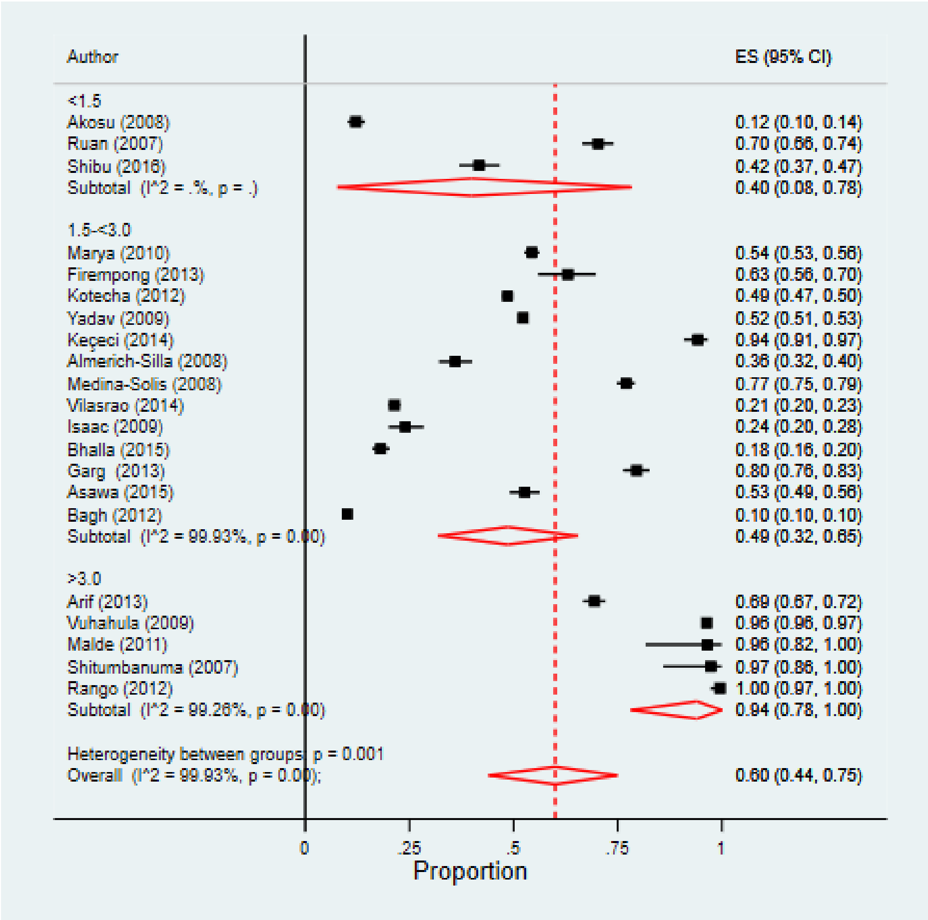
3.3. Meta-Analysis Results

Table 2 presents information in relation to the following variables: the number of participants, the number of people affected by Dental Fluorosis, the average content of Fluoride in drinking water, the average age of participants, the excessive temperature, rainfall, altitude, h-index and finally the number of citations per year of the studies used to perform the Meta-Analysis. It shows that 13 studies are from Asia, 7 from Africa and 1 from Central America. Table 2 allows us to explore some differences between Asian and African studies. For example, comparing the means of prevalence of rate of Dental Fluorosis and content of Fluoride in drinking water we find that for African studies these values are higher than those conducted in Asia. However, differences are significant to the independent sample *t*-test only for content of Fluoride $\left(\bar{X}_{diff} = 2.53; p = 0.0001; df = 18\right)$. For age of participants, we observed the opposite i.e. the average age of participants for Asia $\left(\bar{X} = 19.46; s = 11.56\right)$ is higher than that for Africa $\left(\bar{X} = 10.32; s = 5.12\right)$. Also, this difference was significant to the independent sample *t*-test $\left(\bar{X}_{diff} = 9.15; p = 0.001; df = 18\right)$. As regards climatic variables, we do not observe significant differences between African and Asian studies while for the h-index we observe that African studies are published in more prestigious journals. This difference was significant to the independent sample *t*-test $\left(\bar{X}_{diff} = 79.45; p = 0.001; df = 18\right)$.

3.4. The Meta-proportion results

We start the Meta-Analysis of the 21 selected studies by proposing in Figs 2 and 3 the forest plots related to the impact of age and Fluoride level in drinking water on the prevalence of Dental Fluorosis. The forest plots display the results from each study as a square and a horizontal line, representing the intervention effect estimate together with its confidence interval. The analysis highlights a substantial level of heterogeneity for all the variables.

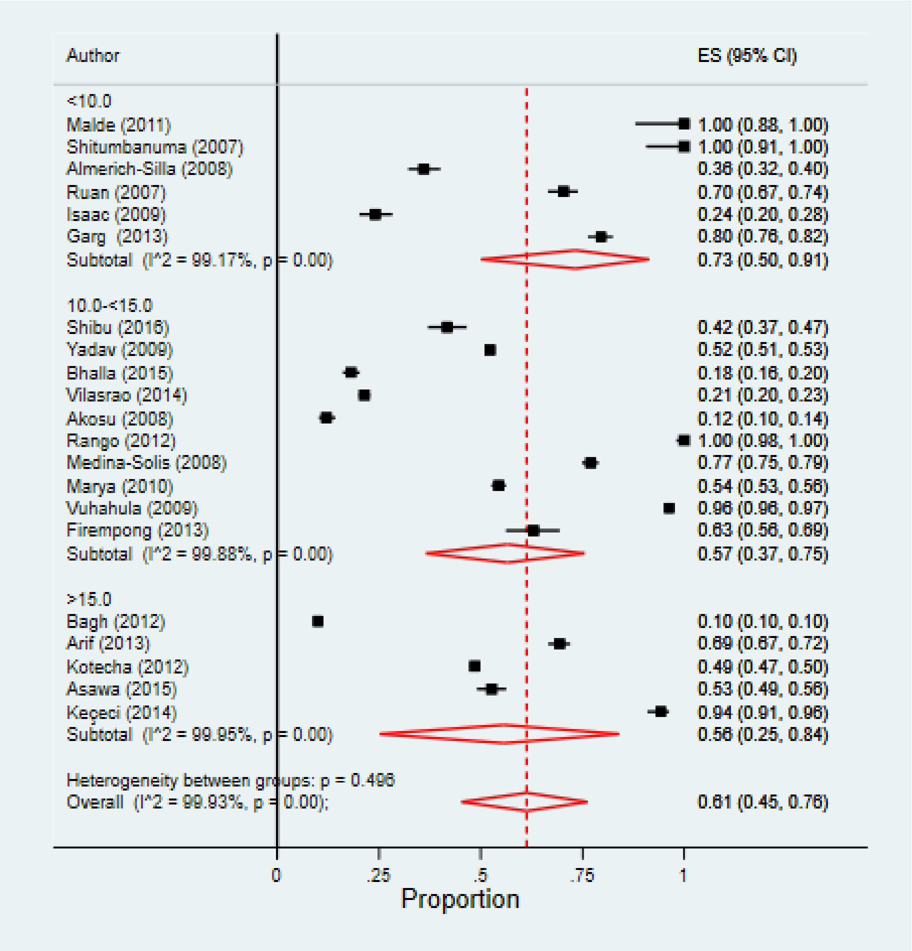
Fig 2. Forest Plot of the prevalence of Dental Fluorosis in different level of Fluoride in drinking water.



In Figure 2, the forest plot of the Fluoride content in drinking water is presented. Most of studies showed a level of Fluoride included between 1.5 and 3.0 mg/L. The forest plot also shows that the overall prevalence rate is 60% (0.60; 95% CI = 0.44–0.75) and that increasing levels of Fluoride in drinking water affect severely the incidence of Dental Fluorosis. For values below 1.5 mg/L, which is the recommended, the prevalence rate was 41% (0.41; 95% CI: 0.03-0.80). For values higher than 3.0 mg/L the percentage of people affected by Dental Fluorosis disease was 92% (0.92; 95% CI: 0.84–0.99). However, the heterogeneity was significant ($p < 0.001$, $I^2 = 99.93\%$).

With respect to AGE, Fig 3 presents the pooled prevalence rates of the studies divided in three subgroups, under 10, between 10 and 15, and above 15 years. The results indicate higher prevalence rate for the first group. However, in this case the heterogeneity is relevant ($p < 0.001$, $I^2 = 99.93\%$) as well.

Fig 3. Forest Plot of the prevalence of Dental Fluorosis for different age.



3.5. The Meta-regression results

Considering the relatively high heterogeneity shown in these studies, meta-regression analysis was conducted to explore the possible sources of this issue further. Table 3 shows the results of two meta-regressions analyses where the dependent variable is the prevalence rate of Dental Fluorosis of the 21 studies reported in Table 2.

Table 3. Factors influencing the prevalence rate of Dental Fluorosis

Variables	Meta-regression 1	Meta-regression 2
FLUOR (mg/L)	0.076 (0.024) {0.005,0.019} [95% CI: 0.026 – 0.126]	0.088 (0.0287) {0.005,0.015} [95% CI: 0.031 - 0.144]
DAFRICA	--	0.114 (0.132) {0.398,0.43} [95% CI: -0.165 – 0.394]
DAMERICA	--	0.425 (0.248) {0.106,0.146} [95% CI: -0.101 – 0.951]
TEMP	--	0.780 (0.367) {0.050,0.084} [95% CI: 0.001 – 1.555]
Constant	0.357 (0.088) {0.001} [95% CI: 0.172 – 0.541]	-0.703 (0.496) {0.175} [95% CI: -1.756 – 0.348]
N. obs	21	21
T^2	0.0610	0.0532
I^2	99.97%	99.94%
Adj. R^2	31.49%	40.85%
***F* test and *p*value Joint covariate test**	--	4.44 {0.013}

(*) In parentheses () the standard errors, in parentheses {} the p-values of the t-statistics. The first is p-value under the t-statistic distribution, the second one is the p-value computed using a permutation test proposed in (Higgins, 2004) to simulate the data under the null-hypothesis. 20000 replications were used to compute the p-values. The $\mathbf{T^2}$ is the estimate of the between-study variance and $\mathbf{I^2}$ is the percent of residual variation due to heterogeneity

Meta-regression 1 included only the Fluoride level (FLUOR) in drinking water while meta-regression 2 includes also other regressors: two dummy variables DAFRICA and DAMERICA respectively *with 1* if the observation is in group of countries in Africa or America and *zero* otherwise. The two dummies where included due to the possible differences between the three group of studies (Africa, America and Asia) emerged from the preliminary analysis. In meta-regression 2 we also included the TEMP indicator calculated as ratio between the maximum and average annual local temperature through which we want to take into account for possible increases in water consumption due to warmer temperatures. Data regarding this variable was retrieved from the studies and when not available, from https://www.weather2visit.com/. Other models have been estimated that include the rainfall and altitude variables. For brevity these results were not reported due to the non-significance of the two variables.

Table 3 shows that FLUOR is significant ($p < 0.05$) in both models and the TEMP variable in model 2 ($p < 0.05$) is also significant while the two dummies are not significant. These results are extremely important because it allows us to work out the marginal effect of FLUOR from a large number of studies. In both meta-regressions, the FLUOR beta parameter is positive, and this means that the higher FLUOR is the higher the Dental Fluorosis is. In particular, this is important for policy makers because *ceteris paribus* if FLUOR is reduced by 1 mg/L this will reduce the number of people affected from this disease by 7.6% (95% CI: 2.6% – 12.6%) using the beta parameter in model 1, or 8.8% (95% CI: 3.1% – 14.4%) in model 2. By the same token, our results indicate that *ceteris paribus* an increase of one degree Celsius above the average temperature would affect the prevalence of Dental Fluorosis by 2%.

3.6. Publication bias

Results presented in Table 4 suggest that the publishing process of these papers and the scientific community seem to value information regarding the prevalence rate of Fluorosis differently. In model 1, the beta parameter of the h-index is positive and significant ($p<0.05$) and therefore it is likely that the higher prevalence rate of Dental Fluorosis seems to influence more the acceptance rate of papers managed by high-profile journals. On the other hand, model 2 shows that the beta parameter of the number of citations is not significant and thus this does not influence the citation behavior of the scientific community.

Table 4. Assessing publication bias.

Variables	**Meta-regression 1**	**Meta-regression 2**
H index	0.002 (0.001) {0.018,0.003} [95% CI: 0.000 – 0.004]	--
Citations per year	--	0.021 (0.016) {0.194,0.183} [95% CI: -0.011 – 0.054]
Constant	0.441 (0.078) {0.000} [95% CI: 0.276 – 0.604]	.493 (0.089) {0.000} [95% CI: 0.304 – 0.601]
N. obs	21	21
T^2	0.070	0.064
I^2	99.86%	99.93%
Adj. R^2	22.24%	28.24%

(*) In parentheses () the standard errors, in parentheses {} the p-values of the t-statistics. The first is p-value under the t-statistic distribution, the second one is the p-value computed using a permutation test proposed in (Higgins, 2004) *to simulate the data under the null-hypothesis. 20000 replications were used to compute the p-values. The* T^2 *is the estimate of the between-study variance and* I^2 *is the percent of residual variation due to heterogeneity*

3.7. Discussion and Conclusion

To the best of our knowledge, this is the first Meta-Analysis exploring the effects of natural Fluoride contaminated water on Dental Fluorosis pooling together 21 studies collecting information from 88,508 participants in different countries around the world. Forest plots show high levels of heterogeneity of Dental Fluorosis both for content of Fluoride in drinking water and age of participants. However, meta-regression analyses conducted using a random-effect model provides evidence that Fluoride exposure from drinking water and temperature significantly affect Dental Fluorosis. Other predictors such as age of participants, rainfall and altitude were not significant. The beta parameter of Fluoride content indicates that *ceteris paribus* a reduction of 1 mg/L reduces the probability of being affected by Dental Fluorosis of 7.6% (95% CI: 2.6% – 12.6%) in model 1 and 8.8% (95% CI: 3.1% – 14.4%) in model 2. This result can be extremely important to African Rift Valley countries where the average level of Fluoride in drinking water ranges from 6 to 10 mg/L. Technological innovation capable of reducing Fluoride below WHO recommendation (<1.5 mg/L) can provide health benefits to thousands of children in the Rift Valley. For example, in Tanzania and Ethiopia, an abatement of between 5 and 9 mg/L of Fluoride in drinking water, may reduce Dental Fluorosis in their populations between 38% and 80%. Furthermore, the significant positive impact of the temperature on Fluoride in drinking water suggests that the use of innovative technologies cannot be neglected because if temperature increases as a consequence of long run climate changes, the problem of Dental Fluorosis in these geographic areas will be exacerbated. Meta-Analysis also seems to indicate publication bias and thus more attention should be paid to the publishing process to include in high h-index-ranked journals more studies reporting low and medium prevalence rates of Dental Fluorosis disease.

The negative impact of Fluorosis on people's health is well recognized by many governments but not very much is done to tackle this issue affecting the life of millions of people in developing countries. The inadequate capacity of poor people to find alternative water sources is a challenge leading to high exposure of Fluorosis in Fluoride-contaminated regions. Improved water management systems can efficiently respond to Fluoride water contamination, but this solution is often overlooked in villages where people struggle to find better sources of water. Governments should invest in modern social water policy programs that can supply treated or clean water in remote villages where lack of alternatives has forced residents to utilize springs and other unconventional sources of water. However, to achieve such results actions such as the development of simple and low-cost de-fluoridation devices for use at the household or village level represent promising solutions to tackle this problem in many areas of the world (Akosu J., 2008; Isaac et al., 2009; Keçeci et al., 2014 ; Kotecha et al., 2012; Chauhan et al., 2012; Tellez et al., 2012).

The development of innovative low cost technologies on behalf of locals, national or international industry must be supported by technical, socio-economic and psychological research. Technical innovation can provide solutions to abate the level of Fluoride in drinking water, but more efficient and powerful filters cannot be transferred and adopted in these countries without understanding consumption habits and attitudes on drinking water, as well as preferences towards the adoption of the new technology. For example, Flowered (www.floweredproject.org) an EU H2020 project is working in this direction to develop sustainable water management systems capable of reducing levels of Fluoride in drinking water in the Rift Valley countries. To achieve this objective the Flowered project employs a scientific interdisciplinary approach that develops and disseminates innovative solutions obtained considering not only technical and scientific aspects but also social challenges and public engagement.

Prevention via innovative technologies and implementation of these policies appears to be a promising strategy to alleviate the life of both children who are reported to undergo socio-psychological distress due to mottling and damage of teeth and adults who also face skeletal and non-skeletal Fluorosis. However, considering the complexity of Fluorosis determined by Fluoride in drinking water this result can only be achieved with more international cooperation and interdisciplinary research to tackle this problem from different angles.

4. CHAPTER 3

THE RANAS MODEL: A FOCUS GROUP ANALYSIS CASE STUDY ON EXPLORING DRINKING FLUORIDE SAFE WATER HABITS IN THE AFRICAN RIFT VALLEY

4.1. Introduction

Numerous researchers have widely studied the consequences of groundwater Fluoride contamination even though data on the real drivers of people in specific context not seeking Fluoride safe water remains scanty (Brindha., 2011; Mugumya. T. S., 2020; Suthar, 2011; Akuno et al., 2019; Hilton et al., 2007; Wong et al., 2011; Chakraborti et al., 2009). Fluorosis is considered one of the most widespread diseases associated with consumption of elevated levels of fluorine in water and to some extent food. This relation of elevated fluorides in natural resources is not the only pathway as sometime anthropogenic sources contribute in specific contexts. In African Rift valley, volcanic activity and rocks releases fluorine generally into the water sources such as springs, rivers, ground water, lakes, soils as well as air (Appleton et al. 1996, Weinstein 2003,). The influence of the African Rift Valley geological nature on human health is known to be related not only to excessive intake of Fluorides but also to their deficiency (Appleton et al. 1996, Edmunds 1996). Human health has been known to depend on a delicate balance between lack of Fluoride (<0.6mg/L) and excess consumption (>1.5mg/L) leading to two extreme impacts (Edmunds 1996).

The research was carried out under European Union Horizon 2020 funded project known as "de - Fluoridation technologies for imprOving quality of WatEr and agRo - animal products along the East African Rift Valley in the context of aDaptation to climate change" (http://www.floweredproject.org) whose main aim were to contribute to the development of a sustainable water management system in areas affected by Fluoride contamination in water, soils and food in the African Rift Valley countries (Ethiopia, Kenya, Tanzania) thereby improving the living standards for local population. One of the main focus of the Flowered project was the introduction of an innovative defluorination technology operating at small village levels while integrating sustainable and participatory water and agriculture management at cross-boundary catchment scale. The project developed several improvable versions of a new de-fluoridation device/filters that were tested at village and household levels.

The present study focused on the African Rift Valley in Kenya and Tanzania sections, an active volcano zone, highly rich in Fluoride with lakes containing highest levels of Fluoride on earth (Nair K. R., 1984; Nielsen, 1999). Naturally, groundwater Fluoride concentrations are associated with diverse geological conditions, mineral reactions, rock formation processes and climate change-temperature and precipitation- in specific contexts across the globe (Akuno et al., 2019). The presence of many variables such as volcanic activity, calcium-deficient aquifers and the presence of high sodium in ground rocks increases Fluoride solubility and ingestion by end users (Edmunds and Smedley., 1996; USA, US Government Printing, 1962) in African Rift Valley. In African Rift Valley, the current excessive extraction of groundwater to meet growing human population demands and the alteration of precipitation patterns, negatively affects the groundwater balance capability. This scenario has not only diminished fresh water resources but also influences the water quality through higher dissolution of fluorites from bedrocks leading to high Fluoride content in most groundwater sources

(Bhupinder and Garg., 2012).

The research aimed to explore and discuss the behavioral preventive measures concerning people's basic behaviors, habits and socio-cultural beliefs that have been known to influence the type of water consumed (Mugumya. T. S., 2020). The objective of the study was to conduct focus group interviews to get insights about water drinking habits, to understand the role of consumers' attitudes, behavior and willingness to pay towards innovative filtering equipment, like the one developed by the floweredproject.com, to reduce the level of Fluorosis in the African Rift Valley and to bring insights on communication campaigns to change ingrained habits of inhabitants of the African Rift Valley. The targeted populations were divided into two ethnic groups of Bantu and Nilotes the most populous in both Kenya and Tanzania African Rift Valley. In the Bantu groups, the Meru of Tanzania and Kikuyu of Kenya shares language dialect, sedentary/farming lifestyle, and common ancestry heritage. The Nilotic group selected Maasai of Kenya and Tanzania, also sharing common language, culture and pastoralism lifestyle. The communities exist alongside each other sharing water sources, trading and access to development potentials. Each focus group contained between 8 and 12 participants. The total number of focus groups for the study was planned to be 8, of which; four for Bantu: 2 in Kenya and 2 in Tanzania and four for Nilotes: 2 in Kenya and 2 in Tanzania. In addition, among the focus groups; two focus groups (1 Bantu and 1 Nilote) had to be conducted in villages where de-fluoridation of water was already available.

The study design primarily focused on ensuring that participants were familiar and comfortable discussing certain concepts and terminologies related to water use from ethnic lenses. This was to explore the drivers of different ethnic groups' utilization of water filters, attitude towards drinking water and awareness of impacts of Fluoride-contaminated water in their daily lives. The study adopted qualitative methodology of focus group discussion (FG), an approach permitting greater understanding of viewpoints, deeper individual and cultural perspectives on water use habits, Dental Fluorosis, purchasing behaviors as well as exploiting FGs' distinct social interaction dynamics (Stake, 2005; Ford et al., 2010; Altea, 2019; Thomas et al., 1995). In the focus groups, the researchers discussed with the participants the functionalities of the proposed filter and their opinion concerning price and adoption or failure thereof and behavioral issues to detect possible behavior change targets. It sought participants' opinion about technical and market characteristics of the filters. Issues of filter sizes, price, and speed to filtering water were discussed. During the discussion, prototype filter images and their functionalities were spread on the table for the participants to imagine that a filter drastically reducing the content of Fluoride in water to the level recommended by WHO (<1.5mg/L) was available and could filter any type of drinkable water. In the two study areas, the available technologies were bone char buckets by Nakuru Catholic Church in Kenya (https://nakurudefluoridation.co.ke/about-us/) and Ngurudoto Defluoridation Research Station (NDRS) in Arusha region of Tanzania. Other technologies are solarwater disinfection (https://www.ircwash.org) among other isolated community filtration centers for other non-Fluoride related contaminants (e.g. using chlorine).

Considering the importance of behavior changes connected to introduction of new technologies, the research adopted the "*Risk, Attitude, Norms, Ability and Self-regulation*" (RANAS) approach to reach out the stakeholders in the two countries and to understand the underlying issues related to non-uptake and usage of available water filtration technologies as well as adoption of new innovative technologies. According to Mosler and Contzen (2016), there is the real need for assessing consumer both at household and village levels in order to induce a behavioral change in adopting a new technology (Mosler., 2016) since different factors may influence the behavior of people in the choice to drink safe/unsafe water.

These factors advised the use of RANAS approach to help in developing a systematic behavior change model for the studied regions. RANAS has the ability to help to recognize consumers motives to engage in specific manner in terms of health behaviors or not (Tamas et al., 2009; Kraemer M., 2011; Contzen et al., 2014; Contzen., 2015; Huber et al., 2014). The psychological factors presented in RANAS was hoped to address household perceptions on the Risks of contracting Fluorosis while consumers' Attitude factors such as their feelings on a new technology was gauged both in terms of their consequences and cost (Mosler H.-J. , 2012.) In communities, the Norms play an important factor such as other person having the power to influence or not a behavior concerning type of water consumed was also investigated. The Ability factors concerned with household's perceived capability and planning capacity to maintain using filtered water once they begin to and maintaining the same behavior and possible reasons for fall back. Self-regulation factors comprise self-monitoring strategies such as evaluating and reacting to one's own current behavior. This includes reminding oneself of one's intentions, coping with barriers and difficulties arising, and finally establishing a habit (Mosler., 2016). The RANAS model was conceived to support behavior change in development contexts and has shown to be useful in developing successful intervention strategies for the promotion of health-relevant behaviors across the water, sanitation, and hygiene sectors (Mosler H.-J. , 2012.; Inauen, 2013; Mosler et al. K. S., 2013; Tumwebaze, 2015)

To understand these drivers behind Fluoride safe/unsafe drinking water habits in the African Rift Valley in Kenya and Tanzania, the research questions were proposed with sub themes that were expected to generate detailed required information. The questions were developed following three levels of categorizing research questions due to the interconnected nature of qualitative components where each question transforms the others, and the need to come up with an integrated meaningful conclusion. (Tashakkori., 2007; Creswell, 2007; Newman et al., 2003; Teddlie et al., 2008)

The following research questions were posed:

1. What are the household water consumption habits?
2. What is Fluorosis? How do participants understand or describe Fluorosis?
3. What is the purchasing behavior of households or community members in consuming de-fluoridated water?
4. What are the behavioral factors that pre-dispose households to consuming Fluoride contaminated water?

The research questions were developed with hybrid and integrated sub-questions following recommendation by (Teddlie et al., 2008; Parmelee et al., 2007) where four principal questions were proposed, followed by broken down separate sub questions in each section with flexibility to none obvious questions arising from the interchange between 'how' and 'why'. These questions were deemed relevant and important in dissecting the complex socio-cultural, and economic values, attitudes, habits, human behavior and perceptions behind utilization Fluoride contaminated water (white, 2017). Even though there was a gap in literature, it also generated curiosity on the topic, and opened the opportunity to contribute to science and literature hence the motivation to come up with complete qualitative analysis in these two regions (Vuhahula et al., 2009; Mabelya L, 1997; Akuno et al., 2019).

The remainder of this chapter is organized as follows. The methodology section will describe the study areas and why they were selected, data collection methods, design of focus groups and the analytical approaches used to analyze the data. The results section will report analyzed findings for each question, sub-question and brief conclusion reinforced with publications. At the end, the general conclusions and recommendation will be based on the research findings, highlight new recommendations, and possible policy implications that emerged from the study.

4.2. Methodology

Several scholars have noted that for technologies in water filtration to be accepted and effectively utilized, a behavior change component is a key element (Du Preez et al., 2010; MaUsezahl et al., 2009). Very often, population in developing countries have been provided with technologies also referred to as "hardware" (Peal et. al, 2010), while the "software", which is core in ensuring proper adoption and utilization of the hardware as well as creating a change in behavior is needed to accompany such investment (Stanton et. al., 1991). Psychological factors may induce a behavior change within an individual. According to (Peal et. al, 2010), several social interventions effecting behavior change exits that can enable effective policies. In this list, (Peal et. al, 2010), summarizes them as (a) a systematic model of behavior-determining factors; (b) a methodology to measure these behavioral factors; (c) a method to analyze and verify the impact of these factors on target population behavior; and (d) instructions for determining the necessary behavior change techniques based on the preceding analysis. Peal et al. (2010) indicate that if these are systematically, well directed and applied in a behavior change process, chances of success are high in specific contexts (Peal et. al, 2010). In this study we proposed "The RANAS model: r(isk), a(ttitudes), n(orms), a(bilities), and s(elf-regulation) of behavioral change". RANAS, a behavior change model, which has been originally proposed for the analysis of behaviour change in water sanitation and has been described in (Mosler, 2012), is divided in four distinctive components: (1) factor blocks, (2) behavioral factors, (3) target behaviors, and (4) behavior change interventions corresponding to the factor blocks (Fig.1.).

The Five factor blocks must be satisfactory to the expected new behavior for the change to be successful e.g. the risk factors, attitudinal factors, normative factors, ability factors, and self-regulation factors (Fig.1.). Scholar (Albarracı´n et. al., 2005) describe the several theories of behavioral change factors that can skillfully classify these five factor blocks. The risk factor block describes an individual's understanding and awareness of the health risk as found in theories of (Rosenstock, 1974; Floyd et. al., 2000; Schwarzer., 2008). On the other hand, attitudinal factors describe the positive or negative attitude toward a behavior (Fishbein and Ajzen., 2010). Normative factors postulate the principles about the occurrence of a behavior and the thinking within the social stratum on the said behavior. Ability factors refer to the capacity of an individual's belief in him or herself must possess in order to acquire the behavior. Self-regulation factors are focused on the endurance and preservation of the changed behavior over time to cement the newly acquired behavior (Albarracı´n et. al., 2005; Prochaska and DiClemente, 1983). In health behavior change, RANAS Model's has proven to be successful in influencing factors behavior in the water and sanitation when combined with theories such as "Theory of Planned Behavior (Ajzen et al., 2007) and theory of Health Action Process Approach (Schwarzer., 2008). Some of the known examples, beside the original application on Fluoride contamination, have been in developing countries such as: solar water disinfection (SODIS) in Bolivia and Zimbabwe (Heri and Mosler, 2008; Kraemer and Mosler, 2010). Others include the hygiene behavior in Kenya (Graf et al., 2008) as well as utilization of arsenic-free deep tube wells in Bangladesh (Mosler et al. B. O., 2010). The application of behavior change theories have been found to be successful in proposing behavior changes in drinking uncontaminated water and sanitation facilities in these countries.

4.2.1. Behavioral factors

According to the RANAS model, behavioral factors focus on the perception of vulnerability determining the risk factors. Perception of individual's vulnerability refers to the consciousness of one's danger of acquiring a disease (Floyd et. al., 2000).

In (Albarracı´n et. al., 2005), individual's understanding of the likelihoods for potential contamination leading to a disease is very important. Issues of attitude towards this potential such as beliefs concerning prices, time, and effort as well as potential positive outcomes such as savings, health, and other advantages of the new behavior when combined with individual's feelings or thinking of the behavior plays a core role in effecting a behavioral change in people. Further, personal norm refers to issues that an individual believes she or he should do (Schwartz, 1977). In norms, several kinds arise such as the descriptive norm that focus on what others do and influences an individual in approving or disapproving ones actions (Cialdini et al., 2006; Schultz et al., 2007). Schwartz (1977), also talks about the institutional norms that prescribe a community's dos and don'ts that are instituted by social and cultural leadership such as village elders, ethnic leaders, religious or other institutions that can influence in one way or another (Schwartz, 1977).

To accomplish a behavior, an individual need to acquire some level of confidence in his or her own ability. In Frick et al. (2004), an individual should know how to utilize the knowledge acquired to accomplish a behavior (Frick et al., 2004). This is referred to as the ability factor where an individual can take action to manage behavior change situation (Bandura, 1997). In this context of ability factors, self-efficacy becomes very relevant to sustain the change by supporting dealing with barriers arising during the preservation of the behavior, and the experience of failure and recovery from setbacks (Schwarzer., 2008). On the other hand, the self-regulation factors in this section deals with self-management that assist an individual to manage contradictory areas and divergent views during the implementation of a new desired behavior (Gollwitzer and Sheeran., 2006; Schwarzer., 2008; Bandura, 1997; Albarracı´n et. al., 2005). These actions, in totality should as well involve the action control strategy that continuously evaluate the behavior and thoughts on when, where, and how of the new behavior (Gollwitzer and Sheeran., 2006; Schwarzer., 2008). To continuously achieve a behavior, an individual must constantly remember the behavior as well as commit to it over time (Tobias R., 2009).

4.2.2. Target behaviors

Targeting behaviors focuses on the possible outcomes of the behavioral factors. RANAS add that within those desired behaviors there are also other competing behaviors that should be considered. These competing behaviors can also be found in water and Fluoride contamination studies and can highlight issues like a). Drinking safe water represented as (Behavior A) verses drinking Fluoride contaminated water as (Behavior B). In this section, the use of any type of water, the intention to use such water gauged as the behavior-determining factor resulting from several beliefs (Fishbein and Ajzen., 2010) and habit of using specific water filtration technology represents the factor outcomes in addition to behavior. In this sense, a behavior change is defined by the possible adoption of technology in water and Fluoride contamination described through the available water sources and technology infrastructure. This use or adoption of the technology can only be gauged as an outcome of the behavior change process. To form this intention that generates this new behavior, risk perception, attitudinal factors, and ability factors contribute to intention building and self-regulation factors while ability factors contribute to behavior performance. Habits are the utmost significant outcome, as the aim of each behavior change drive is to shape a long-term typical behavior amongst most of the target population. Habits are formed through an interaction between original obligation, memorizing, and repetitive performance of the behavior. This repetition may be supported by planning factors (Schwarzer., 2008; Tobias R., 2009; Aarts and Dijksterhuis., 2000).

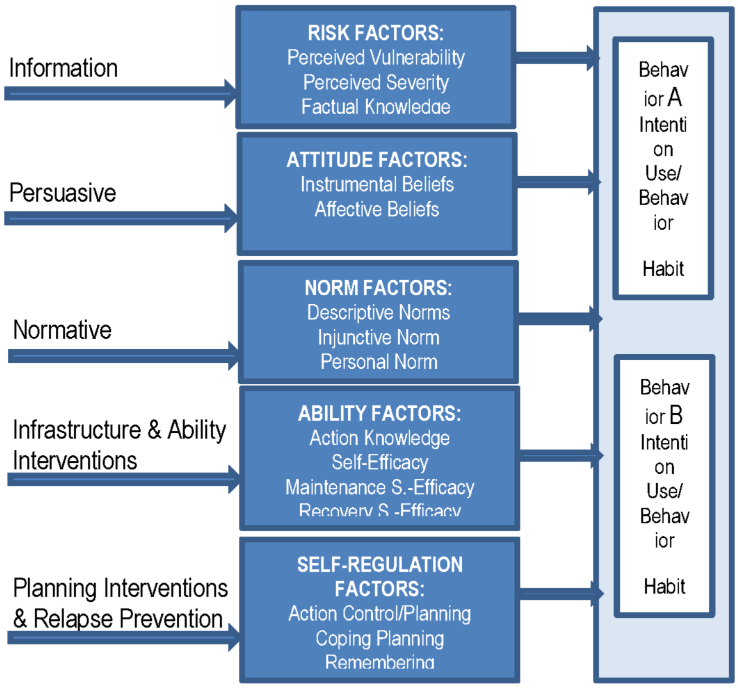


Fig. 1. The RANAS Model

(Mosler 2011)

4.2.3. The Research Questionnaire

A research protocol was developed that guided the design of the research questionnaire (ANNEX 1) and study, where the questionnaire was subjected to a 2-days research conference discussing issues of interest for the field survey. The rationale for the research questionnaire was based on the literature gaps that were identified within studies on naturally fluoridated water in the African Rift Valley (Chakraborti D. D. B., 2016; Chakraborti D. B. N., 2009; Kaseva, 2006; Nanyaro, A geochemical model for the abnormal fluoride concentrations in waters in parts of northern Tanzania, 1984). Most of studies have tended to focus on water de-fluoridation also referred to as “hardware” by (Peal et. al, 2010) and Fluoride in food and soils and it’s impacts on humans as studied by (Marian, 1997). But, importantly, based on the gap, the present research aimed to explore and discuss the approaches that can be adopted to induce a behavior change. This analysis has not attracted much attention, but it is reputed equally very important to combating Fluorosis (Mosler, 2012). People’s basic behavior, habits and socio-economic and cultural beliefs have been known to influence what type of water consumed (Mugumya et al., 2020). The objective of the study was to conduct focus groups discussions to get insights about water drinking habits, to understand the role of consumers’ attitudes, behaviour and willingness to pay towards innovative solutions to reduce the level of Fluorosis and to bring insights on campaigns to change ingrained habits of inhabitants of the African Rift Valley. To achieve this aim, the study protocol was designed to utilize focus group discussions where the population in Kenya and Tanzania African Rift Valley were targeted. The recruitment of the participant targeted the Bantu and Nilote ethnic groups in both countries. Each focus group was designed to contain between 8 and 12 participants. The total number of focus groups to run for this study was expected to be 8, of which; four for Bantu: 2 in Kenya and 2 in Tanzania and four for Nilotes: 2 in Kenya and 2 in Tanzania. In addition, among the focus groups; two focus groups (1 Nilote and 1 Bantu) had to be conducted in villages where Fluoride safe water was already available. The study was conducted within a period of three weeks in September 2018, where interviews were recoded, and observational skills, descriptive and analytic formats of cross-sectional analysis were to be carried out. The safety of research participants was included during design of the protocol to ensure that only those who were free to answer questions posted without fear of repercussion from family members or villagers. The procedure for recording and reporting results and their follow-up was considered hence the contact details of the participants were taken for such purpose (Fathalla., 2004).

The research questionnaire gave a clear indication that another group of researchers were to follow-up on the study with the water filter prototype to understand further participants' perception as well as demonstrate the filter prototype and its use at local levels also agreed by (Fathalla., 2004). The research questionnaire, originally written in English, was later translated into the Kiswahili language which is the national language in the two countries. Through established project network and local partners, the researcher planned access and recruitment of participants using a pre-determined category. This helped the researcher to establish initial contacts with participants, guaranteeing their contribution as recommended by (Ruiz, 2014). This selection included indirect project participants that ensured a more heterogeneous sample of respondents. The risk of bias due to cultural and gender issues were minimized by; rephrasing or individualizing the questions and conducting different sessions for male and female respondents where necessary.

4.2.4. Data collection and design of the Focus Group discussions

The data was collected between 2nd to 27th September 2018 with each first day discussions, testing and contextualizing the questionnaire involving project partners' staff, research assistants and a community group in each country. The questions were adjusted according to the context, especially the translation and terminology following (Altea, 2019; MacDonald et al., 2013) approaches. During the interviews, the researcher recorded the interviews using a recording device, asked each participant same question to allow for clear separation of answers, and at the same time recorded on paper issues that were of interest for the research.

A total of eight FGs were planned to comprise four Bantus and four Nilotes (2 in Kenya and 2 in Tanzania each) containing between eight to twelve participants each. However, nine FG were conducted, five in Tanzania due to emerging issues of interest arising from shift in socioeconomics influencing cultural practices among the Nilotes. In Kenya Nilote (Maasai) men's refusal to sit together with the women forced the researcher to organize a different session for the women slightly increasing the number of women participants. In each country at least one FG was conducted among participants with experience in filtering water. Each group was heterogeneous in terms of age, sex, ethnicity, education, local knowledge and long-term residents as recommended by (Rabiee, 2004).

The discussions were conducted in Kiswahili language usually at local community and government halls arranged by the local government officials. In a few circumstances where there was lack of understanding of Kiswahili language, participants' mother tongue was used and directly translated to English by the researcher and research assistants who had been recruited due their ability to speak at least one local language. Participants were asked questions and given opportunity to answer, ask and converse for better clarification giving room to pursue emerging issues of interest and adjustments in the research as recommended by (MacDonald et al., 2013; Patton, 2003; Kvale, 1996). Room for clarification was allowed in cases that generated interest from both sides (Patton, 2003). The questionnaire (ANNEX 1) contained preliminary questions e.g. a). general questions requiring mass answers of YES and NO. These questions were geared to determine whether the participants had taken part in Fluoride focus group discussions in the past, whether participants were involved in decisions regarding drinking water at household level and requested to know the willingness to participate in the group discussion on drinking water. The second set and the core questions of the research were individualized questions within the groups with opportunity for contribution from any member as permitted by the researcher to control deviation from the topic. Concerning the questions, photos of different stage of dental and skeletal Fluorosis were printed and handed to each participant to provoke participants thought and gauge their knowledge and understanding of Fluorosis as well decision making on key concepts (ANNEX 2). Additionally, water filter prototype photos were printed and handed to the participants (ANNEX 3). The prototype filter photos explained the mechanical, operational and chemical structure that would be applied to filter water. The participants were then asked questions depending on their preference of a specific prototype. Finally, 12 payment modality plan cards were printed and put on the table for the participants to choose from (ANNEX 4). The questions explored potential of purchasing behavior using payment plan cards to get insights about water drinking habits; b) to understand the role of consumers' attitudes, behaviour and willingness to pay towards innovative solutions to reduce the level of Fluorosis in the African Rift Valley and c) to bring insights on communication campaigns to change ingrained habits of inhabitants of the Rift Valley.

The first question investigated the sources of and availability of water for everyone, family water resource management, amount of water families consumed per day, ownership of water sources e.g. bore holes. It also investigated socio-cultural issue such as family member responsible for collecting water, how much efforts families made to access water, the cost of water per liter (safe vs unsafe), awareness of water safety for family health, the process of decision assuring water safety for consumption and sharing the risk of Fluorosis by offering Fluoride unsafe water to guests and children in participants villages and homes.

The second question presented photos of dental and skeletal Fluorosis to examine participants relation to Fluorosis in their homes and villages by asking their thoughts or feelings about the Fluorosis pictures. In addition, it explored the participants knowledge of water as a determinant of Fluorosis, and what to do to access Fluoride safe water, whether participants family members were exposed to health problems due to Fluorosis and how participants felt about chances to get Fluorosis. Further, it investigated past interaction with filtered Fluoride safe water and their liking of it. Participants habits was tested with questions on whether filtering drinking water was time consuming, whether they needed approval from family members to consume filtered water, their strong personal obligation to consume or buy Fluoride safe water and if the participant had the surety to consume as much Fluoride-safe water as they wished within the next weeks. It also tested risk perceptions on participants feeling about relatives who continued to use unsafe raw water, confidence in freely consuming Fluoride-safe water and in cases where participants stopped drinking Fluoride-safe water, their confidence in resuming commitment to drinking Fluoride-safe.

The third questions explored the capacity and willingness to purchase and pay for clean safe water by placing two pictures of filters that were under development (prototypes) and 12 payment modality cards. It was explained to participant on the mechanical and advantages of the filter prototypes after which the participants chose a card, they preferred that befits his or her wish to acquire a filter and modality to purchase it. These filters were for both household and village levels where household filters were able to filter between 30-50 liters in 2 hours while village filters were capacity of up to 500/1000liters per/day (10hours overnight). The participants were asked about their preference and reasons concerning the capacity, speed and price of the filters. The capacity of the filters was intended to invoke discussions on safe water needs in families and villages, the speed of filtering intended to augur the willingness by participants to invest in time for filtering water and eagerness to acquire specific type of filter. The price, through prepared 12 payment modality cards intended to detect socio-economic dynamics related to access to safe Fluoride water. The participants eagerness to pay for a specific filter determined maximum willingness to acquire the filters. In this section, twelve payment cards both for household and village levels filters payment modalities asked about whether the participant were willing to pay from personal savings, cash, selling property to buy filter, approaching NGO or Church to buy on his/her behalf, getting a loan from women/men groups, those willing to buy with subsidized cost, combining in a group of two to buy one filter, participants willing to buy village level filter as a community to share the cost, participants willing to buy on installments and participants not interested in the filter. These specific sub questions examined the potential of success verses failure of interventions, buying power, poverty or ingrained habits motivating or not to acquire clean safe water or water filters. The researcher asked the same questions to all the participants except when there was a unanimous agreement that answers were the same and repeated also referred to in qualitative research as saturation point by (Charmaz, 2006; Altea, 2019; Weiss, (1994).) The recorded discussions were transcribed using online platform "Go transcript' into Kiswahili language, the researcher then listened to the tape recording and read the Kiswahili version to confirm accuracy and the translated into the English language by the researcher for analysis.

4.3. Results

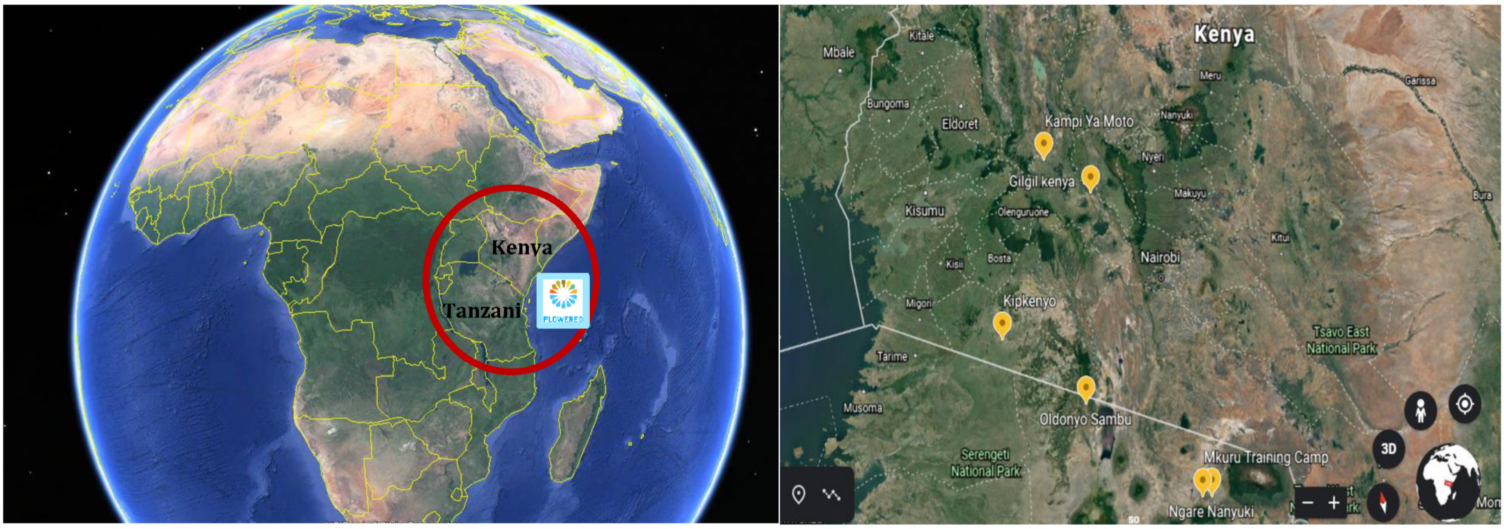
4.3.1. Study areas

In Tanzania, the study was conducted in Meru District, Arusha region (Map 1.). The Arusha region is on the southern slopes of Mt. Meru, 4,600 ft. above sea level, average 25-Degrees Celsius, thin humidity bordering the equator (The United Republic of Tanzania, 1998). The District is bordered to the North, West, and Southwest by Monduli District, to the Southeast by Arusha City and East by the Kilimanjaro region. The District lies between latitude 3' 00^{o} – 3' 40 ^{o}, longitude 36' – 55 ^{o}, characterized by bimodal average annual rainfall between 500 to 1200 MM. The District has 11 all season streams and 143 springs. It is comprised of 3 divisions, 17 wards, 71 villages and 281 sub-villages (The United Republic of Tanzania, 1998). The research was conducted in Ngare Nanyuki, Oldonyo Sambu, Mukuru and Lemada villages.

In Kenya, the study was conducted in Nakuru County (Map 1). The County is at 1,850 M above sea level, humidity of 61.0%, latitude -0.303099, and longitude 36.080025, coordinates 0° 18' 11.1564'' S and 36° 4' 48.0900'' E, average annual temperature (25.6 Degrees Celsius) and annual precipitation between 29 to 963 MM. It is bordered by Counties of Baringo (North), Laikipia (Northeast), Nyandarua (East), Kajiado (South), Narok (Southwest), Bomet and Kericho Counties (West). The County is divided into eleven sub-counties and 55 wards. The research was conducted in Divisions of Rongai (Kambi ya Moto village), Gilgil (Maji Moto and Kikopey villages) and Naivasha (Kipkenyo village). Nakuru County has Lake Naivasha, Nakuru and Elementality with latter two considered to have highest levels of Fluoride globally (Gaciri and Davies., 1993; Williamson, 1953).

The two regions share similarities in socio-economic and agro-ecological traits. The communities exist alongside each other sharing water sources, trading and access to development potentials. This study considered inter-ethnic lifestyle divided into Bantu and Nilotic groups. In the Bantu groups, the Meru of Tanzania and Kikuyu of Kenya shares language dialect, farming habits, and common ancestry heritage. The Nilotic group selected Maasai of Kenya and Tanzania, also sharing common language, culture and pastoralism. The plan primarily focused on ensuring that participants were familiar and comfortable discussing certain concepts and terminologies related to water use from ethnic lenses. This was to explore the drivers of different ethnic groups utilization of drinking water and awareness of impacts of Fluoride-contaminated water in their daily lives as well as habits hindering the use or adoption of de-fluoridation technology.

Map 1. Map of East Africa indicating the study areas in Kenya and Tanzanian Rift Valley



Map1. Source: Google earth

Permission was sought from the participants explaining the purpose and nature of the study, potential benefits, risks and data collection, access, ownership and confidentiality as well as freedom to voluntary participation in line with Patton (Patton, 2003) stressing protection of respondents during and after the interviews. The group leaders or the local government official signed the information sheet and informed consent forms after unanimous agreement by all the participants.

This qualitative research results was not be subjected to quantitative statistical analysis to generate statistical significance of differences due to its explorative nature and heterogeneity. The chapter does not purport to represent explicit quantitative outcomes but rather results based in interviews. This research does, however, deliver a detailed summary of histograms that highlight the results and perspectives that consistently emerge with respect to the questions that were being explored concerning water, Fluoride, Fluorosis, filtration technology and socio-psychological behavioral factors related to contaminated water usage in the African Rift Valley.

The total count of water collected and total count of water for drinking and cooking in litres

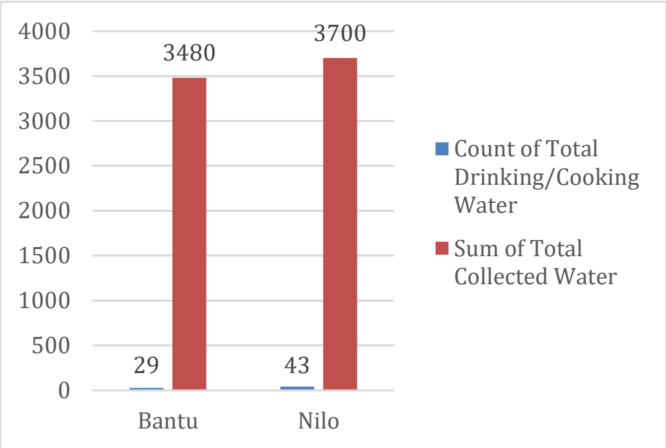


Fig 2. Total count of water collected
Source: Field survey, September 2018.

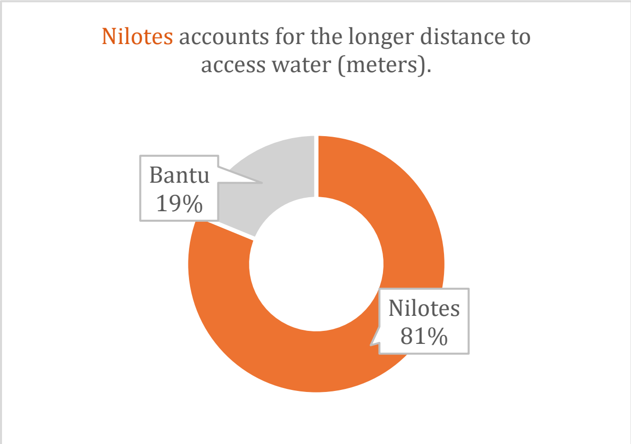


Fig. 3. Total distance walked to collect water

In Fig. 2. Nilote collected little more water than Bantu counterparts. Interestingly, since Nilotes are majority pastoralist, water for animal use seemed to be higher especially small animals that stay at home. In most Bantu groups, sedentary lifestyle means they settle near water sources for ease of agriculture and collecting water when compared to Nilotes. In Fig.3. Nilotes walked longer distance to collect water. This can be attributed to their constant migration in search of pasture. Approximately, it was postulated to be 8KM to access water.

In both Kenya and Tanzania, when total water collected was correlated with years of education it was found that in the lowest education were found in Tanzania and these were also the groups that used more water. When it was compared to family size, these groups in Tanzania apparently composed of more family members than Kenyan counterparts increasing their water demands.

4.3.2. Demographic information of the respondents

This is an essential element in describing the characteristics of research participants. Demographic information here include the participants' age, gender, ethnicity, educational level, and languages spoken as recommended by (Hammer, 2011). The participants were selected from Ethnic groups living close by each other. There was no age limit as long as one was an adult, having a family and utilizing water sources within the selected villages. There was gender balance to understand the differences between men and women when it comes to decision making on water usage, roles in collecting water and knowledge on Fluoride water contamination among other parameter such as price of water and who paid for the fee to collect and or buy water filtering equipment.

Age and family composition by Ethnic groups

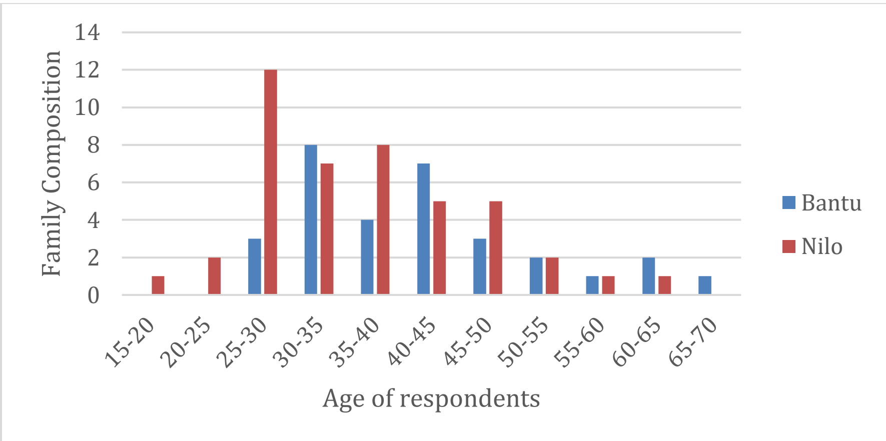


Fig. 4. Indicators of age of respondents and family composition by ethnic groups.
Source: Field survey, September 2018.

Larger families imply higher demand for water. Younger families could also suggest higher demands for water. However, issues such as agriculture e.g. working in the field increases the demand for drinking water and possibly predisposing more Bantus.

Gender of respondents and ethnicity

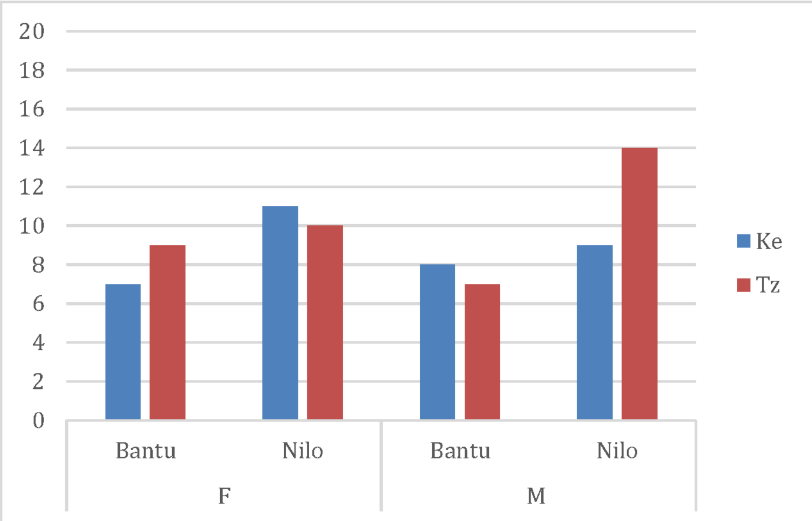
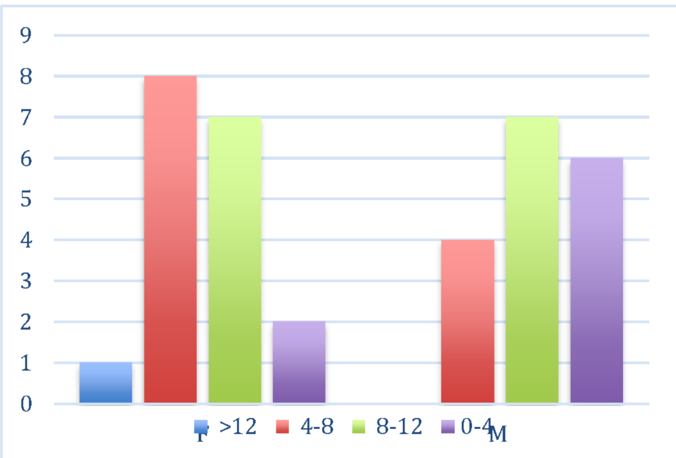


Fig. 5. Indicators of gender of respondents by ethnic groups in two countries. Source: Field survey, September 2018.

Nilote male and female were more than the Bantu male and female participants. In one male groups in Kenya the Nilotes due to cultural practice did not allow for females to sit together in their meeting. This has a direction on water usage at home where it is predominantly females who collect, utilize and quantify domestic water.

Years of education of the respondents by gender and country.



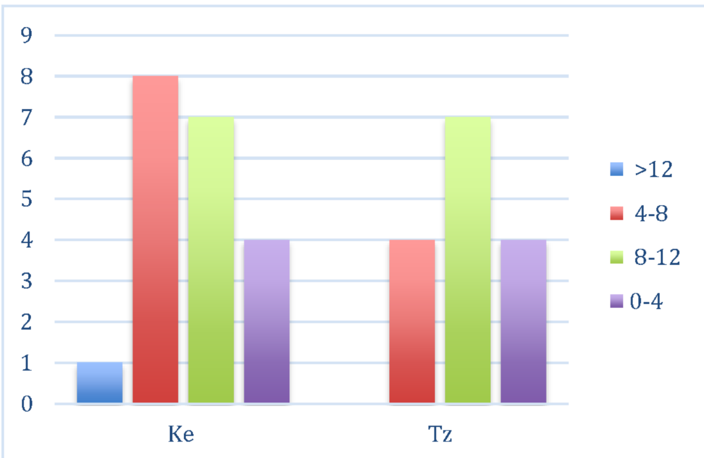


Fig.6. Years of education by gender *Fig.7. Years of education by age and countries*
Source: Field survey, September 2018.

Fig. 6. Indicates that females between 4-8 years of education were the majority followed by 8-12 years. Only females studied beyond 12 years of school. Education as a parameter for decision making on water use then should indicate more women as decision makers of safe water use which is not the case due to culsture. Males between 8-12 years of education were the majority followed by 0-4 years in education. No male studied beyond 12 years of school. Nevertheless, more males studied more than the females. Fig.7. indicates that more population in Kenya were more educated than their Tanzania counterparts.

4.3.3. Sources of water

The respondents' use more than one source of water such as boreholes, rivers, rain, and wells, hot springs, piped Fluoride water, piped water, streams and truck vendors. In Tanzania, springs are popular followed by boreholes, rivers and others while in Kenya it is boreholes, springs, rivers, tap among others. Bantus in Kenya use more boreholes while Tanzania Bantus access more springs. The Nilotes in Kenya use more springs while in Tanzania Nilotes access more boreholes. Water fountains dubbed 'Magadini' or Trona-point in Tanzania and hot springs also called 'Maji Moto' in Kenya are known to contain elevated Fluoride levels (Vuhahula et al., 2009). Respondents collecting rainwater were challenged by lack of space, storage facilities and small hut structure not supporting roof water collection. The rainwaters last between one week (stored at home) to 2 months for open water pans shared with livestock. Piped water quality remained questionable since the water is piped from the unfiltered boreholes or springs near the villages. Only a small section of respondents had the opportunity to collect weekly rationed government trucked water especially in Kenya (WHO, World Health Organisation, 1996; Fitzgerald, 2000; Galagan D. J., 1957).

River water were reported to contain high metal/ chemical pollution from flower farms/industry exposing the communities to other diseases. Given an option, one group upheld that Dental Fluorosis is better than death from cholera, dysentery or other ailments from polluted rivers. When comparing the two countries water sources, Fig. 8. shows that 80% of those who responded to consume tap water in Tanzania compared to Kenya 20%. It is worth to note that these tap waters in both countries originate from the same Fluoride contaminated springs or boreholes. A further 68% in Tanzania use wells against Kenya 33%. Bore hole water has 52% in Kenya compared to 48% access in Tanzania. Additionally, more people access rivers in Kenya to 75% when compared to 25% in Tanzania. Tanzania has more springs at 59% compared to Kenya's 41%. Those who collect rainwater stands at 70% in Tanzania when compared to 30% in Kenya.

Further, water accessed according to ethnic groups where Nilotes accessing tap water were 48% while Bantus were 52%. The Nilotes access more wells at 66% compared to Bantus at 33.3%. Those accessing rivers stood at Nilotes 37.5%, against 62.5% of Bantus. Concerning spring waters, Nilotes were 70% while Bantus were 29.6%. The rainwater access was led by Nilotes due to their migration and accessing distant regions where the rains are to 75% especially in open water pans, the Bantus counterparts were collecting rainwater up-to 25%. The participants who answered to consume bottled water were very few but all were 100% Nilote community who agreed to at times buy bottled water while away from homes or during migration as well as when hosting an event party. Focusing on the two countries Fig.9. indicates the sources of water combined were borehole and springs as leading sources while bottled water, wells and rivers are the least common in the study regions.

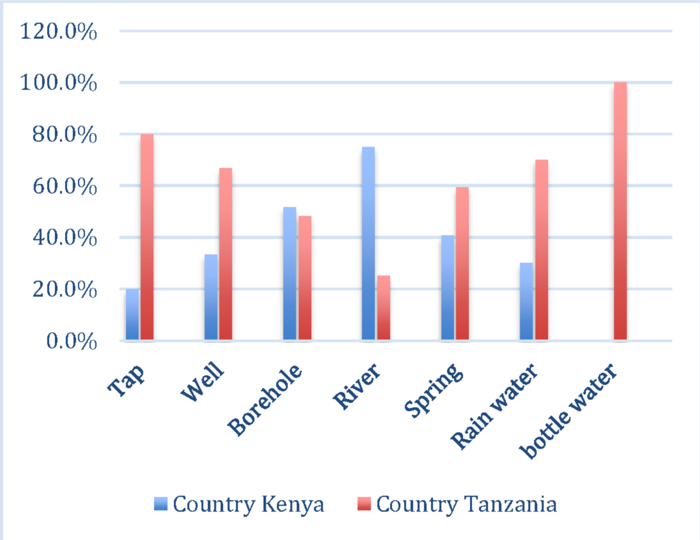


Fig. 8. Sources of Water by Country;
Source: Field survey Sept 2018

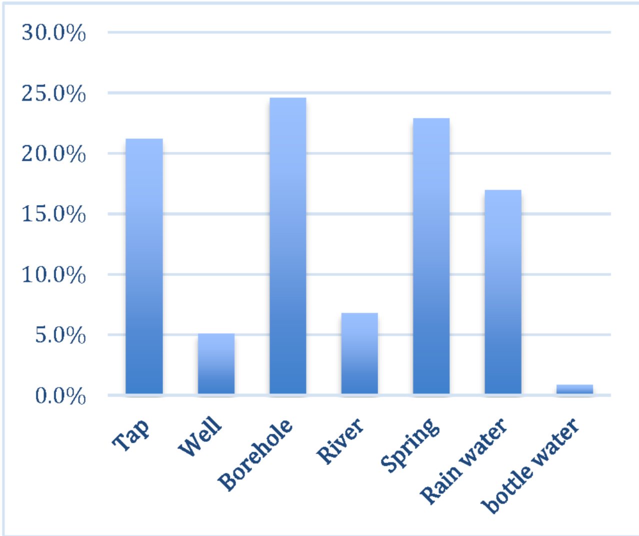


Fig. 9. General sources of water in both countries;

In both countries, borehole seems to be the most popular sources followed by springs, tap and rainwater respectively.

4.3.3.1. Participants responsibility to collect water

The responsibility in fetching water is mainly the duty of women at 72.4%, while the difference saw men for 15%, and children for 12.6% for both ethnic groups and countries. The men (husband) and paid transporter utilized motorbike and trucks to ferry water to the villages while women (wife) and children used donkeys to available water sources in the village or distant regions. Bantu men participated more in water collection than Nilote men. This is attributed to Nilote men being pastoralist and constantly away from home with the livestock as well as culture.

4.3.3.1. Price of water in the villages (Treated verses non treated in US$)

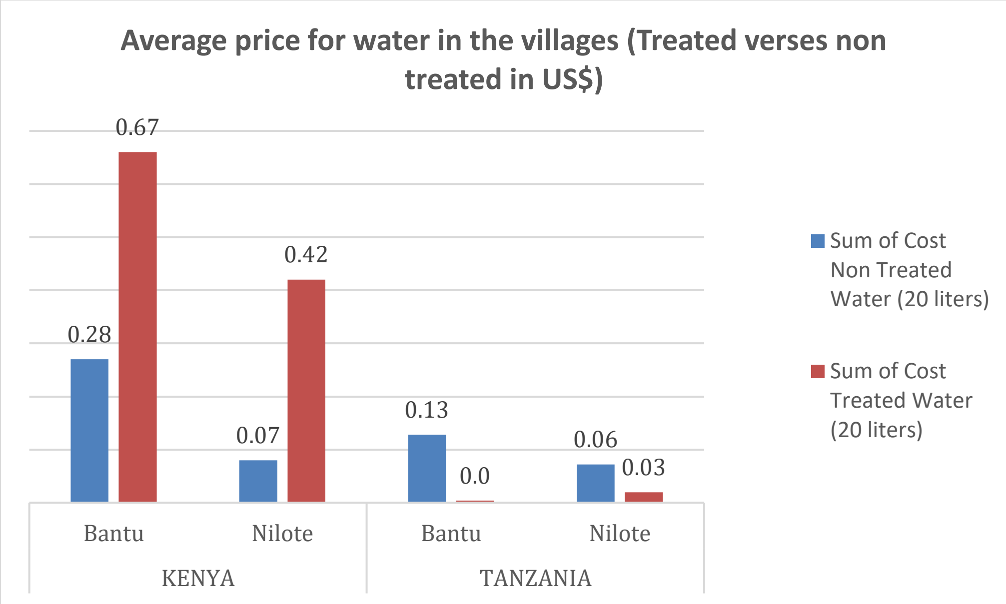


Fig.10. Average Prices of treated vs non-treated water in the villages (US$).
Source: Field Survey, September 2018

The communities showed varied prices to acquire a 20-liter bucket of water. The prices were converted into USD since the Kenya and Tanzania Shillings had a varied conversion rates and in order to compare their values. In Fig.10. in Kenya there was availability of filtered water and the price was very high when compared to non-filtered water. In Tanzania, in the studied regions, filtered water was almost nonexistent apart from bottled water that was very expensive, not indicated in the analysis. Comparing prices by ethnic groups, the Nilotes both in Kenya and Tanzania were not interested in paying for the water whether filtered or not. However, Nilotic group contributed towards the maintenance of the water point, security or filtrations centers. This depended on both the communal culture as well as constant migration. On the other hand, Bantus being sedentary always lived near water points and showed willingness to pay for the water services including buying, filtering and maintaining the water sources. From the questionnaire it emerged that while Bantus in Kenya buy filtered water at 67 cents of USD, Tanzanian counterparts did not pay anything simply because there was no access to filtered water. The Kenyan Nilotes who have embraced sedentary settlements bought filtered water at 42 cents of USD while in Tanzania Nilotes paid on average 3 cents of a dollar when available.

4.3.4. Health safety from drinking water in villages

4.3.4.1. Awareness of the safety of drinking water

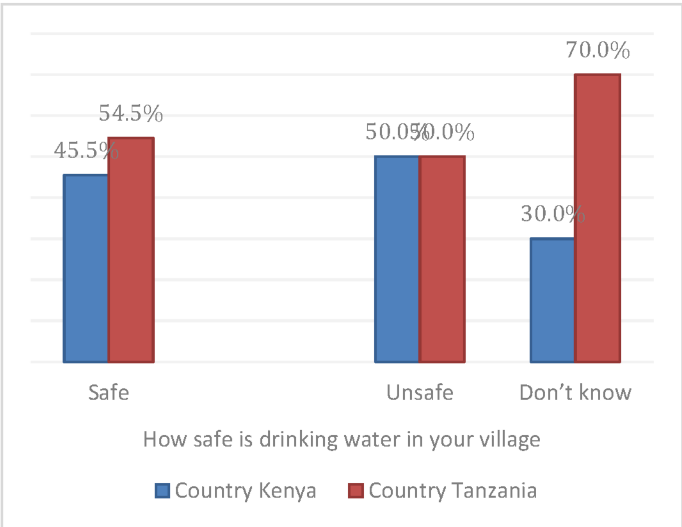
Household size and socio-economic conditions, water collection time and distance, prices are usually defined as the main determinants of household water consumption patterns (Huber et. al., 2012). However, water quality can have an important impact on the amount of water consumed. From the analysis, it emerged that a good number of respondents believed their waters to be clean and safe to drink, not taking into account whether actually the water was treated/filtered or not. This is in line with observation made by (Smith et al., 2008) on the attitude-behavior relationship and the role of norms, past behavior, and self-identity guiding consumer conduct. In the same breadth, borehole water was considered safer than springs while tap water drew mixed reaction depending on the source of the tap. Streams had unanimous agreement to be getting more contaminated with time and as they flow downstream reflecting on the Fluoride containing rocks. Participants identified safe water through observing improved human health, changing/unchanging color of boiled food and lesser taste of "Magadi" and salt.

Nevertheless, the groups reached no consensus on what source of water was more Fluoride contaminated than another due to diverse regions of study. These attitudes exhibited adds to the probability towards the tendency of Fluoride unsafe water usage as these interviewees showed;

- *"I assume the borehole water is clean, the water is clean and safe for human consumption, I just believe it's safe. We have been using it without treating it"*
- *"I believe the stream water is clean and safe to drink. Whether tested or not that is not important, it should be clean water"*

4.3.4.2. Awareness of unsafe drinking water

The perception of feeling unsafe or at risk due to Fluoride water consumption revealed that several factors interact to influence majority of the respondent who responded to the question. This fall under the risk factors block that explains all the factors that addresses individual's understanding and awareness of the unsafety as a health risk and has been described by several theories (Rosenstock, 1974; Floyd et. al., 2000; Schwarzer., 2008). Respondents considered unsafe water too salty, bad taste, too warm or hot, hard and heavy to swallow, containing Magadi, water turning rocks brown, producing crystals when kept in buckets and not quenching thirst. Some of these have been noted by (WHO, World Health Organisation, 1996). A good number of participants preferred rainwater because it is not Fluoride contaminated compared to borehole and hot spring waters, while river water was considered more unsafe due to multiple contaminations. From Fig.11. we see that participants awareness of water safety on health by country was not so varied between the two countries. While 70% of Tanzanians did not know safety of their water, only 30% of Kenyans did not know. Half of participants in both countries declared that their waters were unsafe. As for participant who responded to know about water safety, 54.5% resulted in Kenya and 45.5% in Tanzania. In general, 63.6% of participants confirmed to not knowing the safety of waters they consumed, 25% believed waters to be safe, while 11.4% were not aware about the safeness of the water they were drinking, see Fig.12. The analysis also sought to gauge knowledge on water safety through gender lenses. The study realized that 54.5% males were aware of water safety compared to 45.5% of females.



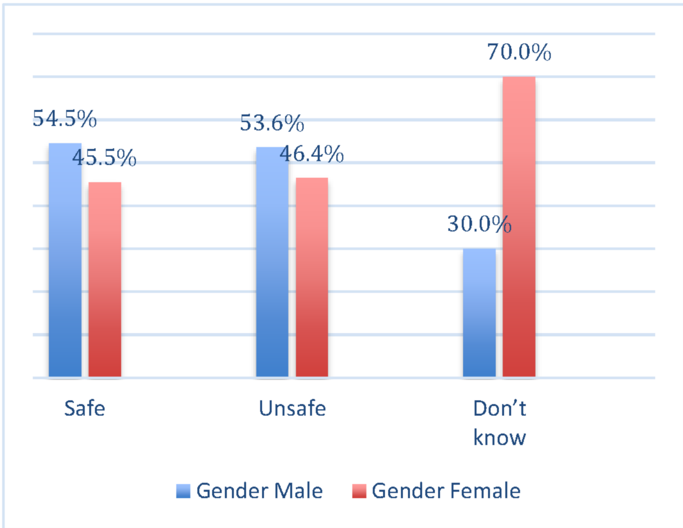


Fig.11.Knowledge of water safety by country. *Fig.12. Knowledge of water safety by gender. Source: Field survey*

Some of the respondents replied that:

- *"It is clean water, but we drink knowing that clean is not safe because there is Fluoride in the water".*
- *"We don't have safe water. We knew because when we visit other regions, people are ok, but we are affected".*
- *"The level of Fluoride concentrations in our water is harmful and it will continue to affect us as long as we use it"*
- *"I am aware the water isn't good for my health, but I have no other option. We use the water we have. Our primary school here has 1200 children, and they use bad water. Secondary school here has 800 students and they drink this bad water"*

4.3.5. Availability and sufficiency of water in the villages

4.3.5.1. Does the water meet the needs in the villages?

Sufficiency of water or a product has been known to highly influence behavioral factors and requires psychological theories such as (Mosler, 2012; Devine, 2009) that describes the opportunity, ability, and motivation. Water sufficiency in villages or its access is composed of social norms and even enforcements such as water rationing that can influence individuals decision on the safe water usage. Knowledge, skills, self-efficacy, social support, roles and decisions, and affordability are determinants of an individual's ability in this process behavioral change interventions that should reflect psychological factors to be changed (Kraemer and Mosler, 2010; Mosler., 2016). In this section, according to the respondents, Fluoride water was abundant with, usually, no limit to how much one could collect especially in Tanzania. In Kenya, frequent droughts could lead to less water from the hot springs leading to scramble. Fig.13. shows that 45.9% of participants agreed that water needs were met. Rainy season emerged to be the best periods where almost everyone water needs were met either by mixing rain and borehole waters as well as utilizing the open water pans. Some participants reported that;

- *"It meets the needs when it is wet season, mostly when it's raining because when it's not rainy seasons the wells dry".*

In very few instances, government provided clean safe water once a week such as in Kenya although the ratio was not possible to last a few days. A good number of respondents reported that either borehole waters dry up during droughts or solar panels not pumping enough during cloudy seasons coupled with population increase creates continuous shortage in villages. The 52.7% percent of respondents believed that their water demands were not met by all water sources combined in specific contexts. Sometimes, respondents reported that the springs and water pipes also got destroyed by wild animals and floods while water diversion by rich farmers spiked prices upwards and hindering access thus affecting the social norms. The main copying mechanism was water rationing decided according to family sizes and demand. In conclusions, many poor respondents were frustrated in accessing water cited:

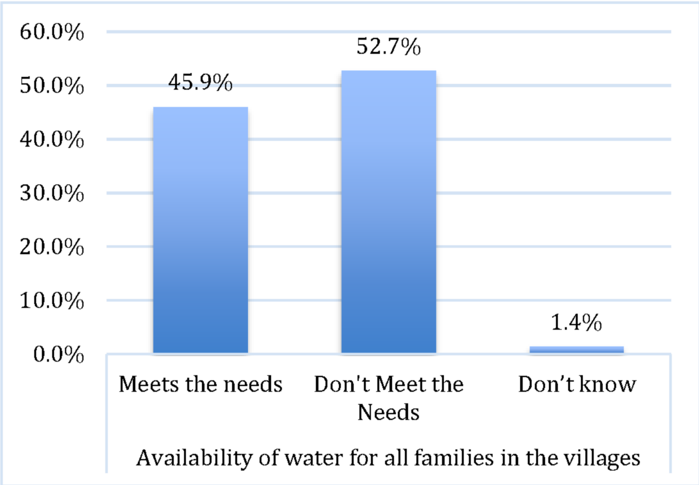
"It is not enough for us because sometimes at the source of water wild animals are destroying and at other times during the rainy season, dirt water blocks it and, in those moments, we go back to our of Fluoride water usage."

- *"We decide limitations of water distribution based on how big a family is for example we know Solomon has a bigger family so we will ration for everyone depending on their family size. We discuss and give water according to family size before the water is finished"*
- *"It's a problematic water because you can go for a whole day and pick up six buckets from very early in the morning at dawn when you get up till Ten o'clock".*

Finally, only a small fraction of population of 1.4% agreed to completely missing out on water depending on the season and time. Uncertainty on how much water one could or not collect at all emerged as a key concern to this group of households. Nevertheless, respondents had hopes to save safe water whether little and not enough. These respondents cited that:

- *"For one day you can collect three or two bucket, safe water is not enough because it often breaks down, and it is not too safe water itself, sometime we get less water, when water levels decrease so we get a little or miss out completely"*

When the water needs were aggregated by country, Kenyan respondents reported that 41.2% water needs were met while 53.8% water need were not met by local water sources, see Fig. 14. This is compared to Tanzania where 58.8% water needs were met while 46.2% were not met.



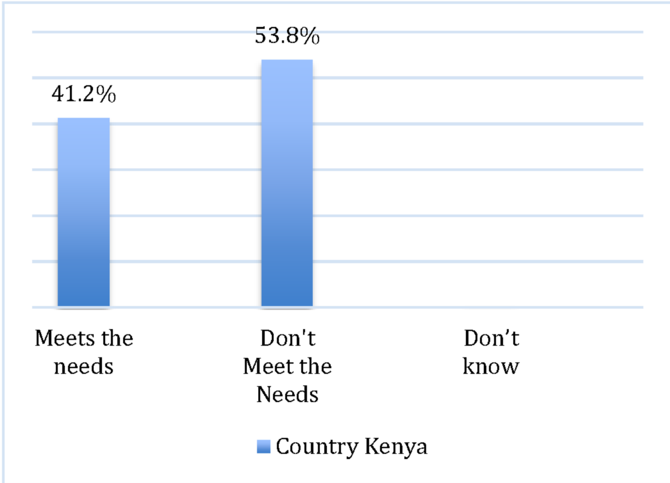


Fig. 13. Water needs
Source: Field survey

Fig.14. Water needs by country

4.3.6. Participants actions to make drinking water safe

In this context, the main purpose was to investigate the social and psychological determinants of the consumption of Fluoride-safe water to support in assessing potential implications for water filtration equipment intervention. Enhancing and impeding factors of filter use if known can support the process of successfully implementing new filter technologies and persuading people to sustainably use such technologies as found by (Huber et. al., 2012). In Fig. 15, 50% of participants reported taking no actions to de-fluoridate contaminated water. Lack of filtration knowledge, lack of filters, high prices of filters and lack of safe-water options were cited as drivers. Some interviewees mentioned that:

- *"we only drink the water because everyone is using it."*
- *"I'm scared but I use the water because it is the only available water"*
- *"Whether safe or not, it is the only water we have so we just drink it a such"*

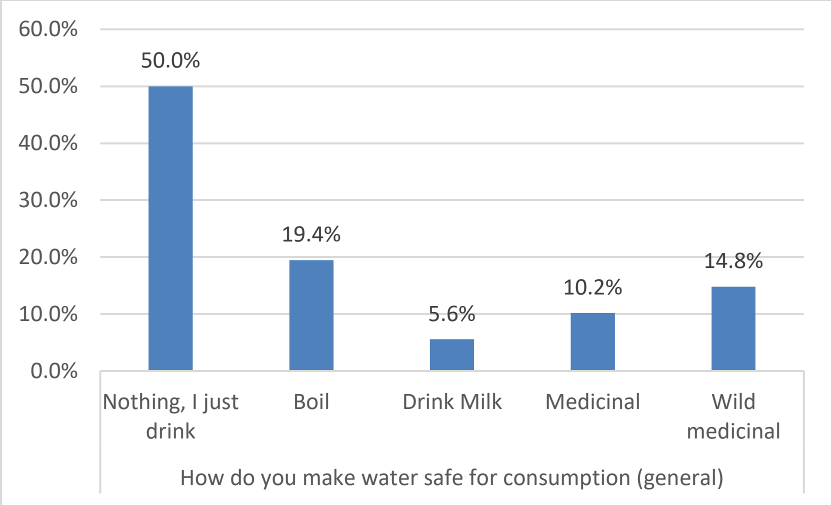


Fig.15. Making drinking water safe; Source: Field survey, September 2018

With respect to the type of action taken to improve the quality of water, respondents cited boiling water and using wild medicines. However, the majority who boiled water reiterated that boiling had no impact on Fluoride content and water taste. The challenges fronted were the lack of custom to boil water especially Nilotes, no impact after boiling water and noncustomary belief in boiling water leading to demoralization.

- *"The doctor's advice is to boil, but the Fluoride remains the same. It is impossible, I also got very sick after boiling and used the same water. The children get sick, I have no other option but give them Fluoride water".*
- *"There are times when we boil, and sometimes we don't boil. If I'm boiling it, I really see that it's like I am increasing the Fluoride".*
- *"Even if you boil the water, children cannot drink it. That custom of boiling water also does not exist here in our area (Nilote-Maasai). It is not easy to drink the water. They even people say that it doesn't gain any value after boiling the water."*

Respondents from Nilote (Maasai) groups came out as distinct group. The Nilotes reported milk as their main food. Maasai children drink exclusive milk until the age of five to six years where exclusive breast-feeding for the first 2-3 years, followed by animal milk for the subsequent 3 years. The Maasai groups believe that consumption of a lot of milk reduces the possibility of acquiring all form of Fluorosis. This was evident from their white teeth amidst colored teeth of the Bantu neighbors. The consumption of milk has also been mentioned by (Liu, 2015; Marian, 1997; Rango et al., 2012) as a key component in avoiding or reducing Fluorosis impacts on humans. Additionally, Maasais' (Nilote) drink little water e.g. one cup per week. Other foodstuff consumed included meat, blood and animal oil with herbs for adults. The respondents cited acquiring the knowledge from their ancestors. In comparison, among those Nilotes who adopted diversified lifestyle and those who lost their herd of cattle, were greatly affected. The affected Nilotes also cited lack of milk as the source of Fluorosis among them further confirming this theory. This theory would need further research as a potential remedy. Respondents cited that:

- *"We use exclusive milk on children until 5 to 6 years. We give children very little water."*
- *"For me I used milk until I started going to herd animals about 6-7 years old. Maasai we use milk and even when we are adults, we use a lot of milk to prepare porridge, cooking oil and other foods mostly meat"*
- *"I am now selling milk, I started the business so I can help my family, for instance where I sell milk, the people were affected but as they use the milk and good nutrition, they get to better shape"*
- *"When we use milk, it reduces the effect of Fluoride. One neighbor had milk cows, even though they use the Fluoride water, not even one child is affected because they have enough milk. We collect water from same source. Sometime their children show very mild Dental Fluorosis but nothing. Then we confirmed what our ancestors used to tell us"*

Other respondents, about the 10.2%, indicated to have tried to use or used different types of medicine to filter water. Some used 'filter buckets', others used 'special stones' believed to filter water. These respondents quoted that:

- *“Yes, we have them (medicines) but I have never come across effective medicine for dental decay”*

As further method to clean water, 14.8% of respondents reported boiling tree branches and herbs known as “Sogonoi, Sununi, OLeisuki, Orekreny, Oremitti and Endemelua” with meat soups and animal fats to prevent or respond to Dental Fluorosis. These wild medicines were mentioned to also treat cold, diarrhea and stomach pains. None of the groups interviewed confirmed impact of the wild medicines on Fluoride reduction as follows:

- “*We use medicine called Olesuki in water. This is traditional medicine. We also use this medicine for the children. This is because the contaminated water was never quenching our thirst. When we add Olesuki, the water manages to quench our thirst. So, we use it all the time in treating water. We still use the medicine even with this current water. These medicines are good for colds and other illnesses apart from reducing the salt in water”.*
- *“At the old water point we used local medicine to help people by reducing the salt and killing bacteria while for animals we didn't treat the water. Medicine such as Oleisuki, Orekreny, Oremitti, yes. When you use these medicines, you will not get diseases, not get thirsty and avoid Fluorosis”*

Respondents who answered to this question had several mixed actions to improve the quality of water by mentioning saving rain water, some cited mixing rain water with Fluoride water, others' only option to search for clean safe water in long distant regions:

- *“I try to save water to avoid that Fluoride water. Like me I have bought a 3,000-liter tank. I try to use it for drinking only”*
- “*Home-based care for drinking water is that, there are some people with filtration equipment. Mostly one can go to request a neighbor to filter for you your drinking water. Such filters are like the ones from the Gongali Company. Here are the filters, I've tried to filter and never really succeeded, because I don't have general training and knowledge”*

- *"The only time we are safe is when it rains because we use rainwater to mix with the borehole to dilute the Fluoride concentration"*

When the "making water safe" question was aggregated by ethnic groups, it was found out that 53.7% of Nilotes, 46.3 % of Bantus did nothing to improve the quality of water. It was found that 66.7% of Nilotes and 28.6% of Bantus boiled water as a method to making water safe for consumption. As concerns drinking milk all Nilotes respondents confirmed to drinking milk to acquire calcium to abet the Fluorosis. Other communities do not believe in milk as a method to slowdown the impact of Fluoride contaminated water. The Nilotes 72.7%, and 27.3% of Bantus mentioned to use some type of medicines. When probed further, these medicines mostly turned out to treat other water problems like bacteria. The use of wild medicine was more popular with the Nilotes mentioning traditional knowledge of bush medication towards water, 93.8% of them stated to use wild medicine to clean water while for Bantus the use wild medicine was minimum.

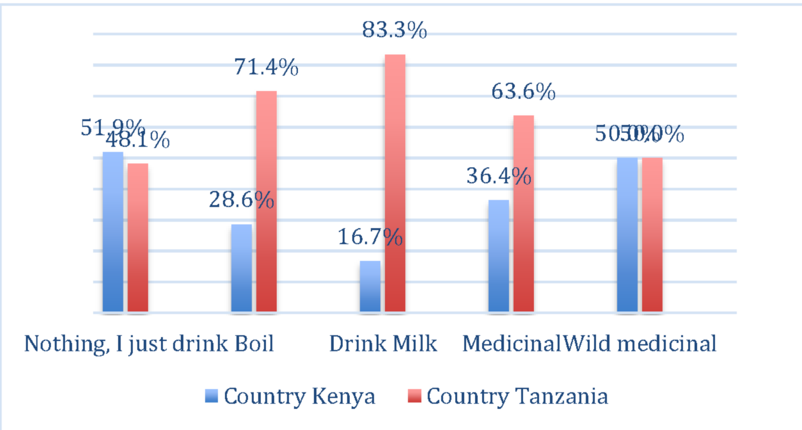


Fig.16. Making drinking water safe by Country
Source: Field survey, September 2018

We also compared making water safe by countries, see Fig.16. Those participants who replied to "doing nothing" in Kenya were 51.9% while Tanzania was 48.1% not a big difference but a considerable number in both countries. As for boiling water, those respondents who reacted to this question were communities from Tanzania seemed to boil at 71.4% which is a very high number compared to Kenyan communities at 28.6%. Concerning drinking milk, those who answered to this question were Nilotes only and 83.3% in Tanzania confirmed to drink milk while Kenya Nilotes has a paltry 16.5% of participants. Tanzania communities also seemed to use more medicinal in an attempt to make water safe at 63.6% compared to 36.4 in Kenya. The use of wild medicine was more pronounced in Nilotic communities and to those who replied to this question, it was 50% for both countries.

The research also investigated gender perception or approach to making water safe for drinking. For the group that answered to do nothing to water, males were leading with 53.7% and females were at 46.3%. Those who boiled water, females were leading at 61.9% with males trailing at 38.1%. Interestingly, for the participants who used milk, their answers were 50% each for males and females. The use of medicine reported men at 81.8% and women 18.2%, while use of wild medicine also recorded 68.8% men and female 31.3%. Medicine are bought in distant towns and markets mostly accessed by men. While wild medicine there were those that women would collect and those that men would collect. This also depended on the distance from villages and owner of the knowledge of the medicines e.g. old men or women, younger women or men but not children.

4.3.7. How to decide on safe water

Decision on water safety from Fluoride can be analyzed within the knowledge that individual possess, and self-awareness, social fabric structure as well as the role of the individual. In addition, affordability of a product such as water is having an influence on this decision-making process. Nevertheless, there are parameters that are employed depending on individuals knowledge and skills and awareness and the motivating attitudes, beliefs, values and social drivers or competing priorities. This section of behavior change process deviate from normal norm factors support prioritizing interventions and improving their effectiveness as postulated by (Curtis et al, 2009.; Smith et al., 2008; Mosler H.-J. , 2012.)

To understand respondents' knowledge of deciding on Fluoride safe and unsafe water, respondents were asked several questions where those who answered that "salty taste" was the main indication of Fluoride contamination were 40.4% (Fig.18). This point proved controversial since Fluoride is known to be colorless and tasteless. Other methods that were cited include crystal in water buckets and changed color of rocks in spring and stream. Some participants cited that water with "Magadi (Trona)" had a bad taste.

- *"Our village has rocks that are dissolving more salts into these waters making it salty as the water move down stream"*
- *"The water, apart from salt, it also has Magadi. We say ''Isokot" meaning water with bad taste. Water with magadi taste bad then we understand that water was not good and has Fluoride".*

A total of 22.9% of respondents believed "heaviness" of the water determined its unsafety. It was realised through difficulty to swallow the water, experiences of bloated stomach, tiredness, slow in waking up in the morning and general body pain. Here some of phrases they reported;

- *"You can never swallow the water; it is heavy cannot pass the throat and stomach is bloated"*
- "*Our water has clean look but very heavy to drink. Other waters are the best, light water. If you drink our water now you will have stomach problem"*

Only 17.3% of respondents cited sweetness of water as a method to detect Fluoride safe water. The respondents' agreed that rainwater, some rivers and bottled water were sweet, and cold and appealing to drink hence regarded as safe.

A share of participants, 29.4% that were labeled as "neutral" had mixed explanations as reliance on beliefs, experts, trust in bottled water, trust in rainwater, experience of improved body conditions such as reduced pain and fatigue to judge the safety of the water. Nevertheless, some people had no knowledge on the differences in the safety of waters they consumed:

- *"There were experts going around us and taking water to test, these were the people who told us that these waters is safe and that the other is not safe."*
- *"There's a difference because at the time when we did not have this bore hole, the body was everyday painful, but when we got this safe water there had been some bodily relief and difference"*

We also studied decision making on water safety by country. Fig. 17. indicated that approximately 60% of participants in Kenya and 40% Tanzania replied that when the water is not salty then it is safe for human consumption. At the same time, a large disparity was detected on water heaviness where 76% in Tanzania against 24% in Kenya believed that water heaviness is a major indicator of presence of Fluorides in water. Concerning those respondents who used water sweetness to gauge water safety, Kenyan communities largely agreed, 75%, that this was a very good measurement of safe water as compared to 25% from Tanzania.

The decision making on water safety was also analyzed by gender lenses. As Fig.19 indicates, 54.5% males and 45.5% females agreed that when not salty then it is safe. More men believe that saltiness determined water safety. Secondly, 52% of women against 48% men believed water heaviness determined its unsafety. More women agreed to this point. Thirdly, 62.5% of men compared to 37.5% women replied to the sweetness as a determinant. More men agreed that water sweetness had an impact on their decision as to water safety. In the fourth place, both men and women tied at 50% to being neutral on decision making in-terms of water safety.

The ethnicity of respondents was also used to analyze decision making on safe water, see Fig 19. We found that those who answered to water not being salty, 47.7% were Nilotes, 52.2% being Bantu community. In this case, it can be said that Nilotes were majority in using saltiness as a method to making decision on water safety. Secondly, respondents who answered to water heaviness, 44% were Nilotes, 16% and Bantu 40%. The Bantu as a single community seemed to have greatly used this approach towards decision making on water safety. Concerning water sweetness, the Nilotes were majority stating visiting far distant place during their migration. Other communities used the word light water. It is important to highlight that those who replied to neutral group the Nilotes were 71.9%, Bantus were 28.2% respectively. Even though Nilotes seem to have several decision-making mechanisms, many Nilotes were still unaware or neutral. This was partly attributed to Nilotes not drinking water often as other communities.

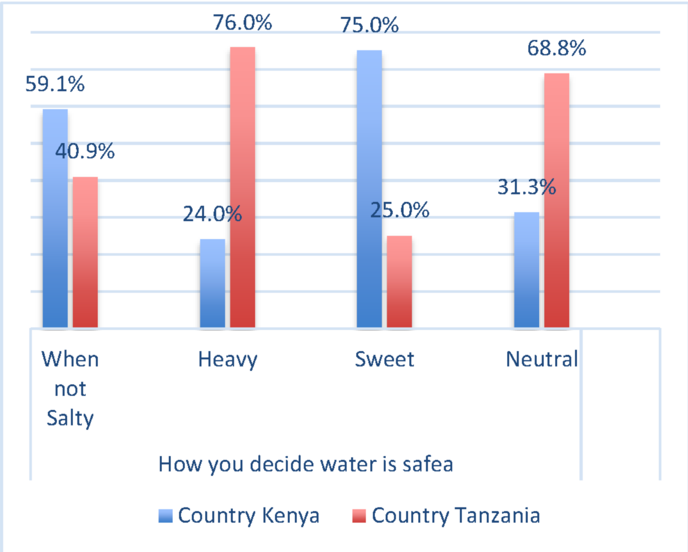


Fig.17. Decision on water safety by country

Source: Field survey September 2018

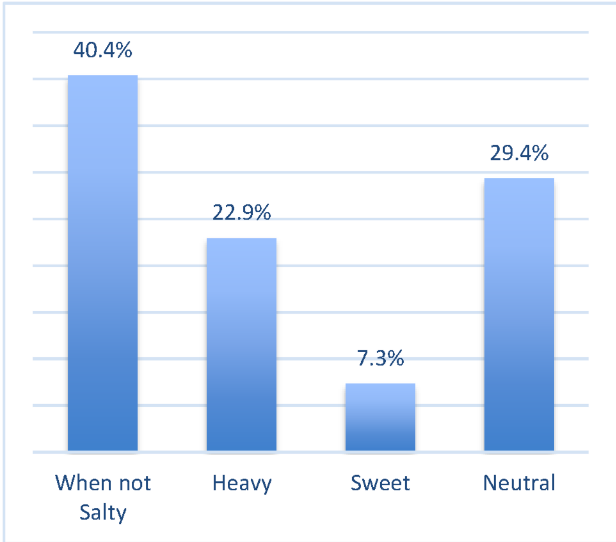


Fig.18. Decision on water safety.

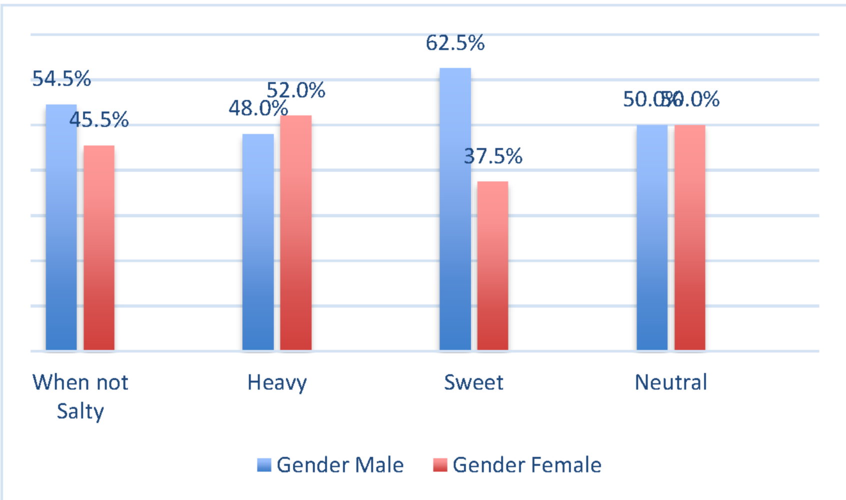


Fig.19. Decision on water safety by Gender; Source: Field survey September 2018

4.3.8. Dental Fluorosis awareness

In this section we present results where respondents were shown dental and skeletal Fluorosis images at different stages in order to investigate their degree of knowledge and awareness over the two conditions as well as instill a photo reminder in their minds on the effects of Fluorosis. Such use of photo reminder had been utilized in Ethiopia that evaluated the effectiveness of a personalized photo reminder on the collection of water at an in-village community filter (Huber., 2013). Respondents were shown first photos of Dental Fluorosis at different stages and the majority agreed that images of Dental Fluorosis were scary. Many participants confirmed that high prevalence of Dental Fluorosis in their areas with the exception of one Nilote group (Maasai area in Mukuru in Tanzania). Further, Dental Fluorosis stages were identified to exist within participant families represented by colored, mottling, splitting and falling of teeth, inability to chew food and removal of teeth. In fact, in one region (Kipkenyo in Kenya) children as young as 5 years old had their teeth removed. Majority feared for the future of their communities with the continuance usage of Fluoride-contaminated water. The migrants within groups compared their original homes of birth and reinforced that Dental Fluorosis was a silent condition not known to many outside the affected regions. Most migrants confirmed having never seen mottled teeth and other Fluorosis effects such as poor health, teeth and bones defects before migrating to Fluoride rich regions. Several respondents said that:

- *"Yes, children are at the initial stages of Fluorosis while adults have reached the advanced levels whereby some have already lost their teeth. My child who is five years is equally highly affected. Fluorosis started to affect him even before the milk teeth dropped".*

- *“They don't look good, I feel sad. Yes, my husband, our four-year-old child and I are all affected by tooth decay. Our child is expected to remove two of his teeth at that tender age. Besides all the teeth of our child is brown graduating to black. The rest of my children have brown teeth. He has 2 molar teeth that were removed. Some teeth have not grown but we already removed the two”*

The number of participants with minor knowledge of Dental Fluorosis were composed of a small minority, approximately 11% of the respondents. Usually the were represented by Nilotes who claimed to either had no idea or had mild knowledge of Dental Fluorosis. In this group of participants, a few relied on observing affected people, had no remorse, neither the willingness to avoid Dental Fluorosis, and demonstrated no plans to change their habits or seek health remedy:

- *“I don't know very well because in our village we have never seen such affected people except that in other places like Oldonyo Sambu and Olikeiti. I have seen such people especially in Oldonyo Sambu (Tanzania)”*
- *“I only hear people talk about it, now we are a lot of us in this area. Many of tribes the Nilotes and Bantus . I hear my Bantu neighbours saying that the water causes tooth decay. The children born in this area, I don’t know if it is the water or the food we eat. I know the chemicals could bring out the effects but eating food, hot potatoes or hot beans can cause tooth decay, you never know if it is the food or chemicals in the food or water”*

4.3.8.1. Participants awareness of Skeletal Fluorosis

In the case of skeletal Fluorosis questions, about 69% of participants described skeletal Fluorosis as creating difficulties in walking, standing, causing knee and back pains, heavy bones, body tiredness, morning problem in rising up from bed, crippled and bowed legged and big heads in children as well as dry joints. Even though the actual victims were fewer, the impact of skeletal Fluorosis seemed graver than Dental Fluorosis. Impacts such as inability to perform labour intensive jobs, inability to participate in sports (children) and athletics, children low IQ and general lazy attitude among the people greatly affected socio-economic dynamics of poor people. Among the interviewed, some had to say the following when asked about their experiences:

- *"You will find that one can bring up a baby so well and when they want to walk, that's the time you can realize that the legs are not good. They can try for weeks or months and you realize they cannot. And this is attributed to contaminated water in many villages".*
- *"Boys with bowlegs, when they kick a ball, the ball goes in another direction creating laughs among children. Other children are abusing them that "your head is big like cabbage". These bowlegs are due to Fluoride. If you see my mum, you can run away. Also, one cannot stand up"*
- *"Of course, yes. For us adults our bones are very affected and give us problems. My wife walks like a duck, their waist and joints are finished. For us men mostly we cannot walk or standing up is a problem because bones are destroyed".*

As for the Skeletal Fluorosis disease, a small number, 4% of respondents, replied to not knowing the cause of the skeletal Fluorosis and were not aware of this disease as an illness condition.

4.3.82. Do you think that Fluorosis is determined by drinking water?

To gain insight into why households can agree or not about water as a source of Fluorosis, it was imperative to assess the underlying socio-psychological factors of decision-making behaviour as provided in the various theories and models of health behavior change. In developing countries such as Kenya and Tanzania, the water safety knowledge and health behavior such as determining safe drinking water or uptake of filtration technology can be categorised under Mosler's systematic approach to behavior change in developing countries (Mosler, 2012). In addition to this, the RANAS Model (risk, attitudes, norms, abilities, and self-regulation) of Mosler (2012) model, psychological factors are ordered in five different blocks—risk factors, attitudinal factors, normative factors, ability factors, and sel-fregulation factors as indicated in (Albarracı´n et. al., 2005) give us insights on issues to determine safe water by either use of perceived vulnerability and perceived severity. Looking at the interpretations of respondents' knowledge on determinants of Fluorosis, it was noticed that majority 76.5% held the view that drinking water was the main source, see Fig. 20. Respondents gained information from dentist, other villagers, ancestors, experts and through observation of health changes in humans consuming Fluoride contaminated water. The respondents further cited high prices and lack of access to safe water as the major bottlenecks hindering consumption of Fluoride safe water. For example, the respondents stated:

- *"It's purely water contamination within our village. For instance, the upper parts of the spring have fewer salts as compared to where we fetch our water down here. I think our village has rocks that are dissolving more salts into these waters. Our children are the ones at the highest risk of Fluorosis because of the borehole water"*
- *"When I started using the water here, I heard people say it causes tooth decay. And now I believe too, my teeth are badly decayed and now I believe what they said about the water".*

There were approximately 12.9% of respondents who highlighted that crops such as vegetable, cereals and potatoes could possess some diverse levels of Fluoride especially when irrigated with Fluoride water. Several participants complained of lack of remedy towards Fluoride in food and its impacts. Some respondents reported that:

- *"We normally understand that it is caused by the food we eat. It is not taken, as a disease; it's taken as the impact of food we eat because it's just how people believe. There is no research that has discovered what kind of food causes the teeth to decay here. So, there is no way people can do to prevent"*
- *"The Bantu community use banana, which if they mix with that Fluoride water their teeth turn red. We Nilotes, (Maasai) don't use bananas, maybe once in a month, as Maasai we haven't adopted other food for a long time like the other tribe"*
- *"It is also in the foods we eat, in vegetables because the Fluoride water is also used to irrigate vegetables, so, even in foods also Fluoride is located. That is extremely correct, maize uses rainwater, but the vegetables that we plant very much are irrigated by this Fluoride water".*

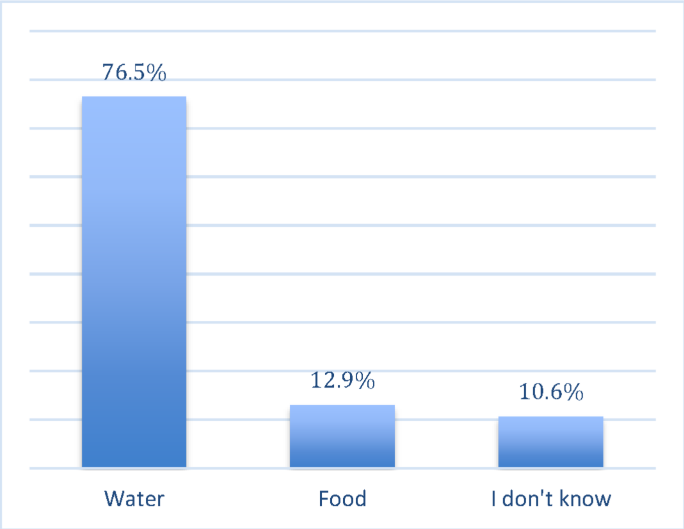
A small number of respondents, 10.6%, admitted to being unaware of the source of Fluorosis and rely on speculations on possible sources of Fluorosis. These respondents cited eating sweets, biscuits and sugary foodstuff. A few of the respondents here agreed to being unfamiliar and never enquired about dental conditions. Further, a 5% neither mentioned water or food but mentioned germs and bacteria as sources of Fluorosis in their villages. Nevertheless, respondents experienced the same dental problems like other groups including teeth removal.

- *"I don't know, I am not sure if it's the water we consume or other dental disease. Initially we thought the problem in children was as a result of consuming sweets and sugary foodstuffs, but later we realized it wasn't the cause. Our children don't eat sweets and yet they are affected".*

In Fig.20. we find that participants knowledge on Fluorosis sources is varied by country. More Tanzanians 58.5% compared to Kenyans 41.5% confirmed water as the mains source of Fluorosis. Those who believed Fluorosis emanate from food, again 54.5%

Tanzanians compared to 45.5% in Kenya. It is also interesting that in the group of those who did not know the source of Fluorosis, it was only 22.2% of Tanzanians when compared to 77.8% Kenyans. This could point to more awareness of Fluorosis in studied Tanzania regions, whereas, Kenyan regions had little awareness of the condition. The analysis also compared knowledge of the Fluorosis sources by gender groups (Fig.21). In this scenario, more males 56.9% believe that water is the mains sources of Fluorosis compared to 43.1% females. As for those who believe Fluorosis to emanate from water, again, males were 72.7% versus 27.3% female counterparts. In the category of those who didn't know, it was evident that more females to 77.8% when compared to 22.2% males who did not know the sources of Fluorosis. This is a pointer that more males are educated that women and capacity building should strategize on how to reach women.

On testing the participants by dividing them into ethnic responses towards knowledge on the sources of Fluorosis (Fig.22.), the Nilotes believed in both water and food as source of Fluorosis. In water as the Fluorosis source, 53.8% Nilotes replied in the affirmative with Bantu participants responding to 46.2%. Participants who replied to food as the source of Fluorosis, it was interesting that only Nilotes believed so. This is attributed to Nilotes population believing that Bantus are affected by Fluorosis because of Bantus' diversified foods and lifestyle when compared to Nilotes believing in Milk and meat as the only food until age 6 years old. The Nilotes also consume very limited water when compared to other communities around them.



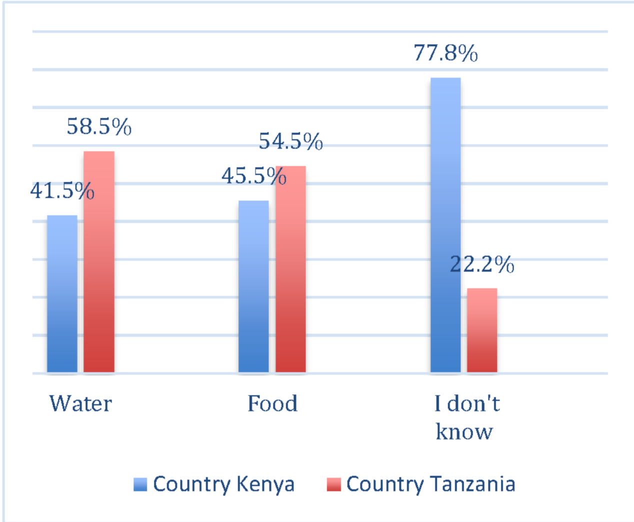


Fig.20. Knowledge on source of Fluorosis
Source: Field survey September 2018

Fig.21. Knowledge on source of Fluorosis by Country

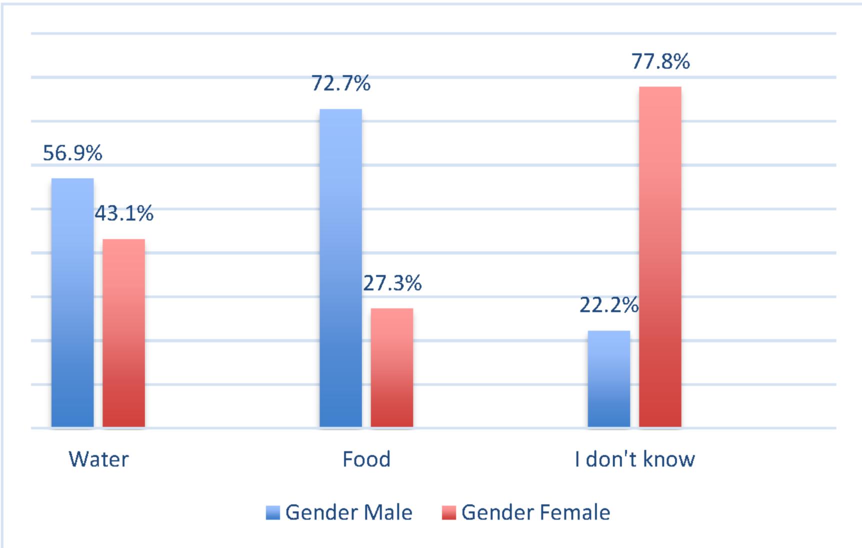


Fig.22. Participants Knowledge on source of Fluorosis by gender
Source: Field survey, September 2018

At the same time, for the group that responded to not knowing source of Fluorosis, the Nilotes again was leading by 77.8% when compared to Bantu who registered 22.2%. It can be informed from the study that the Nilotes possessed a very varied knowledge from traditional ancestor and beliefs and even remedies (many types of wild medicinal treatment as well as utilizing excess milk) to avoiding Fluorosis while the Bantu groups on the other hand seemed to not possess such knowledge and would therefore just continue with life as usual.

4.3.9. Sharing the Risk with others

4.3.9.1. When you have guests, do you offer always-safe water?

This section opined to determine whether participants were willing to either protect or share the risk of contracting Fluorosis with guests and children. This is in line with "The risk factors block" that indicate the factors referring to an individual's understanding and awareness of the health risk as postulated by risk perceptions in (Rosenstock, 1974; Floyd et. al., 2000; Schwarzer., 2008; Mosler, 2012). This vulnerability must be weighed with the severity of the action taken by an individual towards contracting or sharing the opportunity to contract a disease with another person (Floyd et. al., 2000). Approximately 83% confirmed to offering Fluoride contaminated water to both visitors and children. Participants explained to have no alternatives and lack of safe water, lack of capacity to collect and store rainwater and general lack of financial capacity to buy a filter or bottled water as the greatest challenge. However, a few participants reported to inform the visitors about the contamination of the water so to choose to drink or not. Part of the respondents highlighted challenge on Fluoride contaminated cooking water. This could point to some level of awareness of Fluoride spread through cooking water.

- *"When we have visitors, we just use the same water, because that is the water used by the household"*

Nevertheless, the 12% who responded to not sharing the risk of contracting Fluorosis with visitors, mentioned making efforts to find Fluoride safe water for children and or visitors. However, some interviewees agreed that children were offered Fluoride safe water during infancy stage then introduced to Fluoride unsafe water during growth. Respondents were categorical that children would still consume Fluoride-contaminated water at school negating the safe water efforts at home. Finally, very few respondents purchased bottled water for visitors. Respondents mentioned that:

- *"For my children I changed and now they drink the safe water. But in school they take Fluoride contaminated water. So even if I try to help my children, the other children still have the problem and risk".*
- *"If I receive unexpected guests, I offer them local Fluoride contaminated water, but if I know guests will be coming in advance I'll buy from the shop".*
- *"It depends on where visitors come from. If the visitors come from this village or region, they will drink Fluoride contaminated water. If you're coming from a distant place, I'll buy for you some water from shop"*

4.3.9.2. How do you feel about chances to acquire Fluorosis from drinking water?

Factors that investigate an individual's understanding and awareness of the health risk could be grouped as risk perception, attitudinal factors, and some ability factors that can contribute to intention of building self-regulation factors (Mosler, 2012), This question planned to investigate the feelings or individuals fears or habits to explore the opinion and knowledge of contracting or not Fluorosis and 68% feared onset of skeletal Fluorosis more than Dental Fluorosis since most were already at different stages of Dental Fluorosis. The majority respondents were concerned about the future of their children to be prioritized when a treatment or remedy for reducing Fluoride in water is available. The participants confided that with Fluorosis, life becomes shorter, painful, and when coupled with poverty, Fluoride posed the biggest threat to the population under observation. A few of the participants in this section opined that;

- *"I am still giving birth to young children and I am scared for their future if this water continues to be our only source"*
- *"I fear a lot. This is disability brought by water. When we reach 40 years old, we cannot walk completely. You can see a woman today and tomorrow she is old, their lifespan becomes shorter with Fluoride"*
- *"We are already affected and when it comes to standing up you will laugh because I will start walking like a duck due to legs and bones not working properly. When I stand, I feel a lot of pain down in my waist and legs. I can only walk slowly. Because of Fluorosis, now if anybody ask me to run even short race, I better let that job (police and military recruitment exercise) pass me. I can't. Running is out of question here because you are in pain and slow. Only God can help us".*

It was also very important that 13% of the interviewees responded to not believing to be at risk of acquiring Fluorosis. These respondents demonstrated the lack of knowledge coupled with ingrained habits on their beliefs that have also been referred to by (Huber et. al., 2012). These respondents were not aware, not worried, not afraid, or interestingly, considered it all "God's" work". This reinforced the theory of a clear lack of understanding and awareness of the severity of Fluorosis among the poor people in developing countries (Huber et. al., 2012). Some participant ha d to mention that;

- "*I don't know, I am not afraid and not aware if I will get affected but if you experts tell us like today then we will know and then take care"*
- *"I am not sure if my children and I can be affected by the Dental Fluorosis now. This is because if it is only from water we have not been affected so far"*

4.3.10. Consumption of Fluoride safe water

4.3.10.1. Have you ever consumed filtered Fluoride safe water? And if yes, how much did you like it?

This question had two factors to detect such as consumption of filtered water as postulated in the several behaviors change theories and the self-regulation and maintainace of such new possible behavior. The outcomes of the behavioral factors determine the participants approach to other competing behaviors such as going back to drink unsafe water. Considering filtration, the availability and knowledge to utilize filtering technology becomes part of this decision making to maintain the drinking of filtered water of not (Huber et. al., 2012; Mosler, 2012; Mosler et al. B. O., 2010). In this section, a total of 60% of the respondents agreed to have consumed filtered water at one point in their lives. Respondents were of the opinion that filtered water is better describing that it had good flavor, it is light, sweet, cool, soft, quench thirst, appealing, cold, easy to swallow, creates good feeling of health and creates a desire to drink more. In fact, the respondents reported that filtered water quality and flavor seemed particularly relevant in their decisions making process. Nevertheless, a small number that had the experience to filter their own water mentioned the continued challenge of reagents cost (bones and chemical) for filtering water, cost of acquiring filters as well as knowledge to utilize properly the filter. This can point to a direction where not only capacity building is needed but also the availability of low-cost technology. Some of the participants mentioned that;

- *"The biggest difference is the taste that is characterized by lesser salts. It had no taste at all, it was cool. It was clean and cool and had no taste and I could take more to quench thirst".*

- *"I drank filtered water one day from a neighbor. The water was light and really good. When you drink it, the body will be active. When you drink safe water then fall a sleep, you get up in the morning and the body is very light, unlike when you use Fluoride water the body is too heavy".*

However, there were respondents, approximately 19%, who never tasted filtered water. This group mentioned to have had no idea of the differences in water quality.

4.3.11. Do you think that filtering drinking water is time consuming?

When respondents were asked about challenges leading to non-filtering water, 16% cited the cost as a major obstacle. In this category, part of the respondents who had in past filtering devices confirmed that lack of finance and access to reagent led to abandonment. The respondents requested for a possible subsidizing of filters and accessibility to reagents at affordable rates. Some of the respondents said that:

- *"Using the filter won't be a burden, maybe the cost of acquiring and maintaining it. Water is life, and we can also sacrifice to ensure that we have it clean and safe".*
- *"Many individuals will not be able to afford it. Now that's the problem coming up because you do not have the money to change the chemical, then you go on using the filter until you get the money"*

Interestingly, 37% of respondents underlined that one of the main constraints to the use of filtering devices related to the lack of education, awareness and knowledge as a hindrance to filtering water. Participants stressed the need for education on Fluorides, Fluorosis and on handling filters. Most respondents also believed that education had the potential to changing their traditional and cultural myths about water filtering habits and Fluoride contamination. Finally, interviewees stressed the importance to have local manufactures and distributors of reagents to enhance the continuous utilization of the filtering devices.

- *"In my opinion, you experts should give us education on how to use the filters in a safe way. This will allow us to use the filter and the chemicals in a safer manner"*
- *"I can say that we need education before these filters arrive. We receive many equipment, but with no education they always fail after a short time. I am requesting for sustainable education that can last so that we can have long term help. It would be bad if we receive the filters and we end up not achieving anything"*
- *"The first part is the education for users so they can know what's going on and have the knowledge. If they know how to handle the instruments and they see that it is working, then I know that they will see it as something that helps them and will not have any opposition. But first it is the education"*
- *"What you can do for the filters to be sustainable is to train a few people in the villages who can oversee the filtering processes. With that, all the people can get water while a few will be trained for its sustainability"*
- *"Filtering water especially for Fluoride is a very good thing. I think that we need education for everyone on filtering methods. Also, during public meetings like this can be used to disseminate information even to our leaders. At least lets us have 20% of population educated on Fluoride issues. Our children can also teach us at home if they get this education in their schools. 100%"*

It was also investigated the willingness and readiness to filter water using the proposed device and 84% of the participants responded to having no restrictions at all toward filtering drinking water. The main motivation for interviewees were to save family health, avoid diseases, save time on the long distance search of safe water, save lives of children, wish for better health, eagerness to trust the difference between unfiltered and filtered water and the general feeling responsible for the next generation's health. Respondents had to say the following;

- *"If we can walk from here to Lake Naivasha 10 kilometers for water every day, why should it be a waste of time to filter water at home?"*
- *"The desire to have clean water that is free from excess salts will make me use filters very wisely. I desire to have clean safe water free from excess salts."*
- *"I do not see filtering water as hard work, according to me; my health will be safer and that of my children. I will not see it hard work"*

4.3.12. Preferences for specific filters and the reason why?

In terms of filter capacity, a question was presented related to the choice between a family filter with capacity of filtering up-to 50 liters in two hours and a village level filter that had the capacity to filter up-to 1000 liters in 10 hours. The majority 53% of the respondents were categorical that village level filter was more preferred due to the high demand for clean safe filtered water, it's potential to allow people do other errands and collect filtered water after work, potential to serve many people promoting communal lifestyle of sharing, it's opportunity to be centrally managed and the chance to afford due to contribution by community members towards its acquisition, maintenance, repair and replenishing of reagents.

- *"I prefer filter for the whole village as opposed to individual one. Everyone will benefit from clean water. Some people cannot afford and to manage at home maybe difficult due to lack of education to operate the filter"*
- *"I prefer the village filter because we will benefit together. I will prefer the village level filter because if we have individual filters some people will not use and or they will destroy after a short time. But village level will be managed by a central committee and we get safe water for all of us."*
- *"I would like the village filter because the people are not the equal financially, but many people survive through other people, because when it comes to payment, it can be difficult. But if it is in the village, it will help more people. So being established at the source of water will save many people"*
- *"I myself, I prefer this village one, because if I bring household filter home, I might not have the time to filter water due to my woman/wife chores at home. I might ignore it at times."*

However, according to 46% of the respondents, the household filter (30-50 liters in 2 hours) was preferred to village filter. Respondents believed that household filters were better due to easy management, cheaper than village filter, household could decide amount of water to filter and to avoid communal disputes. Nevertheless, a few respondents feared that household filter could be not afforded by a number of the community members and that household filter would only be successful if everyone acquired it. However, some respondents were undecided and vouched for both filters. Some quoted as:

- *"I would prefer the small filter for my household because I will easily manage it. I am afraid of the communal one because we can fail to use it just like what happened to the previous one. Moreover, each person takes personal responsibility to take care of his/her own filter"*
- *"I like both but prefer the household level filter for my family use. I would like to see the filter and know how big it is compared to the space in my house"*

4.3.13. Willingness to purchase filters

To analyze the willingness to purchase filters, 12 several payment cards were prepared indicating different modalities respondents chose to acquire the filters when available. Respondents' chose a card each and read out loud or was supported by other literate respondents presenting diverse reasons for their choices. The two most chosen modalities were paying in cash or pay by installments either individually or as a community group.

There were 27% of respondents willing to pay in cash. These respondents cited as possible in making filter prices cheaper by group contribution. On individuals, only a few respondents deemed household filter to be cheaper compared to community filter. The remaining responded focused on the Fluorosis menace as a motivation to pay cash and immediately acquire the filters:

- *"I would love to pay for my own in cash because communal water source has queue and a lot of disagreements, discussions and conflict"*

- *"The price won't be a problem because if we could have had the filters earlier, we would be safe now, happy and willing to pay cash"*

The Nilote community came out as a group that do not pay for water, water point construction or filter equipment. This group informed that instead, they were willing to pay for water station and filtration equipment maintenance and security. Motivation mentioned towards this were that Nilotes migrate to distant land e.g. from Kenya to Tanzania during droughts or animal diseases outbreak hence abandon the water points.

Approximately 80% of respondents who answered to this question preferred installment payment and were divided in two groups. For the first group, majority cited possible higher cost for purchasing and installing filters. This group cited poverty, inability to afford cash, unsure of the cost of maintenance as motivation to purchase in installments. The second group, who were minority, were confident to acquire as individuals due to their better placed financial position as well as large families and livestock water demands not be satisfiable by communal sharing. Some participants cited that:

- *"This village filter will involve two payments, one in installments because we are not the same in-terms of earning, the contribution as a community"*
- *"I think if we know how much filter can cost then we decide whether we should take a bigger filter as a village and to make our contribution to buy it, if the cost will be lower, we can combine ourselves as neighbors, or buy ourselves as individuals according to the cost"*
- *"Because we live in Bomas (homestead), if we buy a community filter it will be enough for the whole extended family. We could buy it as a Boma and put it somewhere we can all share to filter water. We can contribute towards it and then fill the filter in turns until the whole family has done their duty and the cycle begins again"*

4.4. Discussion

The objective of this study was to explore the Fluoride safe drinking water habits in the African Rift Valley in Kenya and Tanzania. It focused to understand the behavioral issues surrounding low or none uptake and usage of Fluoride water filtration equipment's and the wider socio-economic and psycho-social issues, habits, technology and knowledge on Fluoride and Fluorosis. We were interested in psychological factors that were affecting people behaviors towards Fluoride safe water interventions and to what extent to which these contributed to the possibility for developing a behavior change model for the regions studied before introduction of filtration equipment.

4.4.1. On the efforts to have Fluoride safe water

This question was postulated, it can be argued that the majority of the respondents did not make efforts for reasons such as lack of safe-water options, lack of filtration knowledge, lack of filters and high price of filters and reagents. In this case, two of the five factors blocks can be detected such as the attitudinal factors where interviewees presenting a negative attitude to seek remedy and solutions but instead opt to utilize Fluoride unsafe water (Fishbein and Ajzen., 2010), and the normative factors highlighting the population under observation behavior and social thinking in not making attempts for solutions for either one of the challenges faced favoring their current establishment also referred to as a normative attitude. To this extent, this situation can be related to increasing the exposure to Fluorosis in the villages, however, apart from beliefs, not so much behavioral response or efforts were observed among the interviewees representing both attitudinal and normative factors blocks). The behavior also fall in the second level of (Mosler, 2012), of doer and non-doer situation that needs measurement to determine the correct behavior change communication programme. Higher rates of Fluoride contaminated water consumption were also found in respondents who had received filtration equipment from other intervention activities citing the above-mentioned issues and challenges. In this case since some respondents had been offered filtration equipment's, and their subsequent failure to utilize them opens the doors for analysis within the ability factors. The respondents incapacity to believe in their ability to own and possess and acquire the new behavior of water filtration often lead to sliding back to the old habits of non-filtration regardless of other impediments such as prices and lack of education. Respondents who believed in their ability would seek such education in-order to maintain the habit of drinking clean Fluoride safe water. Further, the respondents also failed the self-regulation factor by not maintaining and preserving the new behavior of water filtration that they had been exposed to, albeit for a short period of filtering water. These have also been studied and postulated by scholars such as (Albarracı´n et. al., 2005; Prochaska and DiClemente, 1983) to be of very essence to be monitored in any attempt at an intervention in behavior change towards water and sanitation.

Another issue noted was that previous interventions were not accompanied by public awareness and information (software) on handling, importance and why and how the filtration equipment's were distributed. Researchers in the previous filtration interventions seem to have not targeted social norms and the perceptions as recommended (Mosler., 2016). During the interviews, interviewees informed about negative health issues faced from Fluoride contaminated water and the hope for remedy on the same which directly refer to the risk factor block describing individual's understanding and awareness of the health risk (Rosenstock, 1974).

4.4.2. On decision making on Fluoride safe water

Individual or family knowledge was key in deciding on the safe/unsafe water. The injunctive norm that refers to seeking approval or disapproval from relatives, friends, or neighbors to some extent arose in this section whereby mostly women would seek approval during the meeting to consult their husband to accept a water filter for Fluoride. This could be seen among Nilotic group's decision on water being guided by traditional ancestral knowledge and attitude towards specific water to utilize. In addition, and self-awareness, attitudinal and normative factors played a key role. This has been described by (Mosler H.-J., 2016) on the roles of the individual or family members influence to others in decision making. The risk factor block did not seem to hold water in this section. Risk factor was overtaken by attitudinal factor whereby respondents believed that even though there is a risk, their attitude towards the consumption of Fluoride contaminated water and adopting water filter were answered by that they have been using the water as it was and will continue. If there was to be a change, the population under observation noted that outsiders e.g. Government or researchers or NGOs should move to develop a remedy for the situation in the villages. In addition, affordability of clean safe water, water filtration equipment and related costs seemed to be have an influence on this decision-making process. Nevertheless, there are parameters that can be employed depending on individuals knowledge and skills and awareness and the motivating attitudes, beliefs, values and social drivers or competing priorities representing normal norm factors to support prioritizing interventions and improving their effectiveness as postulated by (Curtis et al, 2009.; Smith et al., 2008; Mosler H.-J. , 2012.).

4.4.3. On the level of dental and skeletal awareness

The results showed that respondents were relating to the dental and skeletal Fluorosis especially when shown the photos of different types and stages of Fluorosis. This process can be discussed both as passive and active awareness. As discussed by (Huber et al., 2014), awareness creation by the use of photos invoked memory and personal feeling of the magnitude of a condition that otherwise would not be taken seriously in villages where everyone is affected hence taken as normal. With majority confirming high prevalence of Fluorosis in studied villages, the participants agreed that Fluorosis was a silent condition not known to many outside the affected regions. This impact of photo usage can imply that the respondents perhaps understood Fluorosis but not the health risk and severity at the same time. Such situation brings to fore the attitudinal factors such as beliefs in the benefits of filtering water vis a vi health and feelings gained when drinking contaminated water (Mosler, 2012). Further, it also highlighted theories of normative factors specifically the perceptions when consuming contaminated water simply because of failure to relate it to negative socio-economic impacts among community apart from health. Other impacts of Fluorosis such as failure to hard labour in the farms, slow in education, calcification of joints impeding sports activities among children, dental and skeletal fluorosis and stagnant growth among children were mentioned as present among the population. However, the jury remained whether it was from the water or from a curse or simply a normal phenomenon in many villages (Cialdini et al., 2006; Schultz et al., 2007).

The interviewee here reported that;

- *"When I walk, I feel pain and difficulty. Most women are affected here. They complain of bone ache and standing up is a problem every day. If we are invited to a meeting like now and asked to sit down, that's the day you will laugh* *when a woman wants to stand up, she will kneel and start to stand up like an airplane taking off in the runway. She will stand straight 50 meters from here. The men walk with one and same style they limp from one hipbone".*

- *"We have so many of them (Dental Fluorosis victims) here, very many people like those stages in the photos. My whole family has colored teeth at different stages. Look! Mine are mottled and falling out already"*
- *"Yes, and we have tried to make ourselves smile by using soil to clean our teeth, but it is not working. When we went to town and smile people run away from us. I am in the middle of Dental Fluorosis while my wife is in the third stage of mottling now. We shall remove them soon. My cousin already the teeth are breaking and being removed. Some of their teeth are breaking, splitting and they cannot chew or take hot or cold food".*

4.4.4. On drinking water as a source of Fluorosis

Respondents in this section highlighted several factors blocks when discussing water as a source of Fluorosis. While majority agreeing to water as the main source, the underlying socio-psychological factors of decision-making behaviour that are postulated in various theories and models of health behavior change came to the forefront. Determining safe drinking water or uptake of filtration technology can be categorised under Mosler's systematic approach to behavior change in developing countries (Mosler, 2012) as well as the RANAS Model of Mosler (2012). In this study, psychological factors in the five different blocks, we detect the risk factors and attitudinal factors as played out and in accordance to theory of (Albarracı´n et. al., 2005). We find insights on determining water as source of Fluorosis to fall under perceived vulnerability and perceived severity when consuming Fluoride contaminated water according to the respondents. Looking at the interpretations of respondents' knowledge of water as source of Fluorosis, it was noticed that majority perceived specific sources of water as creating their vulnerability while others perceived to potentially increase the severity of the Fluorosis condition existing among them. In such a finding, health behavior changes as postulated in RANAS Model proves to be important in influencing potential behavior change in contaminated water use. If RANAs model is combined with other theories e.g. "Theory of Planned Behavior by (Ajzen et al., 2007) and theory of Health Action Process Approach by (Schwarzer., 2008) a successful behavior change model including hygiene could be achieved as has been demonstrated by scholars (Heri and Mosler, 2008; Kraemer and Mosler, 2010; Graf et al., 2008; Mosler et al. B. O., 2010). Further under these perceptions in the risk factor block, majority of the participants believed drinking water was the main source of Fluorosis in the studied regions. A few of the interviewees reported that;

- *"Because when we keep on using the water it turns the teeth red. Even me, we call it "Magadi". We believe that if a pregnant woman uses the water a lot during pregnancy the baby can be born and have red first teeth. We just believed that the water has Magadi. We did not know it is called Fluoride. When we use the water, we believe that it can change our teeth red. We think there is Magadi in the water"*
- *"The problem of teeth comes from water and our ancestors told us that the water has a problem making the teeth to look like this (showing his teeth)"*

4.4.5. On sharing the risk of contracting Fluorosis with others

This question's key agenda was to detect the participants attitude towards sharing risk with others including children by offering them Fluoride contaminated water. It can be discussed under the sharing risk/vulnerability due to actions taken by an individual towards contracting or sharing the opportunity to contract a disease with another person knowingly (Floyd et. al., 2000). In Floyd et al. (2000) arguments, individuals knowingly could be able to offer others Fluoride contaminated water or products. This increases the exposure and vulnerability of people who might be or not aware of the content of the water consumed. Participants willing to either protect or share the risk of contracting Fluorosis with guests and children can also be found in the risk factors block referring to an individual's understanding and awareness of the health risk as has been studied by risk perceptions theorists (Rosenstock, 1974; Mosler, 2012; Schwarzer., 2008). Most of the participants by agreeing to offering Fluoride contaminated water to both visitors and children confirmed these theories. Even though several issues were highlighted as drivers for such risk sharing, the fact that participants have knowledge and still offer Fluoride contaminated water indicated the affirmative that sharing of the risk is not an important perception in the studied communities. However, a few participants reported to inform the visitors about the contamination of the water so to choose to drink or not and this could point to some level of awareness of risk of contracting of Fluorosis. Part of the respondents informed that;

- *"If you visit me today (the researcher), I will give you the same water that I use. My kids by big percentage only use Fluoride water because even for cooking we use Fluoride water in the village as a result of lack of safe water"*
- *"When I get visitors, I just inform them that the water is containing Fluoride. If they don't want the water, then I don't offer. The children use the same water"*

4.4.6. On the feeling on the chances of contracting Fluorosis when drinking water

This question strategic to investigate the feelings or individuals fears or habits to explore the opinion and knowledge of contracting or not Fluorosis. The majority respondents were concerned about contracting skeletal Fluorosis since majority had already contracted Dental Fluorosis. The participants confided that with Fluorosis, life becomes shorter, painful, and when coupled with poverty, Fluoride posed the biggest threat to the population under observation. This can be categorized in the factors that investigate an individual's understanding and awareness of the health risk as risk perception, attitudinal factors, and some ability factors that if well managed can contribute to intention of building self-regulation factors so that members of the communities can adopt self-regulation toward Fluoride water consumption (Mosler, 2012). It is important to highlight that action from knowledge, self-efficacy, instrumental and affective beliefs as referred to by (Mosler, 2012) forms a key components when designing behavior change related to fear or non-fear towards chances of contracting Fluorosis such as in this study. Some of the individual interviewed has this to say;

- *"First, non-Fluoride water is soft and, for example, I'm talking about myself having a filter but now we are unable to maintain it. When I got the money to maintain it and use the water, even to rising-up in the morning I feel the body is faster, lighter than when I use Fluoride water. So, it's very different.*
- *At home I use this filter from Ngurudoto -bone char- (Tanzania). At the beginning, it was ok, but Fluoride increased over the months. In the first month Fluoride was at 0.8mg/L but 40 days later, it began to rise again, so they advise that for about three months, 90 to 120 days, I should change the filter. Now that's the problem coming up because I do not have the money to change the bones and to travel to find the bones, then I go on using it until I get the money"*

4.4.7. On the individual's feelings when consuming filtered Fluoride safe water

This question had two factors to detect such as feeling the difference in consumption of filtered water as postulated in the several behaviors change theories and the self-regulation and maintainace of such new possible behavior. The outcomes of the behavioral factors are known to be able to determine the participants approach to other competing behaviors such as going back to drink unsafe water. Considering filtration, it could be detected that availability and knowledge to utilize filtering technology can be a key element in determining whether an individual will maintain the drinking of filtered water of not as studied by (Huber et. al., 2012; Mosler, 2012; Mosler et al. B. O., 2010). The sweet and cool nature of filtered water seemed to be the catalyst for a possible maintainace and consistency in use of filtering equipment among most of the participants. In fact, the respondents agreed that filtered water quality and flavor seemed particularly relevant in their decisions making and a possible maintainace of the new positive behavior when combined with education process. Nevertheless, issues of price and availability of reagents seemed to be an impediment and pointed to a direction where not only capacity building (software) is needed but also the availability of low-cost technology (hardware). Some of the respondents quoted that;

- *"The only hindrance might be the cost of buying these filters. It's my wish that you find a means of subsidizing it either through donor support so that it is affordable, this is due to the high poverty levels of most of the residents of this area"*

4.5. Conclusions and recommendations

This study covered the four phases of RANAS approach by mentioning the targeted psycho-social and behaviors to be targeted for change as well as the specific population groups that was targeted. This supported the data collection on the behavioral factors using qualitative questionnaire earlier designed for the purpose. This information collected encompassed the RANAS psychosocial and contextual factors that were identified to have influence or should be employed in the next phase on the introduction of filtration technology on the target behavior of Fluoride free water consumption and technology uptake. While the psychosocial factors refer to the elements in the mindset of people (such as knowledge, beliefs, and emotions), the context factors are elements outside of a person (e.g. distance to a safe water point or filtration center) as mentioned in (Mosler H.-J., 2016). This case study has markedly explored these perceptions and attitudes on drinking Fluoride water habits in the African Rift Valley(Kenya and Tanzania) and severity of Dental Fluorosis, socio-cultural and economic issues and well as the willingness to adopt the filtration technology when available reflecting on the decision on the type of water consumed. From the analysis it emerged that Fluoride water contamination was widely but loosely recognized among the two ethnic groups in terms of its impacts on dental and skeletal Fluorosis. However, Fluoride word was scarcely known. Rather communities refer to Fluoride by several names including 'Magadi" which is Trona, 'Chumvi" which is Salt, 'Maji-moto' which refers to "hot spring" among other names in both countries. Most of the population studied understand Fluorosis through its impacts on health and economics spheres. Impacts of Dental Fluorosis on the social and economic lives of the residents in most of the villages were evident and quite considerable. In their explanation, failure to smile and inability to participate in sports due Fluorosis leads to the failure for young people to be recruited into Police and Armed Forces, Hotel receptions and even media houses due to mottled teeth, inability to do hard labour jobs, sports and other economic activities points to communities experiencing nosedive if not stagnant economic advancement. In addition, children develop fear to interact leads to their low esteem in educational participation impacting on their development as examples. Socially, the communities agreed that it inhibits the development of children whereby those that present symptoms such as big heads and bowlegs face public ridicule and humiliation. Reports of abuse of children to have big head like "cabbage", some with bow legs kicking a ball and the ball goes in a different direction, considered ugly and not intelligent demoralizes children and hamper their participation in socio-cultural and educational affairs that are key to their development. The study also found that the use of fluoridated toothpaste should be restricted from these Fluoride contaminated regions as it highlighted multiple pathways of acquiring Fluorosis from toothpastes. On the other hand, questions on purchasing and using filtration equipment presented diverse responses from the participants. While most Bantu groups preferred to own the equipment, majority preferred to own them as a community and to pay in installments together as a community. The Nilotic group had little interest in paying for the equipment. Nilotic group preferred to only pay monthly installment for maintainace and security for the installed equipment. These presented two scenarios whereby contextual factors can be integrated with behavior change factors to change the Nilotic psychosocial factors. When contextual factors refer to the infrastructure intended to increase confidence in performance through a change in the physical context which is the provision of filtration machines, the importance of the people involved cannot be ignored. In (Mosler H.-J., 2016) describes the two type of people to be handled. Here, they describe that doers and non-doers to be considered in the development of the intervention. These now falls under the two ethnic groups where doers can be the Bantus and non-doers can be the Nilotic groups. These from the study, can further be sub-grouped into socioeconomics and awareness among the two groups studied.

In recognition of climate change impacts on water, increasing population and ingrained habits, governments should invest more on behaviour change led awareness creation and low-cost technology that can remove Fluoride from drinking water and change the habits of the targeted people. The communities that every day are exposed to the tangible effects of Fluoride contaminated water can play a key role in helping to address impacts of Fluoride at local scale given the correct education and instruments/filters and behavior change communication materials. Heightening peoples understanding through harmonized research with Governments and International research institutions will be very important in improving the knowledge base, promoting behavior change processes as well as actions towards water de-fluoridation. The study endorses increasing participatory research spaces, discussions and decision-making processes to support the co-designing of socially accepted and context-based behavior change models for capacity building and implementable policies that are responsive to people water filtration priorities as well as sustainable for poor households. These processes should be inclusive, people centered and gender sensitive because gender (women) and water issues take a center stage in studied regions and has also been recommended by (Manzini, 2016).

The promotion of "science-policy -traditional knowledge interface" should be initiated to harness critical information such as the milk diet knowledge by Nilotic groups (Maasai) community whose traditional knowledge on avoiding Fluorosis is remarkable for further improvement of the situation. This calls for increased awareness creation to highlighting the plight and educating the people on the potential long-term problems emanating from the use of Fluoride contaminated water and the benefits for a proper behavior change communication in improving the health of the studied regions.

5. CONCLUSIONS

The research carried out contributed to gain insights on the silent but equally dangerous disease known as Fluorosis and its impacts. From the introduction, it explored global distributions of Fluorides by regions and countries. It later focused on the African Rift Valley where the field research was to be conducted. The introduction reviewed issues on impacts of Fluoride on several sectors such as Fluoride impacts on health (Dental and Skeletal Fluorosis) on plants, animals and humans. Further, it highlighted the several sources of Fluorides such as water (the most popular), soils, plants and coal, industrial as well as fertilizers. Even though water is the most popular pathway of Fluoride into humans, the first chapter explored studies suggesting that other sources such as food and heating coal could have potential and to what extent.

From the study we found out that there are other confounding factors that also contribute to Fluoride exposure. These confounding factors such as altitude of residence, age of exposed people, gender, temperature of the regions suggested a further research to confirm their influence on Fluorosis acquisition by humans. Additionally, on education it could be seen that in cases where head of households are severely affected by skeletal Fluorosis, this could prompt underage children to get employed for wages to support their families. In this breadth, those families affected also could exploit little savings on medication towards diseases that accompany Fluorosis increasing poverty levels in affected regions. The review also found out that these affected regions are in developing countries and are one of the poorest. Those studied here are always living on hands to mouth meaning working on daily basis, and if affected, at a large-scale communities development takes a spiral since abled people are affected. This impact on working population could also lead to abandonment of farms leading to more poverty and failure of adaptation in agriculture. This knowledge led to the decision to focus on Fluoride water contamination in the African Rift Valley through a Systematic Review, a Meta-Analysis and round up with a qualitative filed research using the focus group approach and analyzed through the RANAS (Risks, Attitudes, Norms, Abilities, and Self-regulation) model (Mosler, 2012).

The first chapter followed the findings from the introduction review where it performed a Ten-Year Systematic Review between 2007 to 2017. It has been recognized that Systematic Reviews gives researchers and practitioners to keep improving databases of studies that support development in different the fields. It also key in identifying research questions based on results obtained in different contexts and to justify further frontiers in research. The Systematic Review previously presented aimed to identify the factors influencing the relationship between Fluoride in drinking water and Dental Fluorosis. After a rigorous search for articles in this field and elimination of many articles, we settled on 39 articles that had the parameters needed for the Systematic Review. This was the first attempt of a Systematic Review covering global scale on Fluoride and Fluorosis prevalence. Further, we focused on what we think were four main questions:

"*What is the relationship between natural Fluoride water contamination and the prevalence of Dental Fluorosis*", *"Is this relationship the same in different geographic areas of the world*?", "*What is the impact of other factors, such as age, climate condition, and altitude on the prevalence of Dental Fluorosis?",* and finally "*What tools could policy makers adopt to tackle Dental Fluorosis?".*

The result showed that all the 39 articles that qualified for Systematic Review confirmed that water is the major pathway for acquiring Dental Fluorosis with an elevation of more than (>1.5mg/L). It also compared confounding factors such as climate, altitude, age, gender and dental caries on prevalence of Dental Fluorosis.

On age and prevalence of Dental Fluorosis, the Systematic Review found that Dental Fluorosis affects all groups of children. The group that emerged as highly exposed were <=11 years where those under observation presented a prevalence very close to 100%. Through this analysis the study suggested for more work to be conducted on this groups of children. In those villages where children are affected, impact on their development emerged as a key issue that calls for awareness creation on Fluorosis. For instance, the Fluorosis influenced not only the health situation but also the social sphere. Children affected by Fluorosis were often perceived to be unintelligent, unattractive, unhappy and unsmiling, with poor hygiene, and lack interactive social skills that greatly impact on their social and educational development. Among older groups, such as those >18 years, Dental Fluorosis was popular and onset of skeletal Fluorosis was detected. Concerning a third group, 35 years of age, experienced advanced skeletal Fluorosis and non-skeletal Fluorosis such as loss of teeth, nutritional deficiencies and bad lifestyle habits. The study suggested that policy makers were in a position to design policies, information campaigns and education aimed at creating behaviour change among the population under observation so that the uptake of and consistent usage of de-fluoridation equipment can be successful such as the recently developed flowered de-fluoridation equipment.

Concerning gender differences connected to the prevalence of Dental Fluorosis, there were no clear sign of dissimilarities. While some studies suggested that males were more susceptible, the opposite was equally argued by many studies. In males, literature showed that highest prevalence of Dental Fluorosis is exhibited between the age of twelve and twenty-four while those >35 years old males their condition deteriorated more rapidly than that of females. The study found out that in the oldest groups, male Fluorosis prevalence rate was consistently higher than that of females. However, these results were not significant. Possible reasons advanced in the studies concerning a possible males being more affected were that males might be working away from home and could have been involved in heavy activities that required them to consume more and different types of water. It also explored the possible biological reactions among male and female as a possible pathway.

The study reviewed articles concerning this matter to find the influence of temperature, rainfall and altitude as confounding factors on the prevalence of Fluorosis. Even though for these factors we did not reach an agreement on their influence on the dissolution of Fluorides, temperature has been studied to trigger higher consumption of water in hot areas and especially those in heavy labour such as poor communities. This higher consumption in regions where Fluoride water is abundant increased this exposure to temperature. When it came to altitude, its role in prevalence rate of Dental Fluorosis was not clear. The Systematic Review found that studies on higher altitudes showed that urine became acidic hence influenced Fluoride ions to last longer in the body therefore provoke faster absorption and spread of Fluoride ions in the intestine. On the other hand, some studies found both lower and higher altitudes to have similar effects on prevalence rates of Fluorosis. Additionally, those farming activities where fertilizer and soil could possess high concentration of Fluoride had the possibility to contaminate ground water and wells during rain run offs.

With respect to research on dental caries, studies found that it led to research on Fluorides since Fluorides up-to ($\leq$ 0.6mg/L) is key in abating Dental Caries. In fact, it also leads to stronger bone mass and teeth. But even though their relationship was not very clear, some studies found interesting results where some severe Dental Fluorosis patients exhibited higher levels of caries. This was explained by the fact that Dental Fluorosis could be characterized by the evidence of hypo-mineralization of the enamel tissue. The review suggested that further research should be conducted to understand how several factors (caries developing resistance to Fluorides, effect of amount of Fluoride dosage, personal oral hygiene, prevalence of cariogenic bacterial strains in the mouth and socio-economic status of individuals) influence the relationship between dental caries and Dental Fluorosis.

The chapter also explored other dietary factors as possible influencers. However, the relationship was not always very clear. Food stuff such as beverages (brick tea, tea, butter tea) baby formula, fish, beans, potatoes, wheat, animal and plant proteins and '*magadi*' popularly utilized as tuber softener, were found to possess significant amount of Fluoride content having the possibility to reinforce Fluorosis from water and thus impacting on Fluorosis prevalence rates. Interestingly other studies that focused on tea, animal and plant proteins found no difference on Fluorosis prevalence rates from the products.

In the second chapter, we presented a ten-year Meta-Analysis that explored the relationship between Fluoride in drinking water and Dental Fluorosis between 2007 to 2017. Meta-Analysis refers to the use of statistical techniques in a Systematic Review to integrate the results of included studies. As data from the 21 studies selected for the quantitative analysis showed Fluorosis heterogeneity, we focused on random effects Meta-Analysis of the Fluorosis prevalence rate defined as the proportion of people affected by Dental Fluorosis. However, meta-regression analyses conducted using a random-effect model provided evidence that Fluoride exposure from drinking water and temperature significantly affect Dental Fluorosis. Other predictors such as age of participants, rainfall and altitude were not significant. The beta parameter of Fluoride content indicated that *ceteris paribus* a reduction of 1 mg/L of Fluoride in drinking water reduces the probability of being affected by Dental Fluorosis of 7.6% (95% CI: 2.6% – 12.6%) in model 1 and 8.8% (95% CI: 3.1% – 14.4%) in model 2.

Such a result was found out to be very important for the communities in the Africa Rift Valley countries. This is because if average levels of Fluoride in drinking water found in Rift Valley as ranging between 6 to 10 mg/L, then de-fluoridation technology prototype were to be made to be able to reduce Fluoride he the levels below WHO recommendation (<1.5 mg/L). In the event that the Flowered technology developed by the project team would be adopted it will provide immense health benefits to thousands of communities and children in the Rift Valley. The result is important because countries like Tanzania and Ethiopia, to comply with their water Fluoride contamination, had set their minimum Fluoride limit in water to be 5 and 9 mg/L which are values far way higher than the WHO set limits of 1mg/L. If the defluoridator could reduce Fluoride in drinking water, then such communities would be able to reduce Dental Fluorosis in their populations between 38% and 80% respectively.

In the third and last chapter, the research focused on applying the RANAS psychological model, Mosler (2012) through a Focus Groups Discussions to explore case study on drinking water habits in the Rift Valley countries of Kenya and Tanzania in selected villages where Fluoride and Fluorosis was a menace. These focus group interviews investigated the insights about water drinking habits, the role of consumers' attitudes, behaviour and willingness to pay towards innovative filtering equipment, and to identify possible behaviour change communication campaigns to change ingrained habits of inhabitants of the African Rift Valley. The focus groups focused on two ethnic groups of Bantus and Nilotic groups in the two countries. The results showed that most communities had difficulty in accessing clean Fluoride safe water. Psychosocial and socio-economic factors have been known to influence peoples' uptake and usage for water de-fluoridation equipment. Additionally, people's attitudes exhibited directed to the probability towards the tendency of Fluoride unsafe water usage. Many interviewees believed it did not matter anymore to filter water citing cost and lack of education. This also reflected on the attempts to make water safe where most people did not take any actions. The process of deciding safe water elicited several answers even though majority believed in taste of the water as salty. This raised some questions whether the water had other elements apart from Fluoride which is known to be tasteless and colorless. This could point to widening of research beyond Fluoride. Finally, the cost of water also appeared to be a hindrance in accessing clean safe Fluoride free water.

The most of the participants were able to identify dental and skeletal Fluorosis from the photos that were shown and relate the images to their families. Majority were awareness of all the Fluorosis stages within their families citing colored, mottling, splitting and falling of teeth, inability to chew food and removal of teeth. Further, participants feared for the future of their communities by continuing to consume Fluoride-contaminated water. However, some participants had no idea about Fluorosis. On sharing the risk perception of contracting Fluorosis as well as the feeling of chances to contract Fluorosis, majority confirmed to share the risk due to lack of alternative water, high prices of safe water and ingrained habit of not filtering. In fact, to acquire and use filtering technology, majority agreed that it was lack of education, awareness and high prices, including lack of reagents and their personal behaviors that needed to be changed so that they could made good use of technology. Payment mode most liked by communities were installment payments for a community filter. That was in contrast with the individual filter adoption, suggesting that strong cultural ties and poverty to cushion everyone among the members. Finally, cost of water also appeared to be a hindrance in accessing clean safe Fluoride free water.

One of the key points to take from the study is that Fluorosis is a real menace to many communities and investment in innovative technologies that can reduce Fluoride are welcome. It is also noteworthy that the most among the poorest are affected and governments and research institutions should invest in this sector. The Meta-Analysis showed that it is possible to save a good number of people when such investments are prioritized towards reducing Fluoride in certain places. Additionally, studies which use behavioral change models using tested theories are a very important step to promoting the adoption of the technologies where the communities have not understood their importance.

This research was a very important step and very critical in understanding the Fluoride and Fluorosis menace. The Systematic Review and the Meta-Analysis were potentially the first attempt at global scale to try and bring to fore the important statistical analysis on the number of people that can be saved from Fluorosis including the confounding factors that have otherwise been studied individually in diverse contexts.

From the research, it is obvious that investment in technology development to reduce Fluoride content in water is paramount. It is also important that these technologies be sustainable in both prices and reagents availability. Training and awareness on the same should be conducted using the behavior change theories available in water, sanitation and health spheres to remove the ingrained habits hindering usage and change of old habits. Governments should also recommend policy changes in areas affected by Fluorosis either to provide clean Fluoride safe water, technology and educations. Additionally, some positive habits from traditional knowledge such as "exclusive feeding on milk until six years old" as carried out by the Nilotic groups should be further subjected to research as means for abetting Fluoride impact. The Nilotic group that practiced this model of feeding happened to remain with white teeth in the midst of very affected neighbors sharing water point. If this is true that drinking milk will save them from Dental Fluorosis then risk of acquiring skeletal Fluorosis will remain open for research.

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ANNEX 1 : THE FOCUS GROUP QUESTIONNAIRE

UNIVERSITÀ DEGLI STUDI DI SASSARI

Desertification Research Center

University of Sassari

PROJECT: ***de - FLuoridation technologies for imprOving quality of WatEr and agRo - animal products along the East African Rift Valleyin the context of aDaptation to climate change project*** **(FLOWERED)**
Project financed by the EU H2020 research framework

Focus group Research Protocol on Exploring drinking habits of Fluoride safe water in the Rift Valley: An application of the RANAS model

Recruitment

Target population: Bantu and Masai ethnic groups of Kenya and Tanzania.

Each focus group must contain between 6 and 8 participants. The total number of focus groups to run for this study is 8, of which:

- **Four for Bantu: 2 in Kenya and 2 in Tanzania**
- **Four for Masai: 2 in Kenya and 2 in Tanzania**

Two focus groups (1 Masai and 1 Bantu) must be conducted in villages where Fluoride safe water is already available in the village.

Q1: Have you ever taken part in a focus group or discussion before?

YES	1	CLOSE*
NO	2	CONTINUE

Q2: Are you involved with decisions regarding drinking water for yourself and your family?

YES	1	CONTINUE
NO	2	CLOSE*

Q3: Are you willing to participate in a group discussion on drinking water? Your opinion will be recorded but there is no possibility to trace you back.

YES	1	CONTINUE

NO	2	CLOSE*

Recruitment must be balanced in terms of gender, education and age. This means that the final sample size should contain more or less 32 males and 32 females and etc. As discussed via SKYPE, recruitment in the Rift Valley should be conducted involving academic partners.

* Thank respondents for their willingness to participate in this study.

Focus group Research Protocol /Questionnaire

September 2018

African Rift Valley Countries
(Tanzania and Kenya)

General instructions

a) The focus group should last around 90 minutes. Timing of each part can be adjusted a little as required.
b) Progressive numbers refer to issues to be covered. Questions can be slightly adapted in consideration of the cultural context.
c) Text in *italics* contains indications for the facilitator.
d) The set of pointers under the heading "memo for facilitators" are meant to clarify which dimensions and aspects of an issue are of interest for the research. Lists are not necessary exhaustive, nor must each point be addressed.

By no means, the pointers are to be interpreted as questions to be asked as such. They are to be used as reminders to facilitators for keeping discussion within the research aims.

PART 1 - Introduction by moderator (5 minutes)
Introduce yourself. Introduce the project and research theme (See 'Blurb' below). Explain facilitators' role. Explain what use will be made of audio recordings: the recordings will only used by the researchers, and the identity of the participants will not be revealed. The group will be discussing aspects of water drinking behaviour. Explain that participants are free to express their opinions, that their opinions matter, that there are no right or wrong answers, and that this should be enjoyable.

Blurb:
The **FLOWERED** project is funded by the EU H2020 research framework. The aim of the present study to interview people in selected countries of the African Rift Valley(Kenya and Tanzania): a) to get insights about **water drinking habits**; b) to understand the role of consumers' attitudes, behaviour and

willingness to pay towards innovative solutions to reduce the level of Fluorosis in the Rift Valley; c) to bring insights on communication campaigns to change ingrained habits of inhabitants of the Rift Valley.

Warm-up question

1. Will you please each introduce yourselves (first name and any funny questions to create a warm environment for discussion)?

Memo for facilitators: Please be aware information about age and education should have been already recorded – See instructions for Focus recruitment.

PART 2 – *Water consumption habits (15 minutes)*

- **What are the sources of water in your village?**
- **Is water available for all families in your village?**
- **How do you manage/consume water resources for your family?**
- **How much water does your family consume every day?**
- **Do you have your own/community well? If not, where do you buy/collect water from?**
- **Who is responsible for buying/collecting water?**
- **What is the effort that you make to collect water?**
- **If you buy water, how much do you pay for a litre (unsafe vs. safe)?**
- **How safe is for your health drinking water in your village?**
- **How do you decide that water is safe?**
- **What do you do to assure that water is safe?**
- **When you have guests, do you offer always safe water?**

Memo for facilitators:
- Consumption in relation to drinking, cooking, personal use and farm animals
- Separation between drinking water and other uses
- Is there a limit of water that you can collect or buy every day?
- Rainwater hAfrican Rift Valleyesting
- Very important to explore different prices for different types of water (drinking vs. other uses, and non-filtered vs. filtered)
- Efforts in terms of walking distance, time, physical effort etc.
- Explore safety drinking water strategies e.g. storage facilities and techniques used to avoid bacterial contamination, boiling, refrigeration, tanks, community filters and so on.

PART 3 – *Behavioural factors (45 minutes)*

- **What is Fluorosis?**

According to WHO, more than 260 million individuals are affected by elevated levels of fluorine in usable water. In your living area, Fluorosis is a big issue and because drinking water contains Fluoride can impact negatively on your health. This is what happens when you drink water

containing a high level of Fluoride (Please show cards for Dental Fluorosis).

- **What do you think about these pictures?**
- **Do you think that Fluorosis is determined by drinking water?**
- **Do you know what you could do to drink Fluoride safe water?**
- **Are you or any members of your family exposed to health problems caused by Fluorosis?**
- **How do you feel about chances to get Fluorosis when drinking water?**
- **Have you ever consumed filtered Fluoride safe water? And if yes, how much do you like it?**
- **Do you think that filtering drinking water is time consuming?**
- **Do your family members/relatives consume Fluoride safe water?**
- **In general, do you think that people who are important to you approve or disapprove that you drink Fluoride safe water?**
- **Do you feel a personal strong obligation to consume/buy Fluoride safe water?**
- **Are you sure that you can consume as much Fluoride-safe water as you need within the next week? Next month?**
- **If your relatives continue to use raw water, how confident are you that you can freely consume Fluoride-safe water?**
- **Imagine that you have stopped drinking Fluoride-safe water for several days. How confident are you that you would be able to start drinking Fluoride-safe water again?**
- **How committed do/would you feel to collecting/drinking Fluoride safe water?**

Memo for facilitators:
- Investigate on unsafe water and Fluorosis in particular
- Find out whether and how Fluoride safe water is already available in their village. If yes, explore whether they forget to collect Fluoride-safe water and any barriers that could obstacle to collect/consume Fluoride safe water.
- Filtered better than non-filtered?
- Investigate on different types of social norms in terms of influence of reference groups
- Investigate how they feel to perform the desired behaviour

PART 4 – Purchasing *behaviour (20 minutes)*
Prepare cards depicting the characteristics of new filters and explain how they work (to be fine-tuned)

Identification of attribute and relative levels for the choice experiment to be run in engine.

Show card with market scenario and prototype filter.
Imagine that a filter reducing drastically the content of Fluoride in water is available for you to use tomorrow. This filter reduces the amount of

Fluoride to the level recommended by WHO (<1.5mg/L) and they can filter any type of source of drinkable water. Because companies are optimising these filters for you, we would like to know your opinion about technical and market characteristics of these filters.

- **These filters might be available both at family level and village level. What filter do you prefer and why?**
- **In terms of filter capacity, family filters are available in different formats [50,100,150 litres/day] while village filters are up to 500/1000. What filter do you prefer and why?**
- **After use, the reagent for family and village filters can be disposed by you or collected by your supplier. What is the best solution for your family?**
- **The filtering speed technology of the system can vary between 2 and 10 hours (overnight function). What speed would you prefer for your family?**
- **Prepare a payment card both for family and village levels where participants will indicate the maximum willingness for both filters.**

Memo for facilitators:
What filter:
Filters: be aware that they understand that these filters have mono-use reagents and different plant fixed costs depending on the number of litres filtered.
Explore ethical economic-social reasons in the decision to dispose the used reagent.

How strong do you feel about using these filters in your village next week?

Memo for facilitators

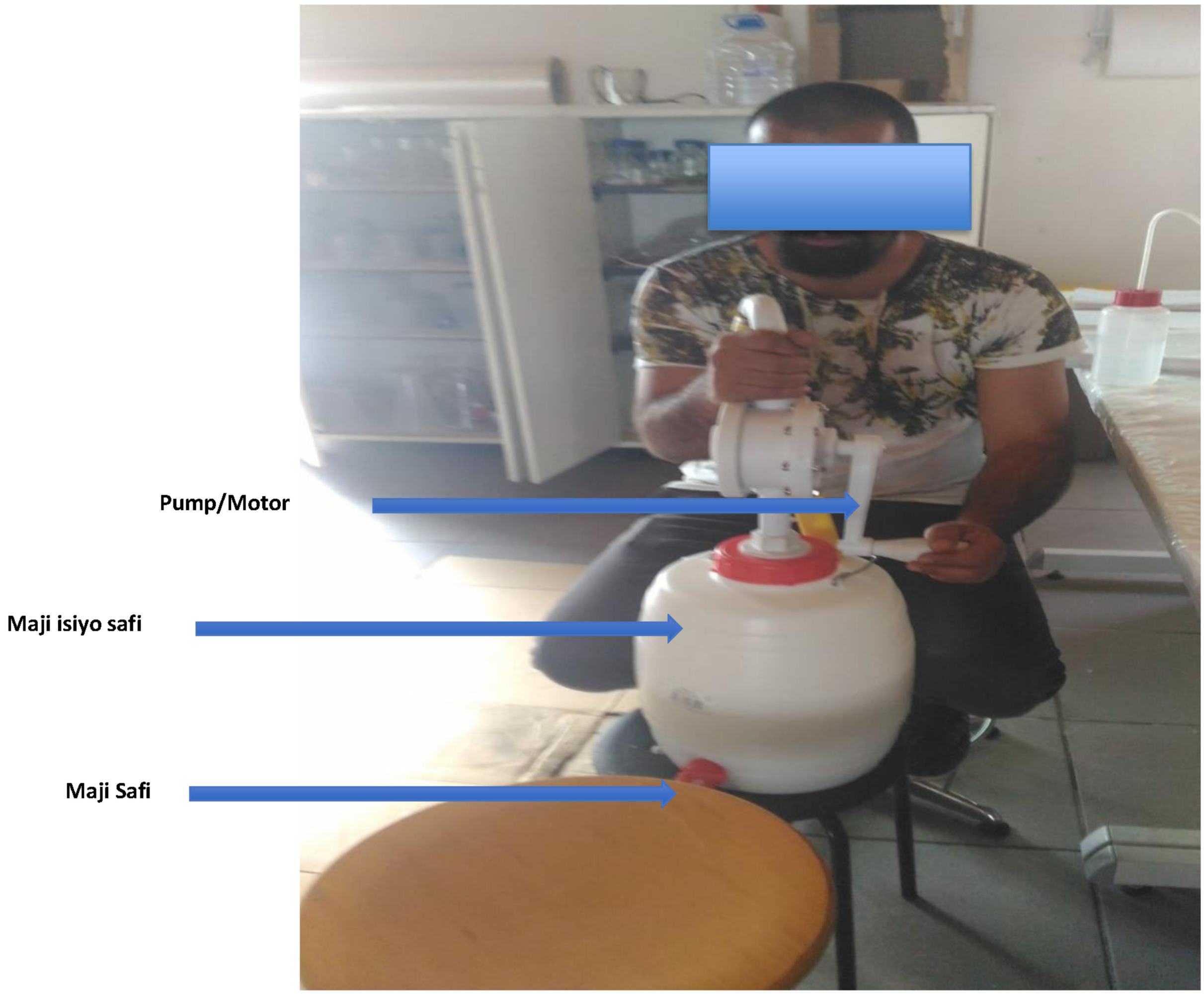
- *Success vs. failure*
- *Influence of family and friends*
- *Long term (introducing functional ingredients in their life)*

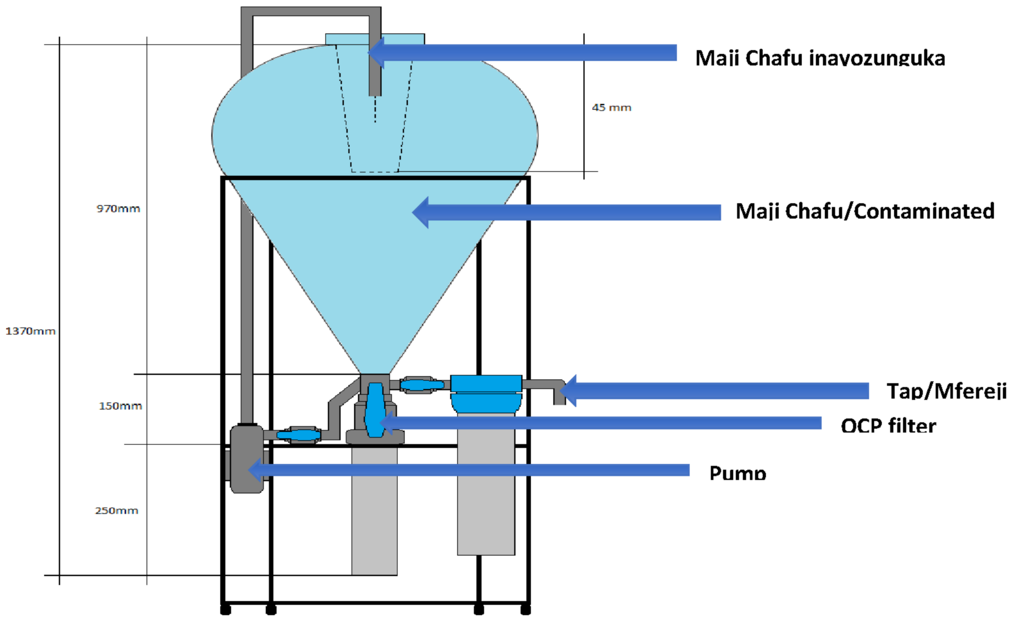
FEEDBACK AND CLOSE (5 minutes)

Thank you everyone for coming your participation has been extremely valuable to our project.

ANNEX 2: PHOTOS OF DENTAL AND SKELETAL FLUOROSIS

ANNEX 3: WATER FILTER PROTOTYPES (HOUSEHOLD LEVEL MANUAL USER AND VILLAGE LEVEL)





ANNEX 4: PAYMENT MODALITY CARDS IN ENGLISH

How locals buy/pay their assets: Women group loans, Merry-go-round-fund raisers-loan from SACCOs, loan from Banks etc,. Lets say Household level Filter cost KSH 30,000 and village level cost KSH 100,000.

FROM MY PERSONAL SAVINGS	I WILL SELL MY PROPERTY TO BUY	I WIL APROACH NGO/CHURCH ETC.
I WILL GET A LOAN FROM WOMEN/ MEN GROUP	I AM NOT INTERESTED IN THE FILTER	I WILL BUY IF THE PRICE IS SUBSIDISED
WE WILL COMBINE WITH ANOTHER FAMILY TO BUY	WE PREFER THE VILLAGE LEVEL FILTER TO SHARE THE PRICE	WE WILL BUY THROUGH FARMERS ASSOCIATION
I WILL BUY CASH	I WILL PAY BY INSTALMENTS	I CAN'T AFFORD AND CANNOT GET LOAN