

Fluoride Concentration Modelling in Konya City Drinking Water Wells via Geographical Information System

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Fluoride is one of the important elements in drinking water. This element is needed in small quantities; because it has an important role for health. Even small quantities of some trace elements have significant effect on human health. In this study, bearing in mind that especially excessive or low fluoride content of drinking waters is important for human health, water samples were collected from 50 different water wells in Konya city centre for determination of their fluoride concentrations. Water fluoride data analyses for modelling were carried out using Geographical Information System (GIS) then, fluoride level maps were presented to aid the identification of areas where high-fluoride waters and fluorosis may be a problem. It was observed that fluoride levels of all collected samples were below the limit given in T.S.-266 and WHO standards. The highest fluoride concentration was detected in water wells at Sakarya area with 0.42 mg L^{-1} . The lowest fluoride level was obtained from Ali Tasoluk well water with 0.092 mg L^{-1} . Fluoride level in the tap water has a great importance for tooth and bone health. In the systems where water is supplied from wells with low fluoride content, it is necessary addition of fluoride using appropriate methods. In addition, if it is not possible for fluoride addition, it is necessary to inform the people who using this water about application fluoride tablets.

Key Words: Fluoride, Geographical Information System, Well water, Konya, Health, Tooth, Risk assessment.

INTRODUCTION

Fluoride is one of the important and necessary trace elements for human health in tap water. Trace elements are formed in small quantities, however some of them are very toxic and some others indispensable for health. It was discovered that children living in areas where drinking water contained naturally elevated levels of fluoride experienced less tooth decay¹. On the other hand, even small quantities of some other trace elements have significant effect on human health²⁻⁴. Since some fluoride compounds in upper layer of the earth dissolve and reach well in the water, both surface water and ground waters contain fluoride. Fluoride concentrations in ground waters indicate a considerable variation^{5,6} between $1\text{-}25 \text{ mg L}^{-1}$.

It is well known that fluoride is a necessary element for human health today, prevents dental cavities. Tooth structure is hydroxyl apatite [$\text{Ca}_5(\text{PO}_4)_3\text{OH}$] compound. The acidic environment that sweet substances will form in the mouth undergoes reaction with hydroxide in tooth structure and causes the teeth to erode and cavity formation. By replacing hydroxide anion in the structure, fluoride ion forms fluoride apatite [$\text{Ca}_5(\text{PO}_4)_3\text{F}$] which has a more strong structure and forms a preventive layer⁷.

Fluoride is commonly added such as some consumption products into the tooth paste, tooth powder, mouth washing supplementary vitamins. Necessary fluoride amount in drinking water^{8,9} is between 0.5-1.5 mg L⁻¹. If this ratio falls below 0.5 mg L⁻¹, this causes important disorders in tooth and bone metabolism. On the other hand, in excessive fluoride intake it was observed that surface smoothness of tooth enamel was deteriorated and dots ranging from yellow to brown appear^{10,11}.

Almost 90 % of fluoride in human body is in the teeth and bones. Fluoride increases the resistance of the tooth enamel towards the acids which cause tooth cavities and decreases tooth cavities up 40-50 %. When concentration exceeds 2.4 mg L⁻¹, the children younger than 4 years of age have to drink water from a different water source known to have appropriate fluoride content or they should drink water which is filtered in reverse osmosis purification process^{12,13}.

In a study which was carried out for long period, it was found that a 25-30 % decrease was observed in tooth cavities in children who used drinking water with fluorinate¹⁴. Necessary fluoride amount in drinking water is between 0.5-1.5 mg/L¹⁵. If this ratio falls below 0.5 mg/L, this causes important disorders in tooth and bone metabolism. If fluoride intake is between the desired levels, it prevents tooth cavities. In excessive fluoride intake (more than 1.5 mg/L), on the other hand, it was observed that surface smoothness of tooth enamel was deteriorated and dots ranging from yellow to brown appear^{10,11,16,17}.

Fluoride is applied in various methods in tap water. These methods include; direct fluorination of the water, direct use of NaF tablets, fluoride of milk and milk powder, fluoride of table salt and direct application of fluoride varnish and pastes to tooth surface¹⁵. In fluoride detection with various samples different techniques such as potentiometer (with sensitive fluoride electros) or spectrometer are used¹⁶.

The waters of earth contain fluoride in various concentrations. With 0.8-1.4 mg/kg levels, sea water contains a significant amount of fluoride. Waters in the skirts of high mountains and sea-originated geologic deposit regions contain high fluoride concentrations. High fluoride concentrations was detected in Lake Nakura which trespass Syria, Egypt, Sudan and Kenya¹⁸.

Geographical information system has been used by different professional disciplines in the world. Geographical information system can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment and managing water resources on a local or regional scale¹⁹. Geographical information systems are tools for collecting, storing, retrieving at will, transforming and

displaying spatial data for a particular set of purposes²⁰. The quality of ground water is equally important as that of quantity. Remote sensing and GIS are effective tools for water quality mapping and land cover mapping essential for monitoring, modelling and environmental change detection²¹. Antunes *et al.*²² presented a new methodology for impact assessment which is based on the assumption that the importance of environmental impacts is dependent, among other things, on the spatial distribution of the effects and of the affected environment. Sample applications were made using GIS software, especially in ground water applications. Some of the studies which evaluated different parameters in ground water are given below.

In their studies which they carried out in Scotland, Vinten and Dunn²³ analyzed the effect of time-bound change of the quality of well water in a nitrate-sensitive region on land use. Hudak²⁴ analyzed chloride and nitrate distribution of 53 water wells in Hickory aquifers in Texas and reported that 70 % of water need of the region was supplied. Hudak²⁵ analyzed sodium and hardness levels in 7728 water wells in Texas, which were opened using GIS for supplying water. McGinnis and Davis²⁶ compared the quality of well waters which were opened domestic use in two separate lands spared for Northern Americans in east of Nebraska. Ortiz *et al.*²⁷ analyzed special fluoride values based on environmental data in Durango State of Mexico. The city was divided into four sections and was assessed in terms of health. According to Sharma *et al.*²⁸, a report indicating fluoride amounts in ground water in Guwahati region in north-east of India was made. The hydro-chemical data of the ground water was associated with this report and the area was categorized using GIS. Mallatt *et al.*²⁹ detected the locations of ground waters in India and detected the locations of naturally-formed fluoride concentrations. Fluoride amounts of the samples collected from 8519 wells were analyzed and were mapped using GIS. Gingerich³⁰ collected samples from 479 wells in different parts of the city in Canada and analyzed fluoride amounts. Geographical information system was also used and categorized maps of the region were produced.

This investigation has been aimed to study the pattern of fluoride abundance in bulk and fractionated soils from Konya district to compare the results with the combined groundwater fluoride concentration of the same area and prepare fluoride concentration map of Konya city ground water.

EXPERIMENTAL

The province of Konya is located on the 36.5-39.50 north longitudes and 31.5-34.50 east latitudes. Konya is the largest province of Turkey with its 38,183 km² area. The population of the city centre is around 980,000 in year 2009. The water samples which were used in experiments were collected from public wells in Konya city centre. The samples were obtained with the help of Konya metropolitan municipality Konya Water and Sewage Administration personnel.

Method: Fluoride measurements were carried out using standard fluoride electrode combined in ion-meter¹¹. For making the measurements of the samples with

this method, before the calibration of the ion-meter, the samples pre-processed. In this process, for providing prepared standard fluoride solutions and samples ion balance and for an accurate measurement fluoride concentration, it is necessary to prepare TUSAB II (low-level) solution and to add this into fluoride samples³¹.

Geographical Information Systems (GIS) have been an important tool for solving many problems in rapid and efficient manner. The use of geographical information systems in the solution of environmental problems is one of the most significant and successful applications³². In the mapping of the data and in analyses, ArcGIS 9.2 was used as GIS software. The location of 50 wells from which drinking water requirement of Konya province were supplied was entered to the software as point data and wells layer was formed. The name of the well was entered as General Information. The attribute information of water quality is fluoride concentrations.

RESULTS AND DISCUSSION

Many studies have been carried out studies on the fluoride levels in drinking water. Tokalioglu *et al.*³³ analyzed fluoride levels of drinking water samples collected from 14 different settlements places of Kayseri province, including its districts, towns and villages. Frequency distributions of 61 drinking water were according to concentration ranges were determined and 23 % of the detected fluoride levels were found to be between 0.1 and 0.15 mg L⁻¹. In around 80 % of all measurements, the concentrations were around 0.25 mg L⁻¹. In water distribution network of Soria province of Spain, fluoride level was found to be 0.2 mg L⁻¹ and it was found that fluoride amount was low. As a result of this an increase was observed in the tooth cavities of the children living in that region^{34,35}. Fluorine has the highest chemical reactivity among all known elements and occurs mainly as free fluoride ions in natural waters, although some fluoride complexes also exist under specific conditions. It was reported that the assimilation of fluoride by the human body from drinking water with concentrations above 1.5 mg L⁻¹ might result in fluorosis^{36,37}. In another study which investigated the effect of fluoride in tooth cavities it was found that, the low fluoride concentration has an important role in tooth cavities³⁸. Spencer³⁹ reported that if fluoride amount in drinking water is below 0.3 ppm, for the prevention of tooth cavities, (the children between 6-month old and 3 years of age) should be given 0.25 mg/day fluoride. In 1996, in California, Los Angeles and Bakersfield, fluoride detection was made in rivers and lakes especially in picnic areas where people usually visited and fluoride amount was found to be between 3.6-5.3 ppm. For reducing these high fluoride values, ion exchanging membranes were developed and applied⁴⁰. Similar with previous studies, fluoride amounts in 40 % of the results found in present study was between 0.15-0.20 mg/L and 92 % of the samples were between 0.15-0.42 mg L⁻¹ (Table-1).

The digital map of the study area was produced and fluoride concentrations of well waters were entered to the map and spatial analyses were made (Fig. 1). The maps of the location of water wells, spatial map according to level of fluoride

TABLE-1
 FLUORIDE MEASUREMENT RESULTS OF 50 WATER
 WELLS IN KONYA CITY CENTRE [Ref. 11]

Sampling points	Fluoride conc. (mg/L)	Sampling points	Fluoride conc. (mg/L)
Parsana 1	0.16475	Mengene 1	0.27188
Hasanköy Çev. Yolu	0.16061	Kovanagzi	0.22650
Tip 1	0.21989	Organize 3	0.11831
Yanik Camii	0.39168	Orman Müdürlüğü	0.12240
Malas 6	0.18792	Beybes	0.20808
Parsana 2	0.19277	Askan	0.13324
Malas 2	0.17859	Aksinne	0.30620
Malas 7	0.13610	Organize 2	0.13212
Kas 6	0.10640	Besyüzevler 7	0.21345
Musalla 1	0.12397	Aksemsettin	0.14322
Selver 1	0.13381	Oto Galerisiler	0.11932
Hatip	0.14879	Sezerler	0.26280
Ali Tasoluk	0.09249	Alakova 3	0.13495
Malas 1	0.15993	Hocacihan Hicaz	0.23735
Besyüzevler 8	0.16972	Sille Çayıçı 2	0.26058
Harmancik	0.11632	Hayvan Pazarı 4	0.19359
Meram 1	0.20458	Hasanköy 5	0.23836
Yunus Emre	0.16198	Alakova 2	0.13268
Esenler	0.13268	Çingirikli Kuyu	0.16980
Uzun Harmanlar	0.12989	Trafik Egıt.Parki	0.15393
Kongaz 2	0.14444	Çakil Harmanlar 1	0.14322
Yediler	0.14879	Alavardi 1	0.25619
Kas 1	0.10731	Hasanköy 4	0.17484
Selbasan	0.27771	Aydinlik	0.28008
Mengene 2	0.16336	Sakarya	0.42278

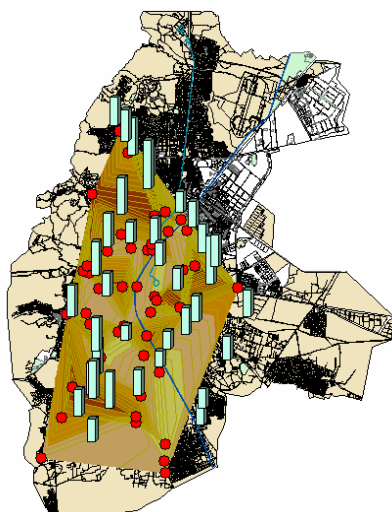


Fig. 1. Fluoride concentration level of study area according to sampling points

concentrations and fluoride amounts in the region are given in the map. In the study fluoride levels were determined, analyses were made with the spatial distribution in Konya city centre and fluoride concentration levels of each region were indicated.

The map which was produced after the association of the data with GIS, indicates that in city centre fluoride amounts are between determined values. However, north-east section of city centre has higher fluoride amount. A part of south-east section of the city appears as the area with high fluoride amount. From the results described above, all city centre places have been investigated with analysis of fluoride showed poor for fluoride minerals that is not gain to underground water enough fluoride levels. From the GIS map, around Selcuklu area a little bit higher than other places but not enough fluoride to gain the public water. When the figures are analyzed it is clear from fluoride map of the city that there is no problem in terms high concentration of fluoride for human health. On the other hand, fluoride levels of most of the places have lower concentration which is inconvenient for teeth and bone health. It is urgently needed to inform the people living these places to take care about fluoride necessity of the body, especially for infants.

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