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 explored health impacts 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 polluted water 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, in 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 in 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 risk score.
Conclusion: Secondary health risks to polluted water 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 its issues have attracted more and more the concern of civil society, public authorities, policy makers and whistleblowers [1].

In his research work in hydrogeology, Hamed [2] showed some fluoride rates that exceeded the drinking water standards [3,4] in the region of Berka in the mining area of Gafsa. Fluoride in drinking water is our main source of it [5]. Different absorption levels of fluoride can be estimated by its concentration in the drinking water in various regions, food and beverages consumption, the use of toothpaste etc [5]. In the absence of specific measurements of the population, fluoride exposure is calculated from scenarios based on different lifestyles [5].

Frequent uptake of fluoride can cause osteoporosis and tooth decay. The fluoride can damage the kidneys, bones, nerves and muscles [6]. For this purpose, in this study, we have considered 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 "the method of Kinney" [7] which is one of the "ranking" methods used to classify risks according to their seriousness. For this purpose, 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, in the mining area of south Gafsa (Moulares-Redayef basin). It covers an area of approximately 300 km^2. Due to the increasing water demand, the use of groundwater becomes very important. Such demand was caused by the industrial installation of the phosphates exploitation company complex (Compagnie de Phosphates de Gafsa - 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 phosphate mine waste lavatory of Moulares and Redayef and releases from the National Office of Sanitation (ONAS) [2].

The mining area contains a multilayer aquifer system. The main levels with hydrous potentials of this system (major water reservoirs) are represented by the formation of: (1) fractured limestone (carbonate) located in recharge areas (bordering areas), (2) friable sand localized in discharge zones (outlet).

The hydrogeology of this system is highly influenced by the discharges from phosphate mine waste lavatory. In the region of Berka [2], groundwater is used by shallow wells with less than 6 m depth.

The infiltration of discharges to water table is promoted by the lithological nature of the land which is mainly sandy (high porosity exceeding 35%) [8]. In addition, the region is geographically located in a seismically active region [9]. The locals use groundwater mainly from the shallow water table for drinking and in agriculture.

2.2 Study population

According to the 2004 census, there were 24 487 inhabitants in Moulares. The region of Berka contains 250 inhabitants. It is a rural area. A primary school is located in the village center educating young children who are a vulnerable exposed population to fluoride. It also has a medical 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 [7].

2.3 Methodology

The used approach in health risk assessment of water polluted with fluoride consists in exploring identified hazards among the study population, analyze them, develop a strategy and set priorities. This approach, the method of "Kinney" [7] 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 [10].

The kinney method is based on tables giving values depending on three factors; the probability (P), the exposure frequency (F) and the effects (E). The risk index or the risk score (R) is numerically calculated by the following expression: R= E x F x P.

- **The probability « P »**

The probability (P) or the (mathematical) risk indicates a prediction and is assigned a reference number from 0.1 to 10 (Table 1.1).

- **Frequency « F »**

The frequency factor (F) gives an idea of the period of risk exposure. Exposure frequency factors vary from 0.5 à 10 (Table 1.2).

- **Effect « E »**

The effect factor (E) indicates damages and possible consequences when the risk occurs. The scale isbetween 1 and 100 (Table 1.3).

Those risk scores are classified into five categories (table 2).

Table 1.1. The probability

0,1	Hardly conceivable
0,2	Almost impossible
0,5	Conceivable but unlikely
1	Unlikely but possible
3	Slightly common
6	Highly possible
10	Predictable

Table 1.2. The exposure frequency

0,5	Very rare (less than once/year)
1	Rare (annual)
2	Sometimes (monthly)
3	Occasional (weekly)
6	Regular (daily)
10	Continuous (permanant)

Table 1.3. Health effects

1	**Small :** benign dental fluorosis
3	**Important:** goiter
7	**Severe:** renal damage
15	**Very severe:** bone fractures (osteomalacia, osteoporosis)
40	**Grave :** disabling fluorosis
100	**Very grave :** neurological damage

Table 2. Risk scores and indexes and potential preventative measures

Risk indexes	**Risk**	**Risk scores**	**Preventative measures to be taken**
R ≤ 20	Very low	**1**	Acceptable
20 < R ≤ 70	Possible	**2**	Attention required
70 < R ≤ 200	Substantial	**3**	Measures required

200 < R ≤ 400	Significant	**4**	Immediate improvement required
R > 400	Very Significant	**5**	Stop the exposure

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 3). However, the security circumstances prevented us to question the remaining 40 subjects. Fifty-three subjects or 88% of the study population reside permanently in the region of Berka (including 34 are male or 56%; and 26 are female or 44%). The health status of individuals participated in this study was described as very good to very poor depending on the participant.

Table 3. 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 9 years.

3.3 Risk assessment

The main clinical manifestations sought in our study population and mean values of risk indexes for each health effect are summarized in Table 4. The thyroid disorder, particularly the goiter was not detected in any of the participants in this study, thus, its mean risk score is low. Event though, few samples are affected by severe neurological damage, its mean risk scores is the highest (74.3) (Table 4).

Whatever the effect, the average risk indexes per age group, increases proportionally with age (Table 5). Indeed, the higher the age is, the greater the duration of exposure to the pollutant is.

In our study population, we noted that 7 cases had a very high risk; 4 cases with very severe bone fragility and 3 cases with significant neurological damages. The risk score of bone fragility varies from 1 to 5 (Table 6).
For dental fluorosis, attention would be required; especially that 58% (35 cases) of our study population belongs to the category 2. Similarly for the problem of crippling skeletal fluorosis and neurological damage, since 55 to 70 % of our study population belongs to the category 2 (Table 6).

Table 4. Secondary pathologies caused by fluoride exposure

Pathologies	Total		Men		Wemen		Risk indexes	
	N	%	N	%	N	%	Min-Max	Mean
Dental fluorosis	**43**	71.6	**28**	46.6	**15**	25.0	0.05-100	**32.06**
Goiter	**0**	0.0	**0**	0.0	**0**	0.0	0.15-1.8	**1.24**
Renal damage	**8**	13.3	**7**	11.6	**1**	1.6	0.35-42	**7.93**
Bone fragility *	**18**	30.0	**9**	15.0	**9**	15.0	0.75-900	**64.05**
Skeletal fluorosis	**0**	0.0	**0**	0.0	**0**	0.0	2-40	**16.53**
Neurological damage	**3**	5.0	**2**	3.3	**1**	1.6	5-1000	**74.33**

* : (osteomalacia and osteoporosis)

Table 5. Risk indexes by age group

by age group (years)	Risks					
	Dental fluorosis	Goiter	Renal damage	Bone fragility	Disabling skeletal fluorosis	Neurological damage
< 6 years	4.7 *(0.1-36)*	0.8 *(0.2-1.8)*	1.8 *(0.4-4.2)*	3.8 *(0.8-9)*	10.3 *(2-24)*	25.6 *(5-60)*
6 to 15	20.7 *(0.1-60)*	1.4 *(0.2-1.8)*	3.4 *(0.4-4.2)*	7.2 *(0.8-9)*	19.2 *(2-24)*	47.9 *(5-60)*
15 to 30	46.3 *(0.1-60)*	1.4 *(0.3-1.8)*	10.4 *(0.7- 42)*	17.2 *(1.5-90)*	18.8 *(4 - 24)*	46.9 *(10 - 60)*
30 to 50	40.7 *(10-60)*	1.3 *(0.3-1.8)*	10.8 *(0.7-42)*	40 *(1.5-90)*	16.9 *(4-24)*	42.1 *(10-60)*
> 50 years	32.8 *(10-100)*	1.1 *(0.3-1.8)*	10.1 *(0.7-42)*	289.2 *(1.5-900)*	14.4 *(4-40)*	234 *(10-1000)*

Table 6. Risk scores based on effects

Case numbers for each effect						R*	SR**
Dental fluorosis	Goiter	Renal damage	Bone fragility	Skeletal fluorosis	Neurological damage		
0	0	0	4	0	3	**R>400**	**5**
0	0	0	0	0	0	**200<R<400**	**4**

1	0	0	10	0	0	**70<R<200**	**3**
35	0	8	2	33	42	**20<R<70**	**2**
24	60	52	44	27	15	**R<20**	**1**

* Risk ** Risk score

4. COMMENTS AND DISCUSSION

4.1. Health risk assessment

Our results match with those in the literature concerning secondary effects of fluoride. Indeed, in our study population, we noted particularly dental fluorosis, bone involvement and neurological damage [11-13].

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 of USA) recommends the Environmental Protection Agency (USEPA) to lower the permitted limit. This was due to a large body of evidence linking fluoride ingestion with increased rates of bone fracture, joint pain (arthritis) and tooth damage (dental fluorosis) [12]. To this end, an important point was raised in the NRC of USA report. It tells that since the enamel's function 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 [14] 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 to be 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 of 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 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:
  - Support 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 polluted water 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. The risk assessment takes into account the risk scores 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).

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