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Physico-chemical and radon analysis of drinking water available in Samtah-Jazan city Southwest of Saudia Arabia

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ABSTRACT

In order to understand the quality of drinking water (tap water, gallon water, and mineral water) supply in Samtah-Jazan city southwest of Saudi Arabia, physicochemical characteristics were studied and analyzed. Water samples were carefully collected for various physicochemical parameters, such as turbidity, water temperature, pH, conductivity, total alkalinity, total hardness, chloride, iron and radon had been analyzed using standard procedures and compared with World Health Organization Standards, Saudi Arabian Specification Standards, and United States Environmental Protection Agency water quality guidelines. The bacterial parameters were analyzed for total count of bacteria, *E. Coli* bacteria and fecal coliform. It was approved that no bacterial contamination present in the water samples. The results revealed that all of the parameters were in normal range and indicated safety and suitability for drinking purposes.

Keywords: Tap water; Gallon water; Mineral water; Quality; Physicochemical characteristics, Radon; Samtah-Jazan; Saudi Arabia

1. Introduction

Water covers 78% of the earth's surface, yet water available for human use is limited. Supply of safe water is univocally a basic requirement for human consumption. It is one of the most important compounds that profoundly influence life. Unsafe drinking water contributes to numerous health problems associated mainly with waterborne diseases [1]. Obviously, the quality of water is described by its physical, chemical, and biological characteristics. Rapid industrialization, urbanization, and indiscriminate use of chemical fertilizers and pesticides in agriculture are deteriorating water quality. Due to use of contaminated water, human population suffers from water born diseases. According to WHO, about 80% of all the diseases in human beings are caused by contaminated water [2]. It is therefore important to check the water quality at regular interval of time.

In the Kingdom of Saudi Arabia, unlike in many other parts of the world, there are no rivers and the rainfall is very scarce unpredictable, irregular in occurrence which may be very extensive during local storms. Lack of safe drinking water is a major problem

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in developing countries. A number of factors influence water chemistry.

The quality of water may be described according to their physicochemical and microbiological characteristics. For the effective maintenance of water quality through appropriate control measures, continuous monitoring of large number of quality parameters is crucial because the changes in properties of water have far-reaching implications directly to the biota and indirectly to man [3]. Water quality data are, thus, essential for the implementation of responsible water quality regulations, for characterizing and remediating contamination and for the protection of the health of humans and ecosystem.

Radon is basically generated in a natural way by ^{226}Ra, which is in the ^{238}U decay chain. Even though ^{222}Rn has a half-life of 3.8 d, such a noble gas is chemically stable. Inhalation of radon and its decay products is responsible of about half of the annual average effective dose received by the human due to natural sources of radiation [4].

Radon in water enters the human body by two different paths, firstly, escapes from household water and becomes a source for indoor radon, and secondly from drinking water enters directly through the gastro-intestinal (GI) [5]. Most water sources have very low levels of radioactive contaminants enough to not be considered a public health concern. Radionuclides emit "ionizing radiation" when they naturally decay [6]. In 1991, the United States Environmental Protection Agency (USEPA) proposed a National Primary Drinking Water Regulation (NPDWR) for ^{222}Rn with a maximum contaminant level (MCL) of 11 Bq L^{-1} [7].

Water has unique chemical properties due to its polarity and hydrogen bonds which means it is able to dissolve, absorb, adsorb, or suspend many different compounds, thus, in nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities [8]. One of the most important environmental issues today is water contamination [9]. and between the wide diversity of contaminants affecting water resources, major metals receive particular concern considering their strong toxicity even at low concentrations [10]. They exist in water in colloidal, particulate, and dissolved phases [11]. with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (i.e. solid waste disposal, industrial or domestic effluents) [10]. Some of the metals are essential to sustain life-calcium, magnesium, potassium, and sodium must be present for normal body functions. The present research was carried out to determine the physicochemical parameters and estimate the radon concentration in different types of water by sensitive plastic track detector (CR-39) and determination the annual effective dose which Samtah-Jazan peoples (Saudi Arabia) had received. Where Jazan Located in southern Saudi Arabia.

2. Material and methods

The water in Jazan city can be classified as tap water, water from wells sterilized by ozone called gallon water and mineral water, the primary source for this water is the Red Sea. For the tap water taking the samples directly from the tap but for the gallon water, prior arrangement with shopkeepers after sterilized the water by ozone and mineral water are local and imported from foreign countries, were taking two samples for each type.

3. Sample collection

Three different types of tap, gallon, and mineral water samples were collected for both physiochemical and bacteriological analysis. The samples were collected in clean glass bottles without any air bubbles. The bottles properly rinsed with deionized water followed by doubly distilled water before sampling and tightly sealed after collection and the collected samples were labeled with date and code. Water temperature was measured on the site using mercury thermometer at the time of sample collection. Water samples were placed in a cooler at room temperature and transported to the laboratory for analysis within 2 h from collection. When immediate analyses were not possible, the samples were kept in refrigerator maintained at 4°C till analyzed.

4. Physicochemical analysis

Physicochemical parameters of these samples were determined by using standard procedures by the American Public Health Association (APHA, 1995) [12].

4.1. Gross appearance, odour and taste

The water samples were observed with naked eyes for gross appearance and examined for offensive odour through the subjective organoleptic assessment.

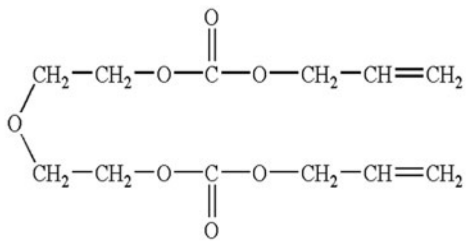


Fig. 1. The chemical structure of the repeating unit of CR-39.

4.2. Temperature

A mercury filled centigrade thermometer calibrated from 0 to 100˚C was used for temperature measurements.

4.3. pH

pH is termed as negative logarithm of the H_2 ion concentration. The pH was determined by Eli co, digital pH meter which gives direct values of pH.

4.4. Electrical conductivity and total dissolved solids

The conductivity was determined by using digital conductivity meter.

4.5. Turbidity

It can be determined by using turbidity meter.

4.6. Total hardness (TH)

Fifty milliliters of water sample was titrated against 0.01 M EDTA (disodium salt) solution using solochrome black T as an indicator.

4.7. Sulfate content SO_4^{2-}

Sulfate content in the water sample was determined by turbid metric method.

4.8. Alkalinity

The alkalinity of water sample was determined by titrating it against standard acid solution using indicators like phenolphthalein and methyl orange.

4.9. Chloride content

The chloride content in the water sample was determined by titrating the water sample against 0.02 M silver nitrate solution using potassium chromate as an indicator.

4.10. Iron content

Atomic absorption spectrophotometer was used for determination of Fe contents.

4.11. Total count of bacteria, E. Coli *bacteria and fecal coliform*

The methods for total and fecal coliform analyses are described in standard reference works (APHA) [13]. A membrane filter method for *E. coli* was developed more recently [14], and it is now standardized for routine use in recreational waters (USEPA; APHA) [13,15]. A more recent development in MF methods for *E. coli* is the transfer of TC and FC membrane filters with their colonies to nutrient agar containing MUG. After 4 h of incubation at 35˚C, the colonies were examined under long wavelength UV light, and those colonies fluorescing blue were considered *E. coli* [16,17].

Some statistical analysis were done using excel program.

5. Measurements of radon concentration by CR-39 track detector

The thermo set plastic material, Polly Allyl Diglycol Carbonate (PADC) (TASTRAK type, (Track Analysis System, Ltd, UK), referred to as CR-39 using in the literature of area 1 cm × 1 cm and thickness 1 mm, CR-39 is high grade amorphous optically transparent plastic and is widely used as a nuclear track detector. The chemical structure of the repeating unit of CR-39 as shown in Fig. 1.

Taking 200 ml from each type of water put in a plastic cup with plastic cover then fixed the CR-39 detector in the bottom of the cover at a distance 5 cm from the surface of the water as shown in Fig. 2. Radon decays with the emission of alpha particles cause damage tracks whose track can be easily recorded by a sensitive plastic track detectors CR-39. After 45 day all CR-39 detectors are collected then making it etching process for 7 h by 6.25 N NaOH at 70˚C using waterbath, during the etching process, the solution was constantly stirred. The detectors were then washed under running tap water for about 15 min. and dried in the fold of a tissue paper. Then, scanned by an optical microscope at 400× magnification and the track density was calculated in terms of

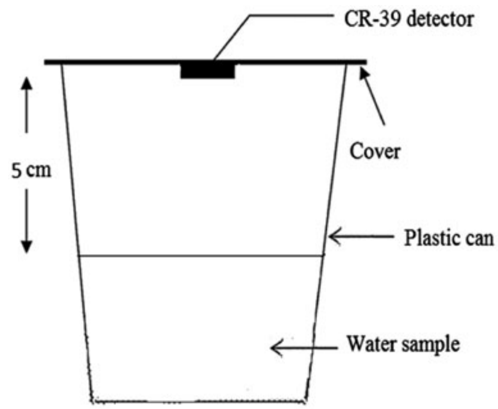


Fig. 2. Technique to determine the alpha track in water by CR-39.

tracks cm^{-2}. The radon concentration calculated using equation given by [6]:

$$C_{Rn} = \frac{N - B}{TC_f} \quad (1)$$

where C_{Rn} is the radon concentration [Bq/m^3], N is the track density [Track/cm^2], B is the background track density (Track cm^{-2}), C_F is the calibration factor equal 0.163 ± 0.002 [cm^{-2} d^{-1} per Bqm^{-3}] obtained from [18] and T is the exposure time [h].

The annual effective dose is related to the radon concentration and given by the following equation:

$$D\left[mSvy^{-1}\right] = \frac{C_{Rn} \times n \times f \times 8,760\,\text{h}}{170\,\text{h} \times 3,700\,\text{Bqm}^{-3}} \quad (2)$$

where f is the equilibrium factor equal 3.88, n is the fraction of time spent indoors equal 0.4, the number of hours per year equal 8,760 and 170 is the number of hours per working month [19].

6. Results and discussions

Tap water sources vary even within communities, in Samtah-Jazan city, most of the tap water comes from underground water sources (wells) after treatment for human consumption. Mineral water is distinguished from other types of gallon and tap water by its constant level and relative proportions of mineral and trace elements at the point of emergence from the source. No minerals can be added to this product. Relatively little information about gallon water quality is readily available to consumers. Few surveys of gallon water quality have been conducted in Samtah-Jazan city. People choose gallon water because it is perceived to be safer and of higher quality than tap water. There is no assurance that just because water comes out of a bottle it is any cleaner or safer than water from the tap. And in fact, most of bottled water is really just tap water in a bottle—sometimes further treated, sometimes not. And since the local tap water is required to be tested, sometimes this tap water is bottled after additional treatment (such as carbon filtration or ozonation), and sometimes, it is bottled with little or no additional treatment.

For comparing the data for tap water quality with those for gallon and mineral water. The hardness of water is an important factor in determining taste; therefore, we tested the hardness of gallon water, mineral water and tap water and tests for other minerals and a microbiological analysis were performed we found our samples to be near and in good quality. We conclude that tap water is of good quality, but to maintain its quality taps must be kept clean and pipes well maintained.

The results of the chemical analysis of ground water from this area are presented in the following tables and figures. So, it is necessary to make a comparison of the tap water, gallon water, and mineral water quality of the study areas with some drinking water standards. In the present study, the water temperature was recorded in the range of 25–27°C.

6.1. Gross appearance, odor, and taste

Color, taste, and odor are the direct investigative of contaminations. According to World Health Organization the drinking water should be colorless, odorless, and tasteless. All water samples were transparent, odorless, and taste was acceptable.

6.2. Total hardness

Soap is precipitated mainly by calcium and magnesium present in polyvalent cation and they often are in complex forms frequently with organic constituents. The role of water hardness may be difficult to define in confirmatory with the current practices. Total hardness (TH) is defined as the sum of calcium and magnesium concentration in mg/l. The present study showed that the TH analyzed in the water samples were found in the range of 38 to 48 mg/l, Fig. 3. The values are found within the guideline as recommended by WHO guideline value (TH range: 80–120 mg/l). The SAS states that the optimum value for the maximum allowable value of TH are 500 mg/l.

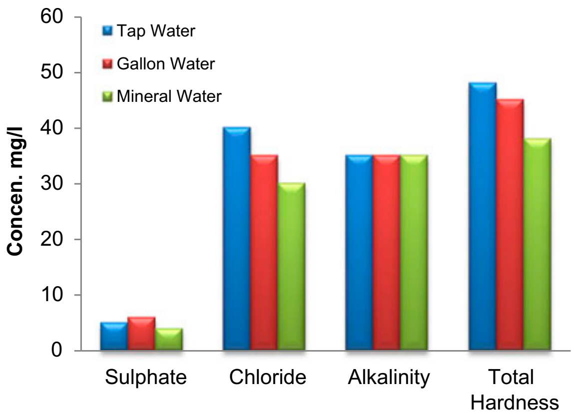


Fig. 3. Comparison of some various physicochemical parameters for.

Using this standards, the observed TH values were well within the limits so it is suitable for drinking.

6.3. Total alkalinity

Alkalinity is an important parameter because it measures the water's ability to resist acidification. Alkalinity measures the various substances related to the basic property of water. The solubility of various substances directly depends on the levels of alkalinity. The constituents of alkalinity in neutral system include mainly carbonate, bicarbonate, hydroxide and other components which may contribute to alkalinity are $H_2BO_3^{2-}$, HPO_4^{2-}, and HS^-. The SAS states that the maximum allowable value of the total alkalinity for drinking water is 400 mg/l, Table 1. All the water samples recorded normal values and within the guideline as recommended by WHO for total alkalinity (200 mg/l).

6.4. Chloride

Chloride is found in most natural waters and the concentration depends on the mineral content of the earth through which the water flows. Chloride is one of the major inorganic anion of water. High concentration of chloride indicates pollution due to organic waste. Naturally occurring high levels of chloride generally means hard water because of chloride's ability to combine with calcium and magnesium. Low to moderate concentrations of chloride may actually make water more palatable and desirable to drink. Chlorides contribute to the total mineral content of water. Chloride will produce a salty taste in water and in high concentrations, and it will produce a brackish or briny taste which is undesirable.

The SAS states that the optimum value of the concentration of chloride for drinking water is 200 mg/l and the maximum allowable value is 600 mg/l. The United Stated Environmental Protection Agency USEPA [20]. states that the maximum allowable value of chloride is 250 mg/l. In this study, the chloride (Cl^-) concentration was found in the range of 30–40 mg/l, Fig. 3 i.e. very less than the tolerance limit (200 mg/l).

Table 1
Tap water, gallon water and mineral water

Concen. (mg/l)	Tap water	Gallon water	Mineral water
Iron	0.04	0.01	0.01
Sulfate	5	6	4
Chloride	40	35	30
Alkalinity	35	35	35
Total hardness	48	45	38

6.5. Sulfates

The range of sulfate occur in drinking water were recorded to be 4–6 mg/l, Fig. 3. The sulfate values were observed below the WHO safe guideline for drinking water.

The results of the tests are shown in the table and the graph below.

6.6. Iron

Iron is also very important to human and other organisms, as it is partially responsible for transporting oxygen through the bloodstream. Iron is easily dissolved in water and can be found naturally occurring

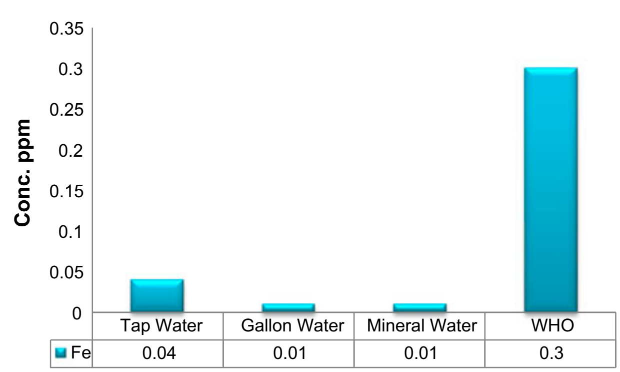


Fig. 4. Variation of iron with different water types.

in water bodies. Iron is an essential element for human nutrition and metabolism. But in large quantities results in toxic effect like hemochromoitosis in tissues if more iron accumulation takes place. The maximum permissible limit of Fe in drinking water is 0.3 ppm. Iron content of different water samples were in the range of 0.01–0.04 mg/l, which is well below compared to standard values as shown in Fig. 4.

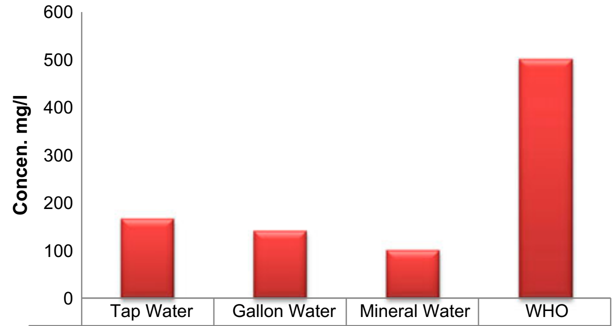
6.7. pH

pH indicates the intensity of acidic or basic character at a given temperature. pH of the tap water should be in the range of 6.5–9.5, which is around neutral and close to alkaline. Some water sources are acidic. Acidic water can be corrosive to metals in piping and equipment. It is important to control the pH of water as a too high or too low pH can be an indicator of other problems in the water. Measurement of pH is one of the most important and most frequently used tests in determining water quality. Every phase of water treatment and water supply like acid–base neutralization, water softening, precipitation, coagulation, disinfection, corrosion control, etc., is pH dependent. Results showed that the pH of the water samples was found to vary from 7.2 to 7.3. However, the values fall within the guideline of the Saudi Arabian Specification Standards (SAS) that requires the pH range to be 7.0–8.5, the United States Environmental Protection Agency (USEPA 1994) and WHO for pH to be in the range of 6.5–8.5 drinking water.

6.8. Total dissolved solids

TDS refer to suspended matter for dissolved in water or wastewater. Solids may affect water or effluent quality adversely in a number of ways. Water with high dissolved solids generally is inferior quality so TDS is a general indicator of overall water quality. It is a measure of inorganic and organic materials dissolved in water. Increased TDS may impart a bad odor or taste to drinking water, as well as cause scaling of pipes and corrosion. High TDS level indicates water hardness in respective sampling station. It reduces the portability for drinking purposes in the region.

The total dissolved solids (TDS) of the water samples ranged from 100 to 167 mg/l, Fig. 5. The Saudi Arabian Specification and Measurements Agency states that the optimum value for the (TDS) is 500 mg/l, and the maximum allowable value is 1,500 mg/l. Using these standards, all the samples were very less than the tolerance limit value of the TDS.



	Tap Water	Gallon Water	Mineral Water	WHO
TDS	167	141	100	500

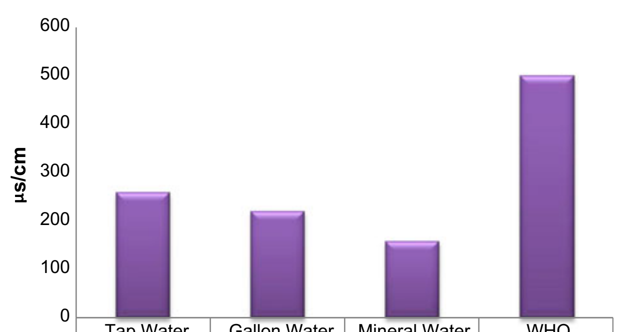
Fig. 5. Variation of TDS with different Water Types.

6.9. Electric conductivity

It is a measure of the ability of an aqueous solution to carry an electric current. It depends on the presence of ions, on their total concentration, mobility and temperature of measurement. Direct measurement of electric conductivity is potentially a very sensitive procedure for measuring ionic concentrations, since conductivity depends on ionic concentration, their mobility, etc. Conductivity is not a problem in itself and just because it is above certain level does not mean that the water will cause illness [21]. The value of electrical conductivity (EC) observed in the range between 158 and 259 µS/cm, Fig. 6. However, the values fall within the guideline of the WHO permissible limit of EC is 500 µS/cm [22].

6.10. Turbidity

Turbidity is an important parameter for characterizing the quality of water. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes,



	Tap Water	Gallon Water	Mineral Water	WHO
EC	259	220	158	500

Fig. 6. Variation of EC with different water types.

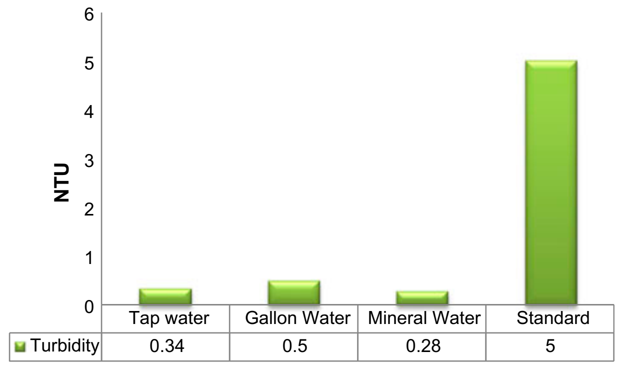


Fig. 7. Variation of turbidity with different water types.

chemicals, and coal dust. The water samples having turbidity 0.28, 0.5, and 0.34 NTU for tap, gallon and mineral water samples, respectively. Fig. 7 which are within the desirable limit of 5 NTU.

6.11. Radon concentration and annual effective dose

Radon concentrations in mineral water, gallon water, and tap water are shown in Table 2. The water samples having radon concentration of 7.20, 9.07, and 16.60 (Bq l^{-1}) for tap, gallon, and mineral water samples, respectively. It is shown that the radon concentration in each type of water is less than the maximum contaminant level for the US Environmental Protection Agency which equal 11 Bql^{-1} [23] except the local mineral water is highest as shown in Fig. 8. The calculated annual effective dose received by Samtah-Jazan people from corresponding radon concentration in water are 0.07, 0.14, and 0.36 (m Sv $year^{-1}$) for tap, gallon, and mineral water samples, respectively as shown in Fig. 9, it is shown that the calculated annual effective dose in each type of water is blow than the recommended limit of the public of 1.1 m Sv $year^{-1}$, So this water types are safe and healthy for use in the process of drinking and other purposes.

Water is a medium of thousands of microorganisms some of which are disease causing. Diseases in humans can be caused by the presence of certain

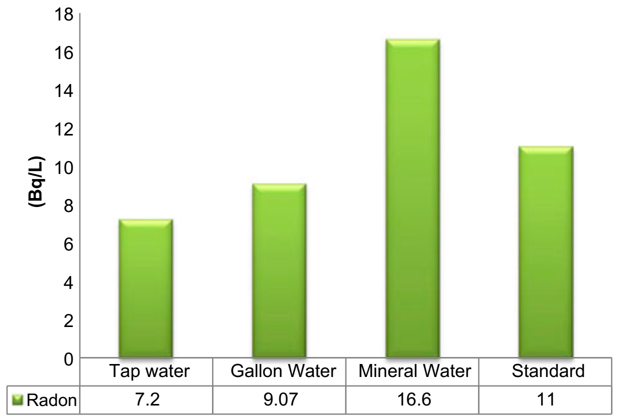


Fig. 8. Variation of radon concentration with different water types.

pathogenic bacteria and other organisms such as viruses, protozoa, and worms. Pathogens, causing diarrhea-related illness such as cholera, are commonly derived from human fecal material. Globally, 4 billion cases of diarrhea are reported every year causing 1.8 million deaths, out of which about 90% are children under five [24]. Pathogens can readily be washed into water bodies such as shallow wells. Without treatment, such water is a major cause of illness if consumed and may result in loss of productivity and increased medical costs Potable water is defined as water that is free from pathogens, low in compounds that are acutely toxic or that have grave long-term effects on human health [25]. Potable water should also be free from compounds that can cause color, taste (high salinity) and odour. Shallow wells are normally located in the valleys where the ground water table is relatively high (1–4 m below ground level) and infiltration of rain and river water plays a main part in ground water recharge.

The standard bacteriological test screens for coliform bacteria. These bacteria do not necessarily cause disease themselves, but their presence indicates contamination and the possible presence of disease-causing organisms such as pathogenic bacteria, viruses, or intestinal parasites. The presence of coliform bacteria

Table 2
The ^{222}Rn concentration in water by CR-39 detector

The samples type	Average radon concentration (Bq l^{-1})	Average annual effective dose (m Sv $year^{-1}$)
Tap water	7.20	0.07
Gallon water	9.07	0.14
Mineral water	16.60	0.36

Note: Five measurements of each sample are taken.

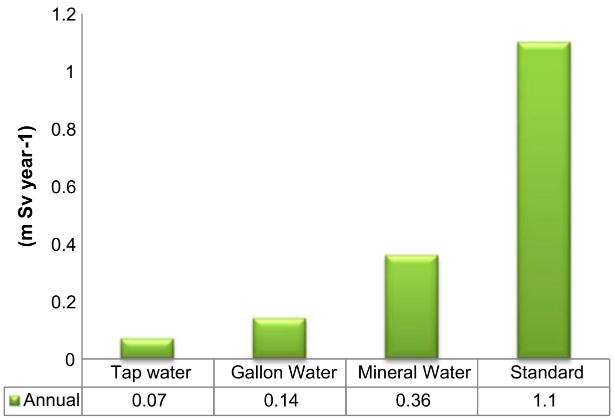


Fig. 9. The variation between the annual effective dose and type of water.

means contamination from surface water sources, as these are not found in ground water. The private wells must be tested for coliform bacteria every one to two years. This is especially important if the well is shallow, old, or of substandard construction. Frequent testing is also recommended if it is located close to a source of human or animal waste, such as a septic tank drain field, barnyard, or animal feeding operation.

Bacteriological parameters of all water samples were suitable. It approved that no bacterial contamination is presented (*E. coli* bacteria, fecal coliform and total count of bacteria).

7. Conclusion

Drinking water can be obtained from a number of sources, the one used often depending on the relative availability of surface water (such as rivers, lakes, and reservoirs) and ground water aquifers. The present work is an attempt to assess the drinking water quality. Water quality analyses reveal that most of the physicochemical parameters of the drinking water fall within the standard limits as per the WHO guidelines. Bacteriological parameters of all water samples were approved that no bacterial contamination is presented (*E. coli* bacteria, fecal coliform, and total count of bacteria). For the analysis of this type of water by determination radon concentration and the calculated annual effective dose received by Samtah-Jazan people from corresponding radon concentration, it is found that are less than the maximum contaminant level for the US Environmental Protection Agency. Hence, by combining chemical and physical analysis it can be concluded that the present status of drinking water quality in Samtah-Jazan city southwest of Saudi are safe and healthy for use in the process of drinking and other purposes.

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