Case Study

Health risk Assessment of water polluted with fluoride in the mining area in southern Tunisia: The case of the region of Berka

ABSTRACT

Aims: As part of risk assessment we looked at the health impact of consuming polluted water with fluoride in an exposed population in the region of Berka in the mining area of Gafsa. The main objective of this study was to evaluate and prioritize the health risks of water polluted with fluoride by the method of Kinney. The secondary objective is to propose a corrective action plan.
Study design: Descriptive.
Place and Duration of Study: The study was conducted in the southwest of Tunisia, belonging to the mining area of south Gafsa (Moulares-Redayef basin) between February and June 2012.
Methodology: The approach adopted in the Health Risk Assessment of water polluted with fluoride is one of the Ranking methods named the method of Kinney which classifies risks according to their severity. It consists on (1) Research of the identified hazards with the population concerned, (2) analyze them, (3) Develop a strategy and (4) Set priorities.
Results: Following this process of health risk evaluation of water pollution with fluoride, we have been able to show that over 50% of the population had presented dental fluorosis and 11% of our population had a very high score of risk.
Conclusion: Secondary health risks to water polluted with fluoride were important in our study population and a corrective action plan was proposed. This encourages us to promote the dosage of fluoride in water and the updating of Tunisian standards for drinking waters.

Keywords: Water pollution, Fluoride, Risk assessment, Method of kinney, Prevention.

1. INTRODUCTION

In recent decades, environmental health and the issues it raised have attracted more and more concerns from civil society, public authorities, policy makers and whistleblowers [1].

Hamed in its works in hydrogeology [2] highlighted fluoride rates that exceed the drinking water standards[3,4] in the region of Berka in the mining area of Gafsa.

Frequent uptake of fluoride can cause osteoporosis and tooth decay. The fluoride can damage the kidneys, bones, nerves and muscles [5]. To this end, we have considered in this study to assess the health risks of drinking polluted water with fluoride in the area of "Berka".

After presentation of the location and the study population, we present the adopted methodology which is one of the methods of "ranking" to classify risks according to their seriousness "the method of Kinney" [6] and for that we have: (1) prepared a questionnaire through which we collected the necessary data in our study; (2) prioritized potential health risks associated with exposure to fluoride; (3) and assess the health risks related to exposure to fluoride in drinking water.

2. MATERIAL AND METHODS

2.1 Location of the study

The study area is located in the southwest of Tunisia, belonging to the mining area of south Gafsa (Moulares-Redayef basin) covering an area of approximately 300 km^2. Faced with an increasing water demand, recourse to groundwater becomes very important. Such demand was caused by the industrial complex installation of the the Gafsa Phosphate Company (CPG), the rapid growth of the population and the development of agriculture (several irrigated areas). A portion of this basin (about 80 km^2: Berka area) is contaminated by discharges from the mining town laundries of Moulares and also the second mining town of Redayef as well as releases from the National Office of Sanitation (ONAS) [2].

The mining area contains a multilayer aquifer system whose main levels with hydrous potentials (major water reservoirs) are represented by the formations of: (1) fractured limestone (carbonate) located in the recharging zones (bordering areas), (2) friable sand localized in discharge zones (outlet).
The hydrogeology of this system is highly influenced by laundry discharges. In the region of Berka [2], groundwater is exploited by shallow wells with less than 6 m depth. Knowing that the land lithological nature is mainly sandy (high porosity that exceeds 35%) [7] which promoted the infiltration of these releases to the water table. In addition the region is geographically located in a seismically active region [8]. The locals use groundwater mainly from the surface water table for drinking water supply and in agriculture.

2.2 Study population

According to the 2004 census, there were 24 487 inhabitants in Moulares. The region of Berka had 250 inhabitants. It is a rural area. A primary school is located in the village center welcoming young children that form a vulnerable population exposed to fluoride. It also has a dispensary type I, located 8 km from the delegation of Moulares. In order to assess the health risks of water polluted with fluoride in the region of Berka, we considered taking a sample population of 100 people distributed by age as follows: (1) pre-school child: less than 6 years; (2) school child: 6 to 15 years; (3) Young: 15 to 30 years; Adult: 30 to 50 years; Aged: over 50 years.
In this sample population of Berka, we introduced a pre-established questionnaire to gather necessary data required for the health risk assessment of water polluted with fluoride according to the Kinney's model [6].

2.3 Methodology

The approach used in health risk assessment of water polluted with fluoride, consists in seeking identified hazards among the population concerned, analyze them, develop a strategy and set priorities. This approach, the method of "Kinney" [6] is one of the ranking methods that classify risks according to their severity.
This method from 1976 was named after its inventor, an American researcher; is probably one of the best known [9]. It is based on tables giving values depending on the effect (E), the exposure frequency (F) and the probability (P) and assesses the risk (R) by the following expression: $R = E \times F \times P$.

3. RESULTS

3.1 Description of study population

Initially, we planned to take a random sample population of 100 people. During the first going out to the region of Berka, we were able to interview 60 subjects (Table 1). However, the security circumstances prevented us to question the remaining 40 subjects. Fifty-three subjects of the study population reside permanently in the region of Berka or 88% including 34 are male or 56%; and 26

are female or 44%. The health status of individuals who participated in this study was described as very good to very poor depending on the participant.

Table 1. Real study population « the selected sample »

Age	N	(%)
Pre-school child (< 6 years)	8	13
School child (6 à 15 years)	12	20
Young (15 à 30 years)	16	27
Adult : (30 à 50 years)	14	23
Aged (> 50 years)	10	17

3.2 Data regarding fluoride exposure

Before its connection to the national water distribution utility (SONEDE), the population of Berka was consuming local well water. Currently, some people still use well water due to the difficult access to the public drinking-water distribution system. Fifty-one percent (51%) of our study population consumes mainly well water, the rest consumes tap water since 6 years.

3.3 Risk assessment

3.1.1 Health risk assessment of water polluted with fluoride

The risk score in case of dental fluorosis varies from 0.05 to 100 with an average of 32.6.
The risk score in case of goiter varies from 0.15 à 1.8 with an average à 1.24.
The risk score in case of renal impairment varies from 0.35 à 42 with an average à 7.93.
The risk score in case of bone involvement varies from 0.75 à 900 with an average à 64.05.
The risk score in case of neurological damage varies from 5 à 1000 with an average à 74.33.
Regardless of the effect, the average risk score by age group increases proportionately with age. Indeed, the higher the age is, the greater the duration of exposure to the pollutant increases.

3.1.2 Preventive measures to be taken

We noted that in our population 7 cases had a very high risk (11% of cases); 4 cases with an advanced bone involvement and 3 cases have a significant neurological damage. Attention should be required for dental fluorosis, since 58% of our study population belongs to the category 4. Similarly for the problem of crippling skeletal fluorosis as well as to the neurological damage, attention should be required given that more than 50% of our study population belongs to the category 4. The thyroid disorder, the goiter in particular was not detected in any of the participants in this study.

4. COMMENTS AND DISCUSSION

4.1. Health risk assessment

Our results match those of the literature in terms of secondary effects of fluoride. Indeed, we noted particularly in our study population dental fluorosis, bone involvement and neurological damage [10–13].

The risk score was very significant in 7 cases (11% of our study population). This is a quit important number for a study population of 60 people. This tells us that special attention should be paid about this issue.

Presently , the National Research Council (NRC) recommends the Environmental Protection Agency (EPA) to lower the permitted limit due to a large body of evidence linking fluoride ingestion with increased rates of bone fracture, joint pain (arthritis) and damage to teeth (dental fluorosis) [12]. As such, an important consideration in the NRC report explains that since the function of the enamel is to protect the inside of the tooth from external attacks, dental fluorosis cannot be regarded as a

purely aesthetic problem [12]. In fact, Dr. John Colquhoun said that "Common sense tells us that if a poison circulating in the body of a child happens to damage the cells in developing teeth, there are probably other harmful effects". Common sense also tells us that since dental fluorosis affects more than 50% of our study population, corrective action must be taken as soon as possible.

4.2. Corrective action plan

Water is said potable when it satisfies a number of characteristics that make it safe for human consumption. Reference standards in this field vary over time and countries and according to the authority in charge in some countries. The concept of "drinkability" varies around the world. It is the result of historical, scientific and local cultural context. It determines the issue of access to water, since good quality water is essential to the economic and human development.

An action plan must be set up to prevent any impacts that may result from the identified risk (water polluted with fluoride):

- On a collective level:
  - Submit water to people who have difficulties to access to the public drinking-water distribution system.
  - Raise awareness of Berka's population of the harmful effects of polluted water consumption (well water) on their health.
- On an individual level:
  - Supports subjects with a very high risk score.
  - A quantitative risk assessment of urinary fluoride concentrations may be practiced by taking measurements.

5. CONCLUSION

The health risk assessment of water polluted with fluoride, in the region of Berka was conducted by the method of Kinney. The latter allowed us to objectify risk assessment by prioritizing the health risks and assessing risks taking into account the risk score calculated from the product of the occurrence probability score of a harmful result, the exposure frequency and the severity of that consequence or effect. Thus, this will allow us to identify priorities for preventive actions to implement.

As a result of this health risk assessment approach to water pollution with fluoride, we were able to show that over 50% of the study population had dental fluorosis and 11% of our population had a very important risk score.

An action plan must be set up to prevent any impacts that may result from the identified risk (water polluted with fluoride).

REFERENCES

1. Regional Observatory of the Rhône-Alpes Health Montestrucq L, Guye O. The quantitative health risk assessment (EQRS). Principle and method. 2007. Accessed 26 Feb 2012 Available: http://www.ors-rhone-alpes.org/environnement/pdf/dossier1.pdf

2. Hamed Y. Characterization Hydrogeological, hydrochemical and Isotopic Aquifer Systems of Syncline Moulares-Tamerza (South West Tunisia). 2009. French.

3. French standards of water quality for human consumption. Decree of 11/01/07 concerning the limits and quality references of raw water and water intended for human consumption referred to in Articles R. 1321-2, R. 1321-3, R. 1321-7 and R. 1321- 38 of the Code of Public Health. Accessed 26 Feb 2012 Available: http://ile-de-france.sante.gouv.fr/santenv/eau/regle/a070111_l_r.pdf

4. World Health Organization. WHO standards for drinking water. French. Accessed 26 Feb 2012 Available: http://www.lenntech.fr/applications/potable/normes/normes-oms-eau-potable.htm

5. Fawell J. *Fluoride in drinking-water*. Geneva: World Health Organization, 2006. Accessed 7 Apr 2012. Available: http://www.who.int/water_sanitation_health/publications/fluoride_drinking_water_full.pdf

6. Kinney GF, Wiruth AD. *Practical Risk Analysis for Safety Management*. China Lake, CA: Naval Weapons Center 1976. Accessed 26 Feb2012.
Available: www.dtic.mil/dtic/tr/fulltext/u2/a027189.pdf

7. Mr. besbes hydrogeological study of Moularès Redayef-basin (mathematical model). 1978. French.

8. Ahmadi R. Using morphological markers, sedimentological and microstructural for validation of kinematic models of folding. Application to the southern Tunisian Atlas. 2006. French.

9. © FPS Employment, Labour and Social Dialogue. The risk analysis. 2009. French. Accessed 26 Feb 2012
Available: http://www.emploi.belgique.be

10. Connett P. 50 Reasons to Oppose Fluoridation. *Med Veritas* 2004;1:70–80.

11. Malchaire J, Koob J-P. Reliability of the risk analysis method Kinney. 2006; 43: 3-8.

12. Committee on Fluoride in Drinking Water, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies, *et al. Fluoride in Drinking Water: A Scientific Review of EPA's Standards*. National Academies Press 2007. Accessed 7 Apr 2012.
Available: http://books.nap.edu/openbook.php?record_id=11571&page=R1.

13. Fluoride action network. 10 Facts About Fluoride. 2012. Accessed 7 Apr 2012.
Available: http://www.fluoridealert.org/fluoride-facts.htm