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Wastewater discharge impact on groundwater quality of Béchar City, Southwestern Algeria: Approach by microbiological analysis and health risk index evaluation

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This manuscript studies the problem of the wastewater influence on groundwater chemistry, particularly the microbiological quality setting and risk to public health in an urban environment, in an arid climate. The study of the spatial and temporal variation in the chemical and microbiological composition of Béchar city groundwater identifies the impact intensity that directly affects its quality. Microbiological analysis (total bacteria, total *coliforms*, *Streptococcus*, *Clostridium sulphite-reducing*), including microorganisms research (fecal *coliform*) indicators of anthropogenic pollution (sewage) is also made, confirmed and interpreted by significant microbial load presence, the highest ones are located south of the city. The evaluation of the risk index for the determiner: groundwater ingestion, with Pb and Zn ions, for children and adults, is significant, and worth 1.3 (Pb, children) which expresses a public health real risk presence, and appropriate measures must be recommended to eliminate it.

Key words: Béchar, quality, groundwater, microbiology, waste water, risk index.

INTRODUCTION

Developing country cities usually undergo rapid population growth, which generates multiple and complex problems (Ahoussi, 2008). To the growing challenge that water demand and management pose, is added wastewater rejection problems (Tandia et al, 1999; Bloundi 2005), and in our case arid climate influence on water resources (Mondal, 2005).

In the Third world countries, since full development time 1981 the "International Decade of Water Supply and Sanitation (IDWSSD)" we only dreams of multiplying the water amount to provide people. Yet in the poorest countries, the littlest are dying of thirst. However, millions of adults and children disappear every year due to water and environment pathogenic pollution. According to WHO,

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between 3 million directly and 20 million indirectly, per year, these cases are increasing with the world population growth (Monjour, 2000).

As a solution, we need a continuous water quality followed; this continuity must characterize the groundwater pollution monitoring evolution, particularly at depth. The water transfer modes and pollutants in the unsaturated zone, firstly in the aquifer, on the other hand, they must now imperatively be characterized in order to prioritize the various factors of pollution and take action appropriate protective (Chippaux et al., 2002; Ramakrishnaiah et al., 2009; Bricha et al., 2007; Obeidat et al., 2013).

In Béchar city, groundwater chemistry is influenced by the geological formations dissolution effect and the wadi water (urban wastewater, or precipitation) (Kabour et al., 2013). The waters of these aquifers are sought and used, despite their low flow, for daily needs (irrigation, Turkish bath, etc…), this situation requires to conduct an objective study to evaluate diagnosis of the water discharges impact on the environment, including the pollution degree (chemical and microbiological) of the groundwater quality in Béchar city.

The microbiological analysis of water used for drinking purposes allows us to understand the risk from pathogenic microorganisms; these microorganisms have the natural habitat intestines of man or some warm-blooded animals (Rabiet, 2006; Alhou, 2007; Elmore et al., 2005; Lamrani et al, 2007).

Biologically, wastewater contains various microorganisms, which in an aquifer contributes significantly changed their biological properties and damages the health of water (Belousova and Proskuriva, 2008), among them, there are numerous pathogens, usually human. As their identification is complex and time consuming, *coliforms* and faecal streptococci organisms more and therefore easier to evaluate are used as indicators of pathogens presence and thus wastewater (Rabiet, 2006). High concentrations can cause sanitary risk (Bonnard, 2001; Bontoux, 1993).

MATERIALS AND METHODS

Study area

Béchar city is located in the south west Algeria (Figure 1), in an arid climate trend Saharan, with irregular precipitation during the year, an average of 71.48 mm for the 1988 to 2008 series. The lowest temperature is recorded in January (4°C) and the highest in July (40°C), with an average of 27.16°C. Evaporation (average 305.29 mm) and evapotranspirations exceeds precipitations, therefore the year is dry.

Béchar wadi is crossing the town of Béchar on its entire length, where it discharged untreated wastewater into multiple points, the city discharge flow is estimated at 248, 28 l/s (Kabour et al., 2013), these wastewater flowing in the bed wadi through several aquifers, hydrogeological conditions are very favorable to a water contact, sometimes directly, facilitating reciprocal transfers of chemical elements; Water levels (depth) measured are ranges from 3 m (P18) to 6 m (P8) with an average of 5 m, which promotes rapid infiltration of surface water (Kabour et al., 2011).

Evaluation of the microbiological quality

The evaluation of the microbiological quality of Béchar city groundwater was performed on 18 wells distributed on both sides of the Wadi (Figure 1), sampled in April 2010. The results are graphically shown, whose x-axis is oriented north - south from the city, to better visualize the spatial distribution of different parameters.

It is necessary to identify the potential microbiological hazards associated with process, products, or all other potential sources of contamination (air, water, surfaces ...) which can be the cause of biological factors responsible for an adverse event (Squinazi, 2006).

The team responsible for the risk analysis should assess the likelihood that hazard identified occurs, taking into account all the risk factors associated to the process and the environment to protect (Squinazi, 2006).

Depending on the level of risk attributed to the process or to the environment, it is determined, in this environment, areas with very high risk, high risk, medium risk or low or negligible risk. A risk area is a defined and delimited space where individuals, products or environment (or any combination of this set) are particularly vulnerable to contamination.

In each area with a defined risk, appropriate measures are identified, to assess the risk of contamination (microbiological). Then determined the critical evaluation points, ie: points, procedures, steps of the operation or the environmental conditions that can be controlled to eliminate microbiological hazards or reduce the likelihood they occur (Squinazi, 2006).

All world standards state that the water used for consumption should be sufficiently free from microbiological danger, physical and chemical, so that the risk they pose to the health and safety of users must be negligible (FAO/WHO, 2004). Infections transmitted by pathogenic microorganisms, as well as injuries and disorders due to chemical and physical water quality problems are among the dangers that direct contact with water may cause to health (CFPTHMT, 2005). This is by oral, dermal, nasal or by the eyes and ears that pathogenic microorganisms (mainly fecal *coliforms*) infect the human body, for this purpose, it is important to note that the users are not immune to risks in contact with polluted water (Navarro and Carbonell, 2007).

Microbiological parameters of groundwater from the town of Béchar are determined by the method of the Most Probable Number (MPN) (Rodier, 2005). This method consists of inoculating, with appropriate decimal dilutions of the sample for analysis, a series of tubes containing the nutrient broth environment to find the total flora. After incubation for 24 h at 37°C, the tubes having a disorder are considered positive.

The assessment of the faecal contamination is performed by the enumeration of faecal coliforms and faecal streptococci. Total coliforms are counted after incubation for 24 to 48 h at 37°C, in the tubes containing an environment with lactose broth bromocresol purple, equipped with a Durham bell (presumptive test).

Positive tubes with lactose fermentation and gas production are transplanted to a confirmatory test in a selective environment containing bile salts. The bouillon Brilliant green bile equipped with a Durham bell and another tube containing peptone water without indole and incubated for 24 to 48 h at 44°C. Gas production in the first tube and indole in the second; reflect the presence of fecal coliforms.

As to streptococci, their search is performed in the Rothe

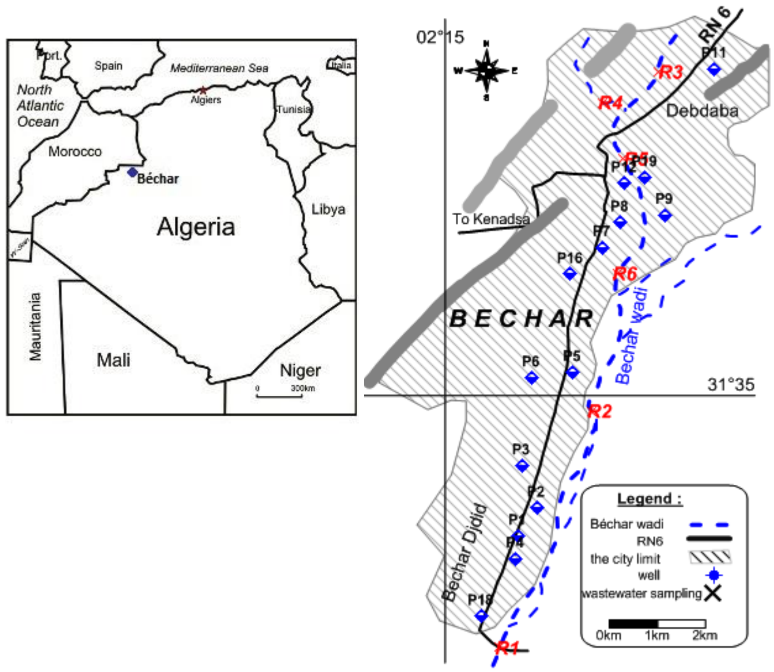

Figure 1. Béchar city (SW Algeria) and sampling sites.

environment at 37°C for 24 h (presumptive test). From the positive tubes Rothe and subculture is carried out in Litsky environment at 37°C for 24 h (confirmatory testing). The results are expressed as number of cells per 100 ml following statistical table Mac Crady. The results are analyzed by a statistical comparison of the mean (test Duncun) (Duncun, 1955). From a level of $p < 0.05$, the test is taken as being significant.

Methods of assessing the impact on health (risk index)

The waste water loaded with pollutants and various contaminants, pose the risk of health problems (Baumont, 2005; WHO, 2005; CFPTHMT, 2005) It may be direct effects on the health of a population and also more indirect effects from intervening factors that influence on the determinant of population health, such impacts are felt immediately or in the short term, or after a long delay. (CSHPF, 1995; Basil et al., 2007; Venugopal et al, 2009).

The "health risk assessments" (CFPTHMT, 2005; Belousova and Proskuriva, 2008; Bonnard, 2001; FAO / WHO, 2004) are conducted to determine the excess risk of developing a disease due to specific exposure to a pollutant (air for example). The health risk assessment (HRA) is a process that is broken down by convention in 4 steps:

1. Hazard identification (which reflects the potential danger of the pollutant considered) describes the biological disorders or the diseases that may appear due to the intrinsic properties of a pollutant; it also describes the degree of likelihood of a causal relationship between exposure to pollution and the development of these disorders and conditions (the "weight of evidence"),
2. "Dose-response" (also called "exposure-response") describes mathematically the association between exposure dose and the observed response (the appearance of a health effect, that is, i.e. the presence of a risk) over a time period,
3. The importance of excess health risk do not depends only on "danger", but also the level of exposure and duration (exposure intensity) and its frequency. The determination of these parameters is part of the exposure evaluation,
4. The risk characterization uses the results of previous steps to describe the type and magnitude of the excess risk due to the expected conditions of exposure to the pollutant identified in a population, considered in its diversity; it also includes a discussion of the uncertainties associated with the risk estimates (www.AFSSET.fr).

Among the diseases transmitted by contaminated water, there is the dysentery, this pathology originates from the *Entamoeba histolytica*, its only host is the human. This parasitic disease is found mainly in warm climates, its symptoms are bloody diarrhea, abdominal pain, and are never treated at 100%. This parasite spreads through contaminated water, it has values ranging from 37 (2007) 181 (2001) cases / 100,000 inhabitants, for ages 0 to 4, 20 to 29, and > 65 years, and Typhoidale fever (a very severe diarrheal disease, the infection is transmitted by water; by type of salmonella bacteria, its diagnosis is inflammation of the gastrointestinal tract. It occurs simultaneously in many people (www.santeweb.ch) varies from one to 14 cases / 100,000 inhabitants (in 2004) for the age groups 10 to 19, 20 to 29. (www.health-dz/Insp/).

For the collective risk, defined as the probability of death of a person or more, the acceptable level is set to 10^{-5} /year (e.g. 100 000 per year) and 10^{-7}/year (e.g. 10 million people per year) percent or more deaths, etc. In any situation where probability is greater than 10^{-5}/year, measures must be done to reduce this risk (Table 1) (CFPTHMT, 2005).

Sampling was performed during the month of April 2008, on 18 selected wells (Figure 1), for chemical analysis; the determination of Pb ions is realized by electrodes method for specific ions, and Zn concentrations were measured by colorimetric method (www.hanna-france.com/upload/PDF/catalogue_general.pdf).

Table 1. The values of the index of risk and their interpretations (CFPTHMT, 2005).

Risk index values	Interpretations
10^{-9} to 10^{-6}	Probable risk
10^{-6} to 10^{-4}	Very probable risk
10^{-4} to 10^{-2}	Highly probable risk
10^{-2} to 1	Possible risk
Greater than 1	Risk with presence of anthropogenic influence, and arrangements should be done.

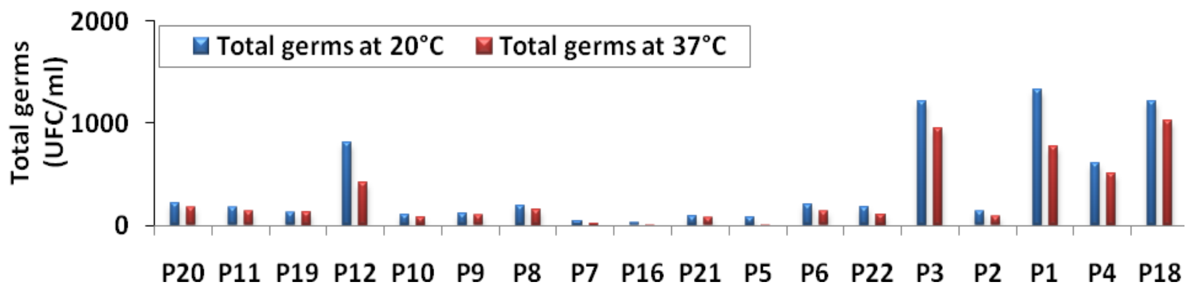

Figure 2. Total bacteria in groundwater from Béchar city (2010).

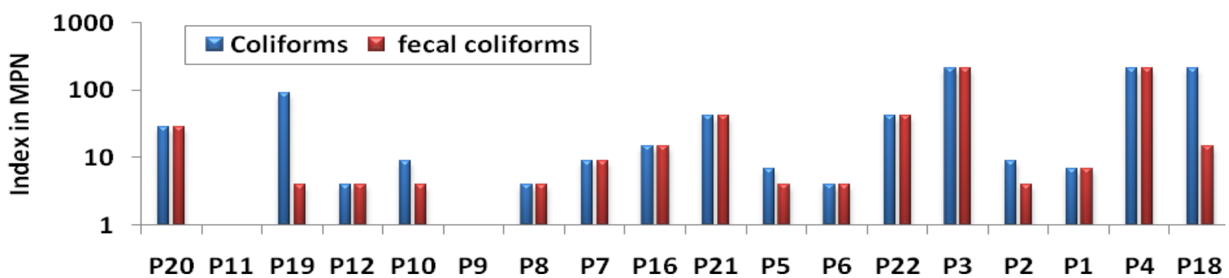

Figure 3. Total *coliforms* and Fecal *Coliforms* in groundwater of Béchar city (2010).

RESULTS AND DISCUSSION

Total germs

This is the natural flora encompassing all germs or contamination that lives in the presence of oxygen (Rabiet 2006; Alhou, 2007; Rodier, 2005). The results show that the germs rate is very high (CFU/ml (Colony Forming Unit: Most Probable Number) at 20°C and 37°C) (Figure 2). It exceeds the standard of Algeria (NA 6360-1992), the concentrations are limited between 8 CFU/ml and 1110 CFU/ml (at 37°C), 28.67 CFU/ml and 1308 CFU/ml (at 20°C), with an average of 292.22 CFU/ml (37°C), 382.09 CFU/ml (20°C). The spatial distribution (Figure 5) shows relatively low values at the center and north (<200 CFU / ml) (P22-20), except the P12, and strong values (> 500 CFU/ml) south from P3 to P18.

Total *coliforms* (CT)

As qualitative indicators, total *coliforms* provide information on water potability of character and the environmental condition of the water resource in question (Belousova and Proskuriva, 2008; Shashikanth et al., 2008).

The results (Figure 3), show that the majority of samples are undrinkable, by the mere presence of CT; values range from 0 to 210 MPN, while the average is 30.38 MPN; the high concentrations are located south of the city (P3, P4, P18); only P9 and P11 present a total absence of *coliforms*.

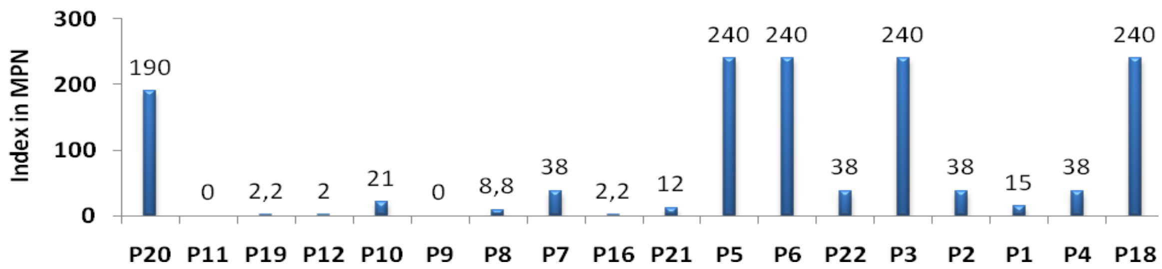

Figure 4. Streptococci in groundwater of Béchar City (2010).

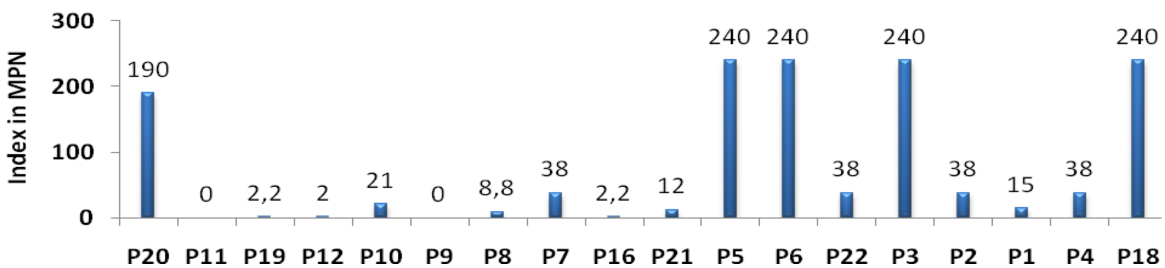

Figure 5. Clostrodium sulphite-reducing (CSR) in groundwater from Béchar City (2010).

Fecal *coliform* (FC)

The detection and enumeration of fecal *coliforms* is an examination offered, because of a statistical correlation between their presence and the existence of an almost certain recent faecal contamination (Gaujous, 1995; Rodier, 2005); and gives the water which contains them the character of non-potability.

Faecal *coliforms* or *Escherichia coli* is a bacterial species belonging to the total *coliform* group. This bacterium is still found in the feces of warm-blooded animals, but, unlike to total *coliforms*, they are not present naturally in the environment (Alhou, 2007; Jestin, 2005).

Figure 6 presents the analyzes results, where values are limited between 0 and 210 MPN, and an average of 33.83 MPN; the highest values are located south of Béchar city (P3, P4); the P11 and P9 have a total absence of fecal *coliforms*.

Streptococci

These are *Streptococcus* serogroup D Lance Field, facultative anaerobic, associated with fecal *coliforms*, they are good indicators of recent pollution, they are witnesses of quite resistant fecal contamination, including salty environments (Gaujous 1995). They can also multiply in the environment having pH of up to 9.6; it can therefore be used as indicators of pathogens which have resistance to a high pH (OMS, 2005).

In all samples analyzed (Figure 4), the Streptococci number is between 2 and 240 per 100 ml, with an average of 80.30 MPN / 100 ml, this results to a contamination in the majority of samples; the highest concentrations are located south of Béchar city, at the wells P5, P6, P3, and P18; North only P20 has a value of 190 MPN / 100ml, the others have low values (P19, P12, P10, P8, P7, P16, P21) see Null (P11, P9).

The potability of the water, in this case, is function of simple confirmation of these microorganisms existence in the water.

Clostrodium sulphite-reducing (CSR)

They are forms of anaerobic organisms resistant, they are normally found in feces but in smaller quantities than *E. coli*; search for Clostridium sulphite-reducing is an indicator of an old contamination, they come in two forms vegetative and spore (Jestin, 2005; Gaujous, 1995; Alhou, 2007).

Search for *Clostridium sulphite-reducing* units, with a number of tubes giving a positive reaction of 4 trials (Figure 5), the absence of this organism in some samples (P11, 19, P12, P9, P16, P5, P2 , P1), while others have the vegetative form (P20, P10, P8, P7, P21, P6, P22, P4), only P18 contains both forms spore and vegetative,

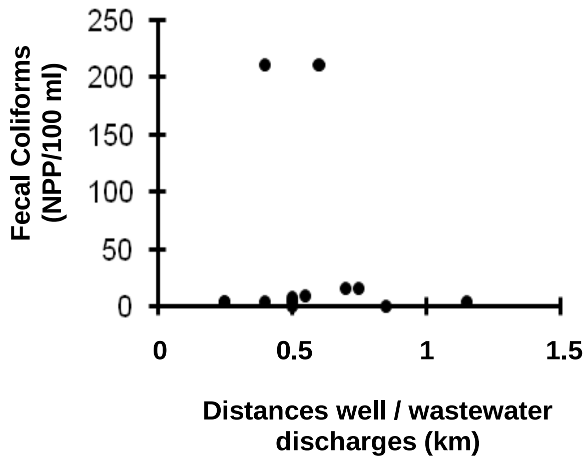

Figure 6. Correlation between fecal *coliforms* and distances well / wastewater discharges.

probably due to its location in the extreme south of Béchar city and its direct contact with discharge water.

Distance wells / releases

It was observed that 89% of the wells, which were the subject of bacteriological analyzes are contaminated by fecal *coliforms*. The absence of *coliform* bacteria in wells does not guarantee that the waters are free of bacteriological contamination (Tandia et al., 1999; Belousova and Proskuriva, 2008).

The correlation between fecal *coliform* and wells distances/point of discharge (Figure 6) shows no clear relationship between the proximity of wastewater discharges and bacteriological pollution of wells, which expresses that bacteriological contamination mechanisms which seem more complex (Tandia et al., 1999; Belousova and Proskuriva, 2008).

Assessment of the risk index for the city of Béchar

The approach is firstly made by analyzing the chemical results showing that anthropogenic pollution (71% of analyzed samples are polluted), is a significant impact on the environment with deterioration of groundwater quality and the proliferation of indicators (NO_3, NH_4, PO_4, Pb, Zn) marking its presence (Kabour et al., 2013).

From the time when contamination is detected and confirmed, a risk assessment process for public health should be embarked; this assessment will take into account certain characters, among other the evidence, expressed by the presence of cases of water-borne diseases such as typhoid and dysentery.

The health risk assessment is quantified by an index, which is estimated based on characterization of substances (or elements) chemical, for factors (also called determinants) determined mainly for ingestion of groundwater, and finally parameters (also called individuals) attributed to adults or children.

The index is classified according to its value, assigning each value a particular interpretation, from probable risk for low values to a present risk for values greater than unity. In this project, the RISK Workbench 4.0 software is used, it is an easy-to-use software package designed for performing fate and transport modeling and human health risk assessments for contaminated sites. RISC WorkBench 4.0 follows standard procedures outlined in the US EPA's Risk Assessment Guidance for Superfund (US EPA: Environmental Protection Agency, 1989) to calculate exposure assessment, toxicity assessment, and risk assessment. (http://www.scisoftware.com/environmental_software/detailed_description.php?products_id=86)

To perform a risk analysis, you have to fellow the steps listed:

Step 1: Choosing suspected chemicals (Zn and Pb)
Step 2: Routes of exposure: - human health, - environmental / water quality.
Step 3: Determine the concentrations at the reception points (concentration in the wells).
Step 4: Describe the receivers (characteristics of wells).
Step 5: Calculate the risk and / or calculate the natural cleaning levels.
Step 6: View the results (as a graph or table).

This software takes into account all parameters (called determinants) in relation to contamination, such as: soil (piezometry, aquifer properties, position of wells, ... etc.), Those of water (chemical elements) and those of consumers (adult and child max age, average weight, ingestion of these waters, skin exposure, duration of the bath, ingestion of plants irrigated by these waters ... etc.).

The evaluation of the health risk with use of the Béchar city groundwater, did he seem never realized. The impact on the environment and health can be translated as the contamination of drinking water (Tandia et al., 1999), the presence of cases of dysentery (upper than 50 cases per year) and fever Typhoidale (upper than 1 case per year) among city inhabitants, confirms this pollution (Figure 7).
The total risk index is the sum of the risk indices evaluated for Lead and Zinc substances, to the following factors (Figure 9):

i. Vegetables ingestion, values between 10^{-4} and 1.
ii. Contact of skin with irrigation water, estimate between 10^{-4} and 10^{-6}.
iii. Inhalation during the shower is treated as zero.
iv. Contact of skin in the shower is between 10^{-4} and 10^{-2}.
v. And mainly ingestion of groundwater, which is $10^{-2} > 1$.

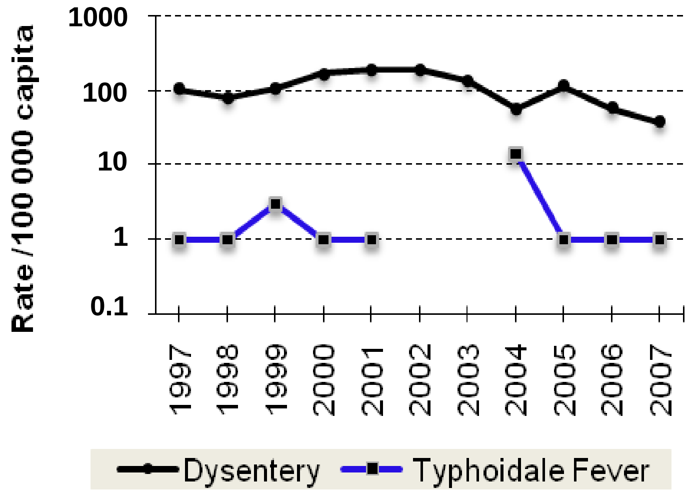

Figure 7. Evolution of dysentery and typhoidale fever in the wilaya of Béchar (www.health-dz / Insp /).

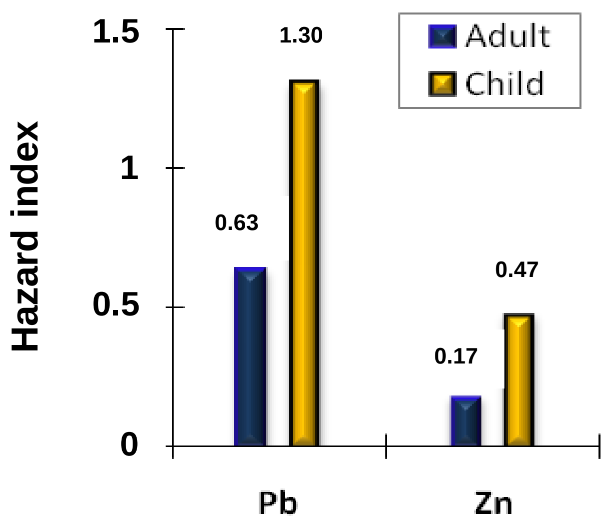

Figure 8. Total risk (hazard) Index for Pb and Zn.

The evaluation of the total risk index (Figure 8), that considers both elements Zn and Pb, which is 1.3 (Pb), 0.47 (Zn) for children, and 0.63 (Pb); 0.17 (Zn) for adults. Referring to Figures 8 and 9 for Béchar city groundwater, the total risk index assumes a possible risk for Childs, and anthropogenic influence this risk, and steps must be taken to minimize or eliminate the risk for children.

Conclusion

Microbiological analysis shows that almost all wells are non-potable; this is confirmed by the mere presence of germs in groundwater from Béchar city, which constitutes a real threat to the environment, especially a real risk to the health of consumers of this water. On the other hand, the correlation between fecal *coliform* and well away / wastewater discharges, describes a complex mechanism of contamination, which opens a research opportunity.

For Béchar city groundwater, the detected pollution is anthropogenic (wastewater discharges in Wadi), it makes these waters unfit for human consumption, the population using this water for their daily needs is expose to real health risks.

The evaluation of the risk index for the determinant: ingestion of groundwater, for the Pb and Zn ions, for

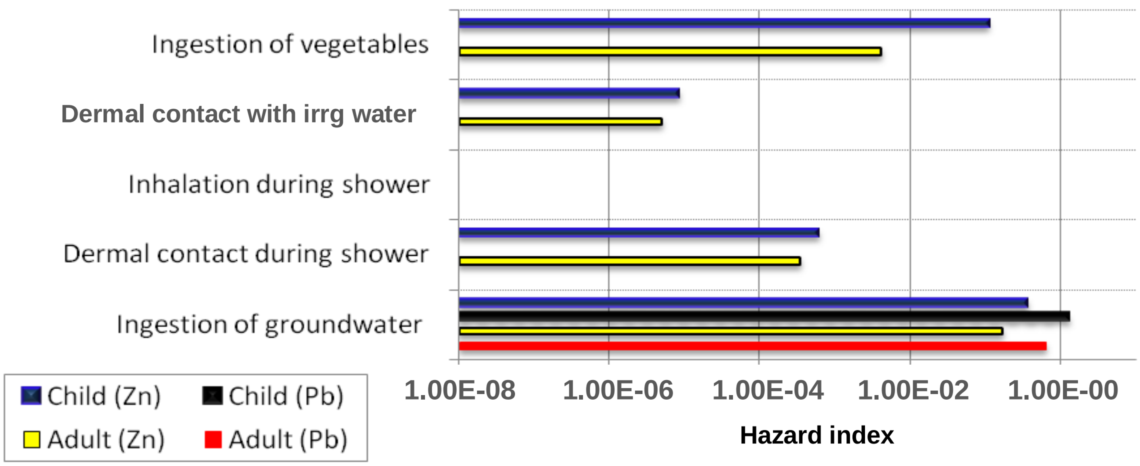

Figure 9. Total risk index (sum of all the determinants for parameters Pb and Zn).

children and adults is significant, worth 1.3 (Pb, children), expresses a risk presence, and measures must be recommended to eliminate it.

Conflict of Interest

The authors have not declared any conflict of interest.

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