PHYSICOCHEMICAL QUALITIES OF WELL WATER CONSUMED BY THE INHABITANTS OF THE BOUJNIBA MINING AREA IN MOROCCO: IMPACT ON THE SPREAD OF DENTAL FLUOROSIS

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Abstract: Groundwater contamination is mainly associated with anthropogenic inputs (fertilisers, filling station, chemical industry, menagers waste). Analysis of physicochemical qualities of well water in the Boujniba mining region determines the concentrations of calcium, phosphates, ammonium, fluorides related to their pollution in groundwater. The calcium, ammonium, and phosphate contents were determined on 17 samples of well water, fountains, by spectrophotometric methods. The fluorine contents of the water were analyzed by the potentiometric reference method using the fluorine electrode. Physicochemical analyses of the calcium, phosphate, ammonium, and fluorine contents of well water for consumption by the population revealed contents between 80 and 144 mg/l, from 0 to 56.5 mg/l, 0 to 75 mg/l, and 0.02 to 6.39 mg/l, respectively. Phosphate, calcium, ammonium levels of the different well waters analysed present higher values to standard references. 50% of well water samples' fluorine levels reveal values above recommended standards for children and adults. High levels of fluoride in drinking water have repercussions on the onset of dental fluorosis in children. This study plays a vital role in determining the quality and its use for drinking water supply and the impact on human health. These results make it possible to warn the population of the risk of developing dental fluorosis by limiting the amount of fluoride ingested by the food consumed and taking hygiene and regular control measures.

Keywords: Fluorine; potentiometer; phosphates; calcium; water; fluorosis, Boujniba mining area.

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INTRODUCTION

Water is an essential element for all living beings and constitutes a non-substitutable resource, essential for biological life. Water is also involved in many physiological functions, enters into the constitution and cellular organization [1], and assigns essential roles in the human body such as digestion, absorption, thermoregulation, and waste disposal [2]. Water is an important source of mineral elements that complete the specific needs of our diet. Water can constitute a site of infection responsible for the transmission of so-called water-borne diseases.

The drinkability of the water intended for human consumption should receive special attention. This water must not contain any dangerous chemical substances or harmful pathogens likely in the more or less long term to individual's health [3-5]. Drinking water qualities raise human health concerns in developed and developing countries around the world. The health risks are linked to the presence of infectious agents, toxic chemicals, or even radiological hazards. Water and sanitation are essential for public health and constitute the base access to safe water and proper sanitation, the fight against many diseases [6].

Agricultural, industrial and threatening environmental practices have challenges on the consumption of drinking water. In the Boujniba region, activities are mainly mining with the exploitation of phosphate resources. An emission of

wastes consisting of fluorine at the base of the gaseous and dusty emissions with a high fluoride load in the receiving environment produces harmful effects on the environment, animals, and humans. Population growth and industrial growth are severe threats to the health of our people today [8]. The supply of drinking water to populations in sufficient quantity during all seasons is a major concern of the various governments.

The treatment by defluoridation of water is a process that has a lot of potential for the availability of drinking water [9,10].

In this study, we seek to highlight the levels of calcium, phosphates, fluorine and ammoniums contained in the well water in relation to transfers to groundwater related to industrial pollution menagers. The physical analyses of the drinking waters of the population of Boujniba reveals the interest in quality controls related to preventive management, encompassing the supply of the water source to the consumer.

EXPERIMENTAL

Geographic meteorological data of the sampling locations

Boujniba is a city in the province of Khouribga belonging to the region of Beni Mellal-Khénifra. It has an area of 4.250 km², with a dimension of about 100 km long and 80 km wide. It's bounded by the meridians 6°30' and 7°35' and the parallels 32°30' and 33°. Khouribga belongs to the regional set of plateaus and massifs of Atlantic Morocco, in a sub-group called "the plateau of phosphates. The Khouribga region, known as a mining site, is made up of several douars. The douars are regrouping the exploitation of phosphate are represented in Figure 1.

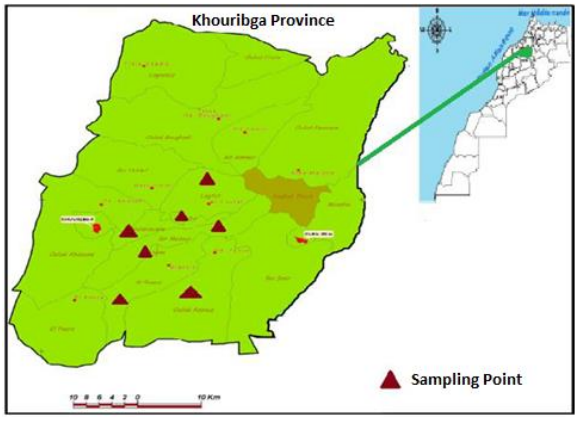

Figure 1. Mapping of rural communities in Khouribga region indicates the different sampling points.

MATERIAL

Characteristics, approximate depth, and the composition of the different wells are carried over to the table 1. Sampling was taken from different wells to assess the physicochemical quality according to the distance from the mining area and the wells position (Table 1).

The water samples were taken during the periods of February and May 2021 in the different well waters of douars of the Boujniba region. The water is collected from different wells, fountains in polyethylene vials and transported in double or triple samples at 4° C.

The samples were taken with the owners' consent and with additional information on the general health status, the impact on the occurrence of dental fluorosis, the consequences on livestock and agricultural production.

Survey on the prevalence of fluorosis in the region

A cross-sectional prevalence study was conducted among 100 inhabitants, to assess the prevalence of dental fluorosis conducted during the 2020-2021 academic year.

Socio-demographic characteristics: sex, age, marital status, environment of origin, occupation, smoking, oral hygiene, food products consumed were determined in order to identify the sources of supply of drinking water. Clinical data on dental fluorosis were collected in the population.

Table 1. Location and characteristics of water sources

Sample	Territory	Distance from the mine (km)	Source	Depth (m)	Use
P1	Oulad Abdoune	4.5	well	80-90	farm
P2	Mchahra Lagfaf	8	fountain	--	farm
P3	Hattane	9	well	60	farm
P4	Bir Mezoui	11.5	well	85	farm
P5	Mchahra	12	well	60-70	farm
P6	M'Fassis x	13	well	50	farm
P7	Lagfaf	18	well	18	souk
P8	Oulad Azzouz	20	well	80	farm
P9	Boujniba	22	fountain	--	town
P10	Souk Lagfaf	25	well	50-60	trader
P11	Douar Alhrar	27	well	50-60	road
P12	Road Beni khirane	32	well	50-60	farm
P13	Road Ezzhiliga	50	well	50-60	house
P14	Oulad Brahim	58	well	18	road
P15	Bir Mezoui	61	well	34	farm
P16	Hattane	9	tap	--	house
P17	Boulanouare	5	tap	--	house

METHODS

Calcium level analysis

The calcium content is determined according to the CPC method described by Moorehead [11]. In an alkaline medium, o-cresolphthalein complexon or CPC reacts with calcium ions to form a dark red colored complex whose absorbance, measured at 570 nm, is proportional to the calcium concentration in the specimen.

Phosphates levels analysis

In nitric acid, phosphates give yellow colored complex with solutions of ammonium molybdate and meta-vanadate. This color reaction makes it possible to carry out a colorimetric dosage of the phosphates.

Fluoride level analysis

The fluoride level is determined by the potentiometric fluoride reference method, direct measurement using selective membrane electrodes indicating the fluoride ion. The method can be directly used to measure fluoride concentrations of 0.02 mg/l to 2.0 g/l. In order to avoid complexes with fluorides or precipitates, the assay is carried out by first adding the buffer solution containing trans-diamino-1, 2-cyclohexane-N, N, N', N'-tetraacetic acid (CDTA) as a decomplexing agent, to release bound fluorides.

Ammonium level analysis

The determination of ammonium ions is carried out using the salicylate method (center of expertise Canada). Ammonia in

the presence of hypochlorite forms a monochloramine, which reacts with salicylate to form 5-aminosalicylate [12]. The oxidation of 5-aminosalicylate is then caused in the presence of a catalyst to form a blue compound, indosalicylate. This compound in the presence of excess nitroprusside (yellow solution) gives a green solution.

Chlorides level analysis

Chloride levels are determined by the colorimetric method [13]. This method is based on the reaction of unsociated mecuric thiocyanate to form non-dissociated mercuric chloride and ions free thiocyanates. Thiocyanate ions react with ferric iron to form a complex colored in red whose absorbance is determined at 400-500 nm. The concentration of chloride levels in the samples is determined by reference to a chloride standard.

Magnesium level analysis

Magnesium levels are determined according to the method described by Guidler et al. 1[1-hydroxy-4-methyl – phenylazo]-2-naphthol-sulfonic acid), a matallochromic indicator, forms a complex colored, in alkaline medium with magnesium. The absorbance is measured at 530 nm and is proportional to the magnesium concentration in the specimen.

RESULTS AND DISCUSSION

Water temperature analysis

The water temperature is an important factor in that it governs almost all physical, chemical, and biological reactions. The different wells water temperature values show variations of between 16°C to 24°C (Table 2).

pH and conductivity analysis

The pH influences most of the chemical and biological mechanisms in water. The pH of the different well water analysis reveals values between 8.28 and 9.16 (Table 2). Four wells have slightly lower pH water values than fountains. The pH value of the water well Oulad Azzouz well is lower than that of the other wells. This ground water has a high level of alkalinity. All the water from the various wells exceeds the WHO's permissible value (6.5<pH<8.5). The alkaline nature of the samples may be due to a high concentration of bicarbonates.

The conductivity values recorded in the water from the various wells are between 4000 and 10700 µS/m (Table 2). The conductivity characterized in the water from the wells of the different douars is greater than that of mineral water. The electrochemical analysis showed high conductivity values, reaching 10700 µS/cm in the groundwater of the region. They greatly exceed 2500 µS/cm, the WHO threshold value [6], and the Moroccan standard set at 2700 µS/cm (NM 03.7.001) [14]. These high values indicate that these waters are highly mineralized, and the infiltration of wastewater could explain this into the water table. Nearby septic tanks could be the source.

Analysis of the level of phosphates

The analysis of phosphates in the water from the various wells and fountains reveals values between 0.4 mg/l to 56 mg/l (Table 2). Spring water and mineral water contain the lowest levels of phosphates. The phosphate content found in well water is higher compared to that in the fountain water. The phosphate levels in all well water samples could not meet the standards of drinkability indicated by the WHO [6], except the fountain and sanitation water, which does not show any trace of those. High phosphate levels in P5 and P8 wells located respectively in Mchahra and Oulad Azzouz farms, house may be due to contamination of domestic waste [15].

The phosphate levels in well water in the Boujniba region are similar to those evaluated in the mountainous waters of the Ganges in India and the rivers of Ouagadougou in Burkina Faso [16,17].

Calcium level analysis

The calcium analysis results determined in the different wells water reveal levels between 73 and 144 mg/l. (Table 2). The lowest rate is found in mineral water well Souk Lagfaf (weekly market).

The rates of 144 mg/l and 142 mg/l characterized respectively in the Hattane and oulad Abdoune douars wells are higher than the wells P6, P7, and that of the well of the Beni khirane road. The further the well is from the village of Boujniba, the more the calcium level decreases. The calcium levels characterized in the water from the various wells exceed the WHO's standard of 75 mg/l (WHO) [6]. These results reveal a phosphatière aquifer of limestone nature. Excessive consumption of calcium by the population is likely to cause hypercalcemia and consequently the development of nephrocalcinosis [18].

Ammonium level analysis

Analysis of the water's ammonium ion content from the different wells reveals variations between 12.5 and 75 mg/l (Table 2). According to the Guidelines for Canadian Drinking Water Quality, wells waters in the Boujniba region contain ammonium levels above the recommended standards of 0.5 mg/l [19]. Three water samples from wells P5, P6 and P7 show high ammonium levels. The waters of the fountains and the P8 well, far from mining sources, contain low ammonium levels. Ammonium in water reflects an incomplete degradation process of organic matter. It is, therefore, an excellent indicator of water pollution by the organic waste of agricultural, domestic or industrial origin [20]. Its inhalation may cause coughing, sore throat, nausea and vomiting. Contact with the skin or eyes causes redness.

Table 2. Different physic-chemical parameters of waters consumed in the Boujniba mining region

Sample	T (°C)	pH	Conductivity µS/m	NH_4^+ mg/l	PO_4^{3-} mg/l	Ca^{2+} mg/l	Cl^- mg/l	Mg^{2+} mg/l	F^- mg/l
P1	18	8.77	7600	59	42	142.22	245.4	44.6	6.1
P2	20	9.06	9500	50	35	115	378.9	41.8	0.9
P3	22	9.05	4000	25	3.2	144.44	178.6	39.2	5.8
P4	17	9.13	9000	25	11	131.11	456.9	32	4.7
P5	19	9.16	10400	70	56	126.66	222.8	30.8	4.1
P6	18	8.78	6100	73	24	91.11	356	32.1	3.5
P7	21	8.94	9100	75	34	120	456.8	29.8	3,8
P8	18	8.2	4300	12.5	50	80	142	26	2.7
P9	22	8.6	6200	55	48	91.11	89	43.1	0.8
P10	24	8.5	2800	53	0.4	73.33	189.2	38	1.2
P11	16	8.8	6300	48	15	90.32	116.63	25.8	0.02
P12	16	8.9	6500	45	26	84.72	66.65	38.4	4.7
P13	24	8.8	5600	35	39	85.48	266.59	35.4	6.39
P14	24	8.5	5600	30	44	114.98	50.5	43.7	0.1
P15	20	8.9	5600	60	28	89.41	2799.21	41.5	0.54
P16	18	8.5	10700	30	12	125.72	399.89	44.3	0.23
P17	20	8.6	8000	33	46	93.34	549.84	45.3	0.21

Fluoride level analysis

The analysis of fluoride content shows variations between 0.54 and 6.39 mg/l (Figure 2). The fluoride content of tap water (P16 and P17) and fountain water (P2 and P9) represent minimum values, thus constituting water permissible for consumption.

10 well waters contain fluoride levels above the recommended standard for adults (1.5 mg/l) and children (1 mg/l) (WHO. 2004) [6]. The water from the various wells has higher fluoride levels than the water from the sewage system and from the OCP (Office Chérifien des Phosphates). In Morocco, the water supplied by OCP has been treated [21].

The fluorine contents of the water from P2, P11, P14 and P15 wells are included in the drinking standards. The majority of the wells have a fluoride concentration above the value of 1.5 mg/l. This increase is due to the deposition of phosphates in the water. The concentration of fluoride in water can also be affected by the pH. Fluoride levels tend to be higher in alkaline waters and geothermal areas.

The results of the level of fluoride in the well water are comparable to those of El Jaoudi [22], which showed a concentration of 7.75 mg/l in the Khouribga region. The work of Moufti has revealed a fluoride concentration ranging from 2.4 to 4.4 mg/l in the Youssoufia region [23]. The low fluoride levels revealed in the other wells could be explained by climatic conditions. This can be explained by the climatic conditions; this year, Morocco experienced heavy rainfall in all regions.

Prevalence of the dental fluorosis in the population.

In such mining region, these high fluoride contents expose the population to a risk of dental fluorosis. The prevalence of dental fluorosis determined among inhabitants of douars in the Boujniba region is 96%. 50% of the inhabitants have missing teeth with colored, yellow, brown, respectively in 28%, 68% of the population (Table 3).

In the population (adults and children), the cross-sectional study revealed that 29% have mild fluorosis, and 71% are infected with moderate or severe fluorosis. The average age of onset of dental fluorosis is 14.46 years. In these mining areas, the high fluoride levels put the population at risk of dental fluorosis.

Table 3. Prevalence of fluorosis and variations in tooth staining in the population

% Patients with Fluorosis	Colouring teeth	Fluorosis degree
0	white spots	normal
4	not spots	no fluorosis
28	yellow spots	light
68	brown spots	severe

A high prevalence of dental fluorosis has been reported in other countries of the world [24,25]. The presence of fluoride in the environment can have adverse effects on animal and human health, including mental status. Other symptomatic effects include lameness, skeletal deformities, reduced feed and water intake, and reduced weight gain and milk production. In humans, increased fluoride intake may have neurotoxic effects and may also play an important role in the pathogenesis of Alzheimer's disease.

In the region of Boujniba Morocco, excess fluoride in water has consequences on the development of dental fluorosis in horses, the decrease in crop production such as wheat cultivation. Cereals harvested in regions where water is fluoridated have a high amount of fluoride [26].

Excessive ingestion of fluorine results in poor tooth development, stains, and erosion of enamel in animals [27].

Well water is mainly used for food consumption and agricultural use in the Boujniba region. Water is a source for preparing drinks (teas) very consumed by the inhabitants and is an important source of risk excess fluorine consumption of the Moroccan population [28,29].

CONCLUSION

The chemical quality parameters of well waters in the Boujniba region are mostly above the WHO potability standard. The water from the different wells has an alkaline pH. Phosphates, calcium, fluorides in 7, 16 and 4 well waters, respectively, have values higher than the recommended standards for population consumption. In Morocco, phosphate areas are considered endemic areas for dental fluorosis due to the high concentration of fluorine in the water in these regions; these results make it possible to warn patients of the risk of developing dental fluorosis by limiting the amount of fluoride ingested by the food consumed and by taking hygiene and regular control measures. The quality of water, sanitation and hygiene systems plays a central role in the prevention of infections and several diseases. Improving the quality of well water in the Boujniba region contributes to economic growth and reduces poverty. Additional measurements with farm owners must be carried out to encourage them to modify the installation and construction of wells and to be protected from external inputs. Communication means must allow easy access to water analyzes in order to ensure the protection of the population.

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