# FLUORIDE PROFILE IN BOTTLED WATER IN NEPAL

**Dr. Rabindra Man Shrestha**
Ms. Sarita Sitaula (M.Sc. Chemistry)
Public Health Concern Trust Kathmandu, Nepal

## INTRODUCTION

Fluoride is ubiquitous and is found in food, water, air and dental products. It is estimated that about 80% of dietary fluoride are from water and beverages[1,2].

## FLUORIDE IN WATER

- Fluoride is the ionic form of the element fluorine. Fluorine is a highly reactive gas, and is never found in a free state in nature.

- At 1 ppm, fluoride is fully ionized in water and it occurs as free fluoride ion in solutions.

- Fluoride occurs naturally in all water, and is present as a result of having been dissolved out of the rocks over which the water has travelled.

- Fluoride ions in water are identical irrespective of whether naturally occurring or added.

Because of solubility of fluoride compounds to some extent in water, nearly all-natural water sources contain a measurable quantity, which varies according to the amount and solubility of the fluoride in adjacent mineral deposits. The naturally occurring water borne fluoride is not always present in concentration sufficient to produce dental benefits. So it is recommended that the natural level should be adjusted. The process of adjusting the amount of fluoride in water to an optimal concentration for the prevention of dental caries is known as water fluoridation. Observational studies by Dean and colleagues during the 1930's identified reductions in dental caries at a naturally occurring fluoride concentration at 1 ppm[3,4]. This level of fluoride resulted in decreased caries prevalence without objectionable level of dental fluorosis; a congenital condition of enamel hypoplasia caused due to excess level of community water fluoride consumed during the stage of tooth development

## MODE OF WATER FLUORIDATION

The dental benefits of fluoridating community water supplies are widely acknowledged[5]. In terms of benefit, the only aim of water fluoridation is to prevent dental caries. There are various modes of water consumption, fluoridation of which can help in dental caries reduction. The community water fluoridation may require government level intervention where as limited source water fluoridation programs could be done by the non-government authorities or local efforts. Various modes of water fluoridation are as follows:

1. Community water fluoridation
2. School water fluoridation
3. Bottled / Mineral water fluoridation

## HISTORY OF WATER FLUORIDATION

In 1901, Dr. Frederick S. McKay noted an unusual permanent stain or "mottled enamel" (termed "Colorado brown stain" by local residents) on the teeth of many people in Colorado, USA[6]. After years of personal field investigations, McKay concluded that an agent in the public water supply probably was responsible for mottled enamel. McKay also observed that teeth affected by this condition seemed less susceptible to dental caries[7].

The hypothesis that dental caries could be prevented by adjusting community water fluoride level from negligible levels to 1.0-1.2 ppm was tested in a prospective field study conducted in four pairs of cities (intervention and control) starting in 1945 in Grand Rapids and Muskegon, Michigan; Newburgh and Kingston, New York; Evanston and Oak Park, Illinois; and Brantford and Sarnia, Ontario, Canada. After conducting sequential cross-sectional surveys in these communities over 13-15 years, caries was reduced by 50%-70% among children in the communities with fluoridated water[8]. The prevalence of dental fluorosis in the intervention communities was comparable with what had been observed in cities where drinking water contained natural fluoride at 1.0 ppm. Since 1950 the number of individuals drinking fluoridated water, including 5.5 million in United Kingdom and 144 million in United State[9]. Recent study shows that over 360 million people in about 60 countries worldwide are exposed to fluoridated water in more than 10,000 communities[10].

## EFFECT OF FLUORIDATED WATER ON DENTAL HEALTH

Abundant data show that fluoridated water not only acts systemically during tooth formation rendering enamel resistant to dental caries, but also acts directly as a topically applied agent. Therefore the procedure benefits both children and adults. Studies of the effect of fluoridation in young children prove that the procedure effectively reduces the prevalence of dental caries in primary teeth by about 40%[11,12]. Although early studies focused mostly on children, water fluoridation is also effective in preventing dental caries among adults. Fluoridation reduces enamel caries in adults by 20%-40%[13] and prevents caries on the exposed root surfaces of teeth, a condition that particularly affects older adults.

Water fluoridation is especially beneficial for communities of low socioeconomic status[14]. These communities have higher incidence of dental caries and less access to dental-care services and other sources of fluoride. Many studies have confirmed the finding that fluoridation reduces the prevalence of dental caries in permanent teeth by about 60%[15,16]. Therefore consuming drinking water with adequate amounts of fluoride does not merely delay the development of dental caries, but also gives substantial life-long protection.

Fluoride benefits the teeth that have erupted as well as those developing in the jaws. Maximum protection against tooth decay is achieved when optimally fluoridated water is consumed from birth. Protection continues throughout the life for persons who continue to live in fluoridated communities.

## MECHANISM OF FLUORIDE ACTION

The precise mechanism by which fluoride protects the tooth from dental caries is not completely understood but more than one mechanism is believed to be involved. The action of fluoride on teeth involves both topical and systemic mechanisms. Topical application of fluoride has been shown to decrease levels of dental plaque bacteria[17]. Fluoride acts to stabilize the hydroxyapatite matrix on internal and external tooth surfaces[18,19].

In 1972, dental experts proved that fluoride principally acts by increasing resistance of enamel to acids produced in dental plaque by bacteria[20]. More recent studies clearly show that other action of fluoride, such as remineralization of initial or pre-carious lesions and host anti-bacterial effects are also important[21, 22].

When fluoride is ingested, it is readily absorbed into the body. The presence of ions such as Calcium, Iron and Aluminium form complexes with fluoride and interfere with its absorption from gastrointestinal tract and little fluoride is eliminated in feces. The elevated fluoride level quickly decreases because fluoride is rapidly taken up by mineralizing tissue (bones and teeth) or excreted by the kidneys[23,24] and fluoride never accumulate in non calcified soft tissues. There is a temporary rise in the fluoride concentration of blood shortly after its ingestion. Fluoride concentration in blood reach peak level in about 30 minutes after ingestion and within a few hours, it returns to fasting level[24]. Fasting levels of fluoride in blood are low about 0.02 to 0.03 ppm.

Laboratory and epidemiologic research suggests that fluoride prevents dental caries predominantly after eruption of the tooth into the mouth, and its actions primarily are topical for both adults and children. These mechanisms include:

- inhibition of demineralization,
- enhancement of remineralization, and
- inhibition of bacterial activity in dental plaque[25]

While teeth are forming, small amount of fluoride is incorporated into enamel as hydroxy fluoroapatite (Ca5PO4)3 F which is more resistant to dissolution by acids than hydroxyapatite (Ca5PO4)3 OH crystal, the principal inorganic mineral of enamel. Fluoride enhances remineralization by adsorbing to the tooth surface and attracting calcium ions present in saliva. Fluoride also acts to bring the calcium and phosphate ions together which helps to produce a crystal surface that is much less soluble in acid than the original tooth mineral[25].

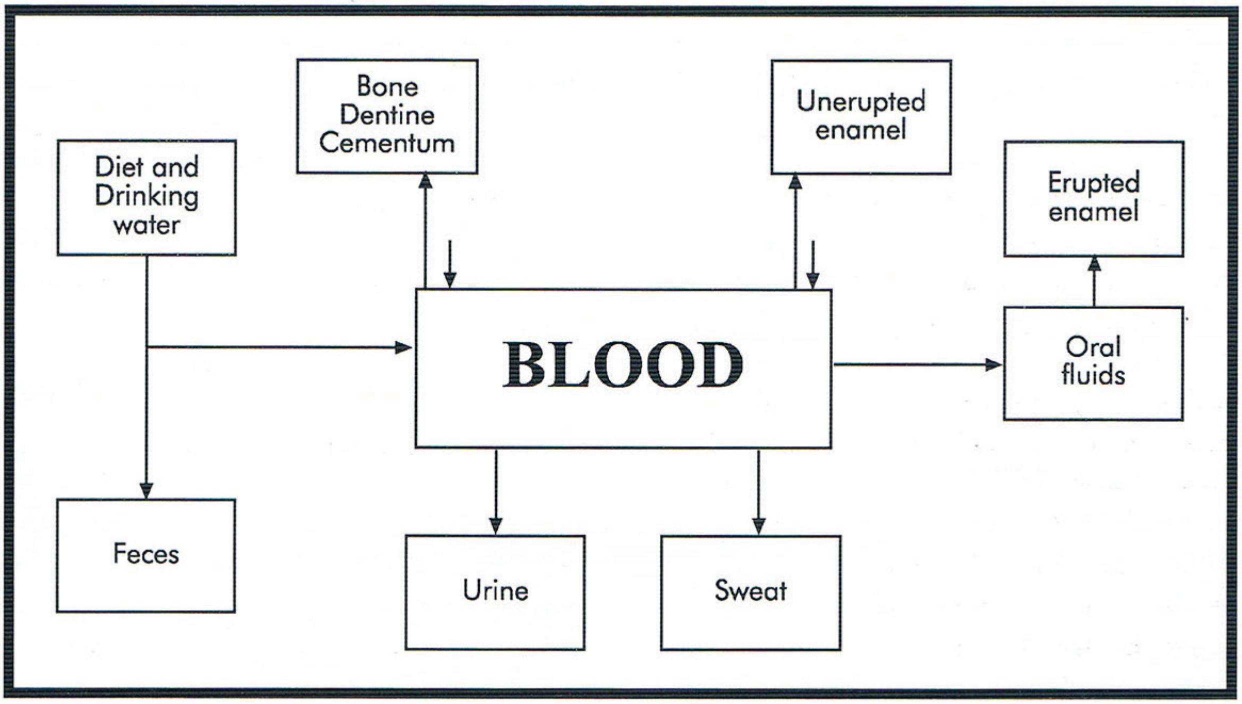
Enamel and dentin are composed of mineral crystals (primarily calcium and phosphate) embedded in organic protein/lipid matrix. Dental mineral is dissolved readily by acid produced by cariogenic bacteria when they metabolize fermentable carbohydrates. Fluoride present in solution at low levels, which becomes concentrated in dental plaque, can substantially inhibit dissolution of tooth mineral by acid.

Topical sources of fluoride such as fluoridated drinking water is taken up by cariogenic bacteria when they produce acid. Once inside the cells, fluoride interferes with enzyme activity of the bacteria and the control of intracellular pH. This reduces bacterial acid production, which directly reduces the dissolution rate of tooth mineral[26].

The pre-eruptives developing enamel in the bony crypt continues to incorporate fluoride if the concentration of fluoride is high during the period of maturation. The enamel of newly erupted tooth is incompletely mineralized, therefore diffusion of fluoride into enamel continues for an indefinite period of time following the eruption. The fluoride uptake occurs only if fluoride is available at the enamel surface.

Fig. 1 indicates that systemic fluoride is excreted in small amount into the oral fluids through the salivary glands and cervical fluid around the teeth. The continuous secretion of low concentration of fluoride is responsible for its anti-cariogenic effects. So, the fluoride must be ingested, circulated in the blood and excreted into the mouth for the protective topical effect to be produced which emphasizes the importance of systemic fluoride.

**Fig-1 Kinetics of ingested fluoride**




## OPTIMAL FLUORIDE CONCENTRATION OF WATER

According to WHO 1994, the therepeutic level of fluoride for drinking water is 1ppm. From extensive research it has been established that approximately on part fluoride per one million (1ppm) of water prevents up to 60% of the tooth decay that would ordinarily occur. In 1993, the National Research Council, US27 concluded that the upper limit of 1.2 part per million (ppm) of fluoride in drinking water be maintained. More recently, the U.S. Public Health Service reviewed this drinking water standard and reaffirmed optimal levels of 0.7 to 1.2 ppm fluoride (dependent on annual average of maximum daily air temperatures) to yield an average of 1 mg per day of consumed fluoride[28]. Where the fluoride content of drinking water is naturally increased, the Environmental Protection Agency recommends the reduction to a level of 2.0 ppm.

In the 1950's Galgan et. Al. Studied environmental factors that affect the consumption of fluoridated water[29,30]. They concluded that only the mean annual maximum daily temperature of an area determines how much drinking water is consumed. The fluoride concentration of water supply should be adjusted according to the climatic cariables because a person in hotter climate consumes more water than in colder climates.

As table-1 shows recommended fluoride concentration for community fluoridation ranges from 0.7-1.2 ppm depending on temperature. The community located in a cold climate should fluoridate water to 1.2 ppm; where as a community in hot climate should fluoridate at 0.7 ppm.

**Table – 1: Mean maximum daily temperature and corresponding optimal fluoride concentration for water fluoridation.**

| S.N. | Ranges of mean maximum daily temperature (°C) | Recommended optimal fluoride concentration for community fluoridation (ppm) |
|---|---|---|
| 1 | 19-20.4 | 1.2 |
| 2 | 20.4-22.2 | 1.1 |
| 3 | 22.2-24.2 | 1.0 |
| 4 | 24.3-26.8 | 0.9 |
| 5 | 26.9-30.1 | 0.8 |
| 6 | 30.1-34.39 | 0.7 |

## WATER FLUORIDATION METHOD

Adding fluoride to community water supply is similar to the addition of other materials to treat water[31]. The compound commonly used for fluoridation is sodium fluoride (NaF), hydrofluoric acid and sodium silicofluoride. Whereas, according to British Fluoridation Society, only two compounds of fluoride are permitted for artificial fluoridation in the UK i.e. hexafluorosilicic acid (H2SiFH6), and disodium hexafluorosilicate (NaH2SiFH6). Important factors in selecting a specific process and chemical for fluoridation include size of the water system, number of sites of application, volume of water used, cost of equipment, pressure at points of application, storage space and convenience of maintenance and handling.

However, installing fluoridation equipment does not assure maximum protection against tooth decay. The optimum fluoride concentration should be monitored regularly which is commonly done by colorimetric assay. The specific electrode for fluoride is now commercially available for this purpose which greatly simplifies the accurate determination of fluoride concentration in water.

## COST EFFECTIVENESS AND COST SAVINGS OF FLUORIDATION

Water fluoridation is especially beneficial for communities of low socioeconomic status32. These communities have higher incidence of dental caries and less access to dental care service and other sources of fluoride. Water fluoridation may help to reduce such dental health problems.

Compared with other methods of community-based dental caries prevention, water fluoridation is the most cost effective in terms of cost per saved tooth surface33. The community water fluoridation program can achieve caries protection with the expenses of approximately 35 cents cost per person per year as based on the data published by National Institute of Dental Research, US. Water fluoridation costs range from a mean of $0.31 per person per year in communities of greater than 50,000 person to a mean of $2.12 per person in communities of less than 10,000 in US34.

Water fluoridation reduces direct health-care expenditures through primary prevention of dental caries and avoidance of restorative care. An economic analysis estimated that prevention of dental caries, largely attributed to water fluoridation and fluoride-containing products, saved $39 billion in dental-care expenditures in US during 1979-1989[35].

## METHODOLOGY

### Equipment:

1. Fluoride Meter
   WTW-pH/mV/Digital Ion meter mode pH 340/Ion
2. Electrode-
   ORION ionplus electrode model 96-09
3. Labwares
   Plastics glass, pipettes, measuring cylinders and droppers etc.
4. Magnetic stirrer

### Chemicals:

1. Deionized water
2. Electrode filling solution- ORION Cat. No. 900061
3. Sodium fluoride solution as standard – 100ppm-Orion lonplus, Cat. No. 940907
4. TISAB III (Total Ionic Strength Adjustment Buffer)- concentrated with CDTA

**Table-2: Composition of TISAB III**

| S.N. | Composition | CAS Reg. No. |
|---|---|---|
| 1 | Deionized water (H2O) | 7732-18-5 |
| 2 | Ammonium chloride (NH4C1) | 21125-02-9 |
| 3 | Ammonium acetate (CH3COONH4) | 631-61-8 |
| 4 | CDTA (C14H22H2O8-H2O) | 13291-61-7 |
| 5 | Cresol Red (C21H18O5S) | 62625-29-0 |

**Graph Paper:**

4-cycle semi-lagorithmic graph paper was used for the calibration of fluoride concentration.

## DETERMINATION OF FLUORIDE IN WATER USING pH/ION METER

The model 96-09 fluoride combination electrode is used for the measurement of sample. Fluoride in water is determined by a direct measurement procedure. Since fluoride ion concentration in water is generally low, it was necessary to produce calibration curve on logarithmic scale from which accurate fluoride ion concentration could be established.

The measurement of fluoride concentration of standard solution and samples were carried at the same temperature. The same strength was adjusted by addition of TISAB III (Total Ionic Strength Adjustment Buffer) to all solution to be measured. Since fluoride in water is expressed in parts per million (ppm), total fluoride concentrations was measured by adding TISAB to standard solution and samples in order to break fluoride complexes of Aluminium and Iron (III). TISAB also adjusts the pH and swamps out variations in total ionic strength.

## STANDARD CALIBRATION METHOD USING ION ANALYZER

The standard solution whose concentration is near the expected sample concentration was prepared. 5 ml of TISAB III to each 50 ml of standard was added. The nominal values of the standards were used in calibrating the electrodes. The fluoride concentration of sample was read directly from the logarithmic scale.

## PROCEDURE FOR STANDARD FLUORIDE CALIBRATION CURVE

The fluoride reference electrode was filled with electrode filling solution upto the filling hold. Then 5ml TISAB III was added per 50ml sample. Then electrode was dipped in sample and magnetic sirrer was used for mixture so as to homogenize the solution thoroughly. Then the meter was switched on and milivolt was pressed on and waited for a stable mV reading. Then mV was measured at the interval of 6min., 12 min., 18min., 24min ..... till reading becomes constant for 6 minutes. Fluoride concentration of reference sample of 10ppm was measured and then diluted to different concentrations.

## OBSERVATION:

Table – 3: Potential of Standard fluoride at 25°C

| S.N. | Fluoride concentration (ppm) | Observed potential (mV) |
|---|---|---|
| 1 | 10 | 38 |
| 2 | 5 | 50.2 |
| 3 | 2.5 | 61.6 |
| 4 | 1.25 | 70.8 |
| 5 | 0.625 | 77.5 |
| 6 | 0.312 | 81.4 |
| 7 | 0.156 | 84.4 |
| 8 | 0.078 | 85.8 |
| 9 | 0.039 | 85.8 |

## CURRENT STATUS OF BOTTLED WATER IN NEPAL

Bottled water has been introduced in Nepal since 2047. Thus the history of bottled water in Nepal is not very old. Although the market of botted water in Nepal is found a large due to tourism and unsafe public water supply by the nation. So the number of bottled water industry has been growing every year. About one and half a dozen mineral water factories have been manufacturing at present. The consumption of bottled water is increasing day by day as the people think that they could acquire sufficient mineral and feel sfe to drink bottled water, however it is questionable. Infact the unmonitored and insufficient water supply to the public by nation has forced the public to consume bottled water, which is financially a burden to the public on the other hand. In reference to a recent article published by Kantipur Daily (3rd March, 2001), shows that people of Kathmandu valley consume sealed jar water and bottled water even for domestic purpose. Consumption of 70,000 jars of 19 litre capacity each and 800,000 bottles of 1 litre capacity each per month is a large proportion for the socio-economic condition of Nepalese population and it has been found that growing water factories instead of circumspect the public health are seem to be profit oriented.

The present study is focused on fluoride concentration of bottled water (drinking water) to aware the public. According to Food Research Laboratory, Nepal Standard (NS), WHO and other international norms the fluoride concentration in bottled water (drinking water) should be as follows:

Table – 4: The comparative fluoride standard for drinking water

| S.N. | Standards | Fluoride concentration (ppm) |
|---|---|---|
| 1 | WHO (1984) | 1 |
| 2 | Food research lab (Nepal) | 1.5 |
| 3 | Nepal standard (NS) | 2 |
| 4 | Indian standard | 1.0-1.5 |
| 5 | Bangladesh standard (1988) | 0.7-1.0 upto 25°C |
| 6 | CODEX | 2 |
| 7 | Phillipines | 1.0 |
| 8 | Indonesia | 0.6-2.0 |

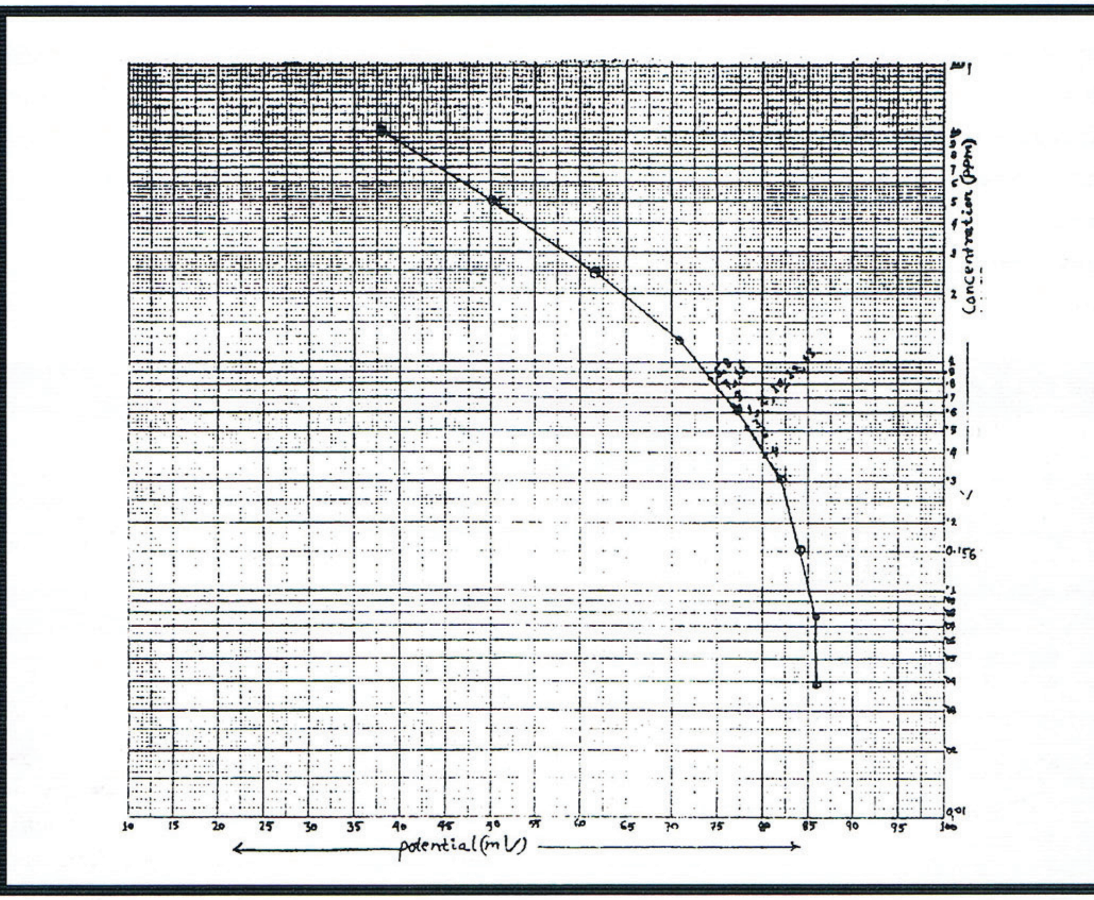
## SAMPLE PREPARATION

Different sealed bottled water samples were collected from market and few random samples of natural water sources and tap water supply of Kathmandu, Lalitpur and Kirtipur were taken for the study of water fluoride level.

The name and location of bottled water and other water samples are listed as follows:

1. Bisleri mineral water, Kavre.
2. Aqua Hundred (la)mineral water, Balaju, Kathmandu.
3. Thrist-PI Mineral water, Kalimati, Kathmandu.
4. Bialley Mineral water, Thankot, Kathmandu.
5. H2o Mineral water, Chauvar, Kathmandu.
6. Penguine mineral water, Pokhara, Kaski.
7. Today mineral water, Pokhara, kaski.
8. Tamor mineral water, Alapot, Kathmandu.
9. Mount Peak mineral water, Lele, Lalitpur.
10. Yes mineral water, Balaju, Kathmandu.
11. Well Water, Tikathali, Lalitpur.
12. Spring water, Kirtipur.
13. Tap water, Bagbazar, Kathmandu.

## CALIBRATION CURVE WITH SAMPLE WATER:




## OBSERVATION:

Table-5: Potentials and fluoride concentration of sample water at 25°C

| S.N. | Name of water sample | Potential (mV) | Concentration (ppm) |
|---|---|---|---|
| 1 | Bisleri mineral water | 77.8 | 0.59 |
| 2 | Aqua (La) mineral water | 77.5 | 0.58 |
| 3 | Thirst-PI mineral water | 78.7 | 0.45 |
| 4 | Bailley mineral water | 80.4 | 0.4 |
| 5 | H2O mineral water | 74.4 | 0.8 |
| 6 | Penguine mineral water | 79.0 | 0.46 |
| 7 | Today mineral water | 75.1 | 0.7 |
| 8 | Tamor mineral water | 74.0 | 0.8 |
| 9 | Mt. Peak mineral water | 76.8 | 0.6 |
| 10 | Yes mineral water | 77.4 | 0.57 |
| 11 | Well water, Tikathali, Lalitpur | 75.8 | 0.6 |
| 12 | Spring water, Kirtipur | 76.8 | 0.65 |
| 13 | Tap water supply, Bagbazar, Kathmandu | 77.3 | 0.6 |

## CONCLUSION

From the review of the literature it has been concluded that the optimal fluoride level can save tooth decay which can reduce an oral health problem. The community water as well as limited source water fluoridation can be accomplished with government level intervention, local efforts and peoples' awareness.

In on side there is a tendency to the consumption of expensive bottled mineral water by the Nepalese population, on the other side fluoride content of various samples of bottled water is sub-optimal to benefit the people's health as shown by the present study. So this study also recommends for the optimal fluoride concentration in bottled water of Nepalese market for which the need of study to determine the optimal water fluoride level in Nepalese context should be carried and logistic norms of mineral content including fluoride in bottled water should be established.

Till date water fluoridation has not been carried out in Nepal, which if undertaken can reduce dental caries which is believed to be more cost effective compared to the direct treatment modality and will be more beneficial to the community of lower socio-economic strata.

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