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# Evaluation of calcium content of drinking water supplies and its effect on calcium deficit in Jordan

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ABSTRACT

In this study, calcium intake by Jordanians from diet and different sources of water was evaluated. For this purpose, a questionnaire was prepared and distributed to 300 persons in three major cities namely: Amman, Irbid, and Zarqa. The questionnaire included the type of diet which people eat daily and the type of water they drink. The amount of calcium intake was calculated by knowing the calcium content of the diet, the type of water and calcium bioavailability. The concentration of calcium in sold-RO water, home-RO water, bottled water and rain water was determined using an atomic absorption spectrophotometer. The calcium content in tap water was obtained from the Jordanian water authority determined by ion chromatography. It was found that 63% of the Jordanian people who live in Amman, 43% living in Irbid and 30% living in Zarqa depend on reverse osmosis (RO) water for drinking and cooking due to high salinity of tap water. Results showed that such water contains not more than 6 mg/L calcium which is much less than the world standards of 20 mg/L [1]. Calculations showed that calcium intake by most Jordanians, specially, in Amman and Irbid where RO water is mostly used is less than the recommended amount. If such reduction in calcium intake is not balanced in the diet serious health problems such as Osteoporosis may result especially in elderly people and women.

***Keywords:*** Reverse osmosis; Calcium; Osteoporosis; Bioavailability

## 1. Introduction

Consumption of distilled or low mineral content water (TDS < 50 mg/L) was demonstrated to have negative effect on taste characteristics to which the consumer may adapt with time. This water was also reported to be less thirst quenching. Although these are not considered to be health effects, they should be taken into account when considering the suitability of low mineral content water for human consumption [1].

Calcium is one of the important minerals in drinking water. It represents a substantial component of bones and teeth and has an important role in bone metabolism. In addition, it plays a role in neuromuscular excitability (i.e., decreases it), the proper function of the conducting myocardial system, heart and muscle contractility, intracellular information transmission and the coagulability of blood [1]. Although excess calcium is regulated by hormones, human body cannot cope up with lack of calcium intake for extended period of time [7]. Calcium deficit in diet has been associated with unhealthy bone growth which may lead to serious diseases such as Osteoporosis [8,9] and risk

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Table 1
Recommended Daily Allowance (RDA) of calcium based on age.*

| Case | Age range (Yr) | Recommended Calcium intake (mg/day) |
|---|---|---|
| Children | 0–3 | 500 |
| | 4–8 | 800 |
| | 9–18 | 1300 |
| Adults | 19–50 | 1000 |
| | >50 | 1200 |
| Pregnant or lactating | <19 | 1300 |
| | 19–50 | 1000 |

*Recommended Intakes for Individuals, Vitamins Food and Nutrition Board, Institute of Medicine, National Academies. http://www.iom.edu/Object.File/Master/21/372/0.pdf

of hypertension [12]. Excess calcium intake, however, was not proved to be directly related to incidence of kidney stones. Kidney stones formation was rather dependent on whether calcium is consumed with food or separately. Calcium that reaches the lower small intestine actually protects against kidney stones by binding oxalic acid (a precursor to common kidney stones) in foods and reduces its absorption. Calcium ingested from water together with food would have the same effect. Increased risk of kidney stones was rather associated with calcium supplements, possibly because the calcium was not ingested with food or the supplements were taken by those who exceeded the upper level of 2500 mg/day [2]. Current RDAs (recommended daily allowance) of calcium based on age are shown in Table 1 [3]. These RDAs have been called into question, with newer guidelines advocating higher daily intakes [11]. Dairy products have been used as a good source of calcium. Some economic and behavioral considerations, however, may limit their consumption [8,9]. These factors led to the use of calcium-rich mineral water, which is a popular beverage that offers a good alternative to calcium intake [11]. Although drinking water is not considered a significant source of calcium, WHO report [1] suggested a minimum and optimum calcium content of 20 mg/L, and 50 mg/L, respectively, in drinking water.

Water treatments such as RO may significantly reduce the content of calcium and other important minerals in water. A study was conducted in Czech and Slovak populations during 2000–2002 showed that using reverse osmosis-based systems for final treatment of drinking water at home for few months resulted in complaints of acute magnesium (and possibly calcium) deficiency. The complaints included cardiovascular disorders, tiredness, weakness or muscular cramps [4]. Similar symptoms were listed in the warning of the German Society for Nutrition [5].

Several studies were conducted on the use of calcium-rich mineral water as a good alternative for calcium intake instead of dairy products and pharmaceutical preparations. A study conducted by Bohmer et al. [11], showed that calcium bioavailability (i.e. the proportion of absorbed calcium and dietary calcium intake) from mineral water was close and sometimes greater than that from dairy products and pharmaceutical preparations. This ratio ranged between 23.8% and 47.5% depending on several factors such as calcium load (i.e. amount of calcium intake), type of water, and if taken alone or with a meal. Similar studies showed that calcium bioavailability from mineral water was at least comparable to dairy products and a useful source of calcium for lactose-intolerant adults [13], healthy women [14], and healthy young men [15].

The effect of calcium deficit on prevalence of Osteoporosis in Jordanian women was reported by some researchers. A large scale survey was conducted by Shilbayeh [16] to study female Osteoporosis in 400 women. The study showed an overall rate of Osteoporosis of 30% among all the Jordanian women irrespective of menopausal status, and its prevalence of 43.3% among postmenopausal women. Other studies indicated, also, similar ranges between 13% and 28% [17,18]. These figures were notably high compared to the published international studies which varied between 3.5% and 16% [19].

Jordanians rely on five different sources of water for drinking namely: tap water which is the water supplied by the Jordanian water authority, sold reverse osmosis (RO) water which is the type of water treated by RO membranes and distributed to people by special shops. A regular check up is performed by the ministry of health on these shops to ensure its quality regarding quality and safety. Home RO water is obtained upon installing small scale RO water treatment units at homes. This type of produced water undergoes no checkup regarding its quality and safety; it is rather left to the technicians skills for installations and calibration of the RO equipment. Usually these technicians are not qualified and often think that as TDS gets lower the unit is better and they do their best to convince consumers about it. Rain water, is collected on the roofs of the buildings and people store in wells to use it later as a source of drinking water. This type of water is typically obtained in rural areas. The last type is bottled water which people buy from supermarkets and such water is obtained from special underground wells or springs.

The objective of this work was to develop, distribute and determine the impact of diet and drinking water

sources on calcium intake by Jordanians living in the largest three Jordanian cities: Amman, Irbid and Zarqa. Due to the fact that water supplies treated with reverse osmosis (RO) and other similar technologies contain low calcium due to the high rejection of divalent cations. It is understood that unless the RO permeate is re-mineralized then the desalted supplies will contain very low calcium. Concerns over the deficiency of calcium in the Jordanian community motivated the development of the questionnaire which serves as a vehicle to obtain more information regarding this issue.

## 2. Methodology

The approach to estimate calcium intake by Jordanian was done by preparing a questionnaire that covers the kinds and quantities of food and liquids Jordanians consume in their diet (see Fig. 1). The kinds of food were divided into vegetables, fruits, dairy products and meats. Another section of the questionnaire focuses on drinks (beverages and water). The water they consumed was further classified into tap water, RO water, bottled water and collected rain water. The questionnaire also contained questions regarding age and sex, since calcium requirement changes according to these factors. It also contains questions regarding the total income, which was used to study the effect of income on calcium intake. The questionnaire was distributed in the largest three cities in Jordan: Amman, Irbid and Zarqa. These cities were chosen because of the followings: Amman is the capital, it has the highest income per capita, it is a big metropolitan and most of its inhabitants do office-like jobs. Irbid, on the other hand, is a big rural area where some of its inhabitants are farmers who grow their own cattle and can collect rain water as well. Zarqa is a big city, characterized by a desert-like weather, and most of its inhabitants are workers. Among these three cities Amman's inhabitants are the most educated followed by Zarka and then Irbid [20].

To estimate the calcium intake accurately, the questionnaire was held by Senior Chemical Engineering students as part of their graduation project who explained the questions well before filling the answers. It should be noted that 300 questionnaires were analyzed.

Calcium content in various fruits, vegetables, dairy product and various meat sources were obtained from USDA NNDSR, R20. The calcium content in the various types, except tap water, was found by analyzing those samples using the atomic absorption spectroscopy. For tap water, however, the calcium content was directly obtained from the Jordanian Water Authority. Measured calcium content in various types of water is summarized in Table 2.

The amount of calcium intake by a given individual was estimated by knowing the quantity and type of fruits, vegetables, dairy products, meats, bread and water they eat then multiplying by the bioavailability of that food. Bioavailability of the various foods and drinks are found in Table 4 [10]. For example assume that a given person (22 years old) eats and drinks the food shown in Table 5. Then total calcium intake is found by knowing the type of food (shown in column 1), its quantity (shown in column 2) and bioavailability of that food (obtained from Table 4). Calcium intake by questioned individuals was compared to the recommended RDA values (see Table 1). Although inquiries regarding calcium supplements were included in the questionnaire, specific questions regarding vitamin use were not included.

## 3. Results and discussion

Calcium intake based on age and sex compared to the recommended daily values is shown in Fig. 2. It can be seen that only children whose age ranges between 0 and 3 years have a calcium intake above the recommended values. The calcium intake for other age categories was below the recommended values. This can be a problem if the shortage in calcium intake is not supplemented by a special diet. The problem of short calcium intake was found to be serious for those in the age of 9–18 years and for those whose age is greater than 50 years. The survey showed that the average intake of these classes is $\sim$700 and 620 mg/l, respectively, where the recommended values are 1300 and 1200 mg/l, respectively. This means that their calcium intake is only 53% of the required amount. Hence people of these ages are more likely to have negative consequences such as Osteoporosis. The better situation for children in the age 0–3 years old is most probably due to the fact that their main diet is based on milk. It was observed also that calcium deficit was worse in female compared to male for all ages.

Calcium intake in the three cities studied is shown in Fig. 3. It can be seen that in the three cities, except for children of age 0–3 years, people are under recommended calcium dose. People living in Zarqa city were in a better situation than those in Amman or Irbid regarding calcium intake. It is interesting to note that people in Zarka depend mainly on tap water for drinking and cooking which has higher calcium content (100 mg/L compared to other water sources which range between 3.4 and 13.6 mg/L). This explains why they were in better situation compared to the other two cities. Contrary to expectation Irbid inhabitants suffer

**A. Basic information:**

**1. Gender**: a. Female b. Male
**2. Age** : a. 0–3 b. 4–8 c. 9–18 d. 19–50 f. above 50
**3. Education**: a. primary b. High school c. University d. Postgraduate
**4. Location of residence:**
**5. Family income:** a. Less than 200 JD b. 200 – 500 JD c. More than 500 JD
**6. Number of family members:**
**Nutritional information:**
**1. Source of drinking water:** a. tap water b. Home RO water c. rain water
d. sold RO water f. bottled water

**B. Amount of water that you drink daily (average):**
a. Less than ½ Liter b. ½–1 Liter c. more than 1 Liter
**3. Other liquids that you drink in addition to water:**
**Juices:** (natural juices) a. ¼ Liter b. ½ Liter c. More than ½ Liter
**Drinks:** (other than natural) a. ¼ Liter b. ½ Liter c. More than ½ Liter
**Caffeine:(coffee, tea, etc)** a. ¼ Liter b. ½ Liter c. More than ½ Liter
**Soft drinks (cola):** a. ¼ Liter b. ½ Liter c. More than ½ Liter
**Soups:** a. ¼ Liter b. ½ Liter c. More than ½ Liter

**C. Average Rate of food consumption on monthly basis:**
**1. meat and poultry:**
a. less than 10 times (750 g) b. 10–20 times (2250 g) c. more than 20 times (3750 g)
**2. Fermented yoghurt:**
a. less than 10 times (1000 g) b. 10–20 times (3000 g) c. more than 20 times (5000 g)
**3. Milk:**
a. less than 10 times (1000 g) b. 10–20 times (3000 g) c. more than 20 times (5000 g)
**4. Cheese:**
a. less than 10 times (250 g) b. 10–20 times (750 g) c. more than 20 times (1250 g)
**5. Eggs:**
a. less than 8 eggs b. 8–16 eggs c. more than 16 eggs
**6. Sea foods:**
a. Less than 2 times (250 g) b. 2–4 times (450 g) c. More than 4 times (750 g)
**7. Fruits and vegetables:**

| Amount | 500 g | 750 g | 1000 g |
|---|---|---|---|
| Bread | | | |
| Rice | | | |
| Tomatoes | | | |
| Cucumbers | | | |
| Potatoes | | | |
| Green leaves | | | |
| Legumes | | | |
| Cauliflower | | | |
| Citrus | | | |
| Apples | | | |
| Banana | | | |
| Others | | | |

**Dietary supplements:**
**1. I take calcium tablets:**
a. Continuously b. sometimes c. if the doctor prescribe them d. not at all
**The amount of calcium taken with tabs is**_____ mg
**2. I use RO water for:**
a. Drinking only b. for all liquid preparations c. for all kitchen uses

Fig. 1. The questionnaire distributed to candidates to estimate their calcium intake.

Table 2
Measured values of calcium content in different types of drinking water in Jordan.

| Type of drinking Water | Average calcium content (mg/L) | | | |
|---|---|---|---|---|
| | Amman | Irbid | Zarqa | Average |
| Sold RO water | 6.3 | 5 | 6.3 | 5.8 |
| Home RO water | 4.4 | 1.5 | 4.4 | 3.4 |
| Tap water* | 100 | 100 | 100 | 100 |
| Rain water | 15.1 | 9.7 | 7.9 | 11 |
| Bottled water | 13.6 | 13.6 | 13.6 | 13.6 |

*_tbl2# As provided by the Jordanian Water Authority.

from calcium intake shortage although they grow their own cattle. It seems that they prefer to sell their dairy product to improve their income to cover their other life requirements. Pregnant women in Amman seem to exceed the recommended calcium dosage. This might be attributed to the high family income in Amman (see Table 3) and to the fact that they are more educated compared to women living in Irbid and Zarqa.

The type and percent usage of various water sources based on income is shown in Fig. 4. It can be seen that people who have high income use more RO and bottled water compared to those with low income who use tap water more (see Table 3). Since tap water contains more calcium ions than other sources of water (sold RO, home RO, rain and bottled water), then they would suffer less from lack of calcium compared to those depend on RO water. Most of these people live in Zarqa (see Table 6, Figs. 5–7). It can be seen that the percent use of tap water by people who live in Amman, Irbid and Zarqa is 25%, 37% and 65%, respectively. It should be noted that the price of tap water is 0.05 JD/$m^3$, RO sold water 37.5 JD/$m^3$ and bottled water is 233 JD/$m^3$ (note that 1 $ = 0.71 JD).

Table 3
Population, per capita income, tap water properties in Amman, Irbid, Zarqa

| | Amman | Irbid | Al_Zarqa′ |
|---|---|---|---|
| Population (1000)* | 2172 | 996 | 834 |
| Per capita income(US $)* | 1902 | 1364 | 1183 |
| Analysis of tap water** | | | |
| pH | 7.56 | 7.52 | 7.45 |
| EC (μS/cm) | 499.5 | 702.0 | 2807.3 |
| Cl (mg/L) | 38.9 | 45.9 | 166.3 |
| $SO_4$ (mg/L) | 23.8 | 32.9 | 108.7 |
| Na (mg/L) | 27.3 | 40.0 | 93.1 |

*: [20].
**: Batarseh [6].

Although shops that sell RO water are spreading all over the country, our survey showed that in average, 45% of Jordanian people still rely on tap water as a source of water to drink and cook (25% in Amman, 37% in Irbid and 61% Zarqa). It is expected that this fraction will drop as time proceeds due to the increase use of RO water compared to tap water. This may

Table 4
Calcium content in various food and drinks and its bioavailability factor.*

| Diet type | Calcium ion content in diet "mg/gm of diet" | Bioavailability factor |
|---|---|---|
| Meat | 0.2 | 0.15 |
| Yogurt | 1.2 | 0.3 |
| Dry milk | 1.1 | 0.3 |
| Cheese | 8 | 0.3 |
| Egg | 0.6 | 0.15 |
| Fish | 0.4 | 0.15 |
| Bread | 1.3 | 0.2 |
| Rice | 0.1 | 0.2 |
| Tomato | 0.1 | 0.15 |
| Cucumber | 0.2 | 0.15 |
| Potato | 0.3 | 0.15 |
| Lettuce | 0.3 | 0.1 |
| Breakfast cereals | 3.3 | 0.2 |
| Cauliflower | 0.2 | 0.5 |
| Orange | 0.4 | 0.2 |
| Apple | 0.6 | 0.15 |
| Banana | 0.1 | 0.15 |
| natural juice | .69 | 0.15 |
| Tea | 0.01 | 0.15 |
| Soups | 0.3 | 0.15 |
| Water | Based on water type used for drinking (sold RO, home RO, tap water, rain water or bottled water) | 0.3 |

*: USDA NNDSR, R 20. http://www.ars.usda.gov/Main/docs.htm?docid=15869

Table 5
Calcium intake by a given candidate from various sources of food and drinks.

| Diet type | Amount of diet | Total calcium intake (mg/day) =(g of diet from column 2) × (calcium content/g of diet from Table 2) × (bioavailability from Table 2) |
|---|---|---|
| Meat and poultry | 75 g/day | 2.25[1] |
| Fermented yoghurt | 100 g/day | 36 |
| Milk | 100 ml/day | 120 |
| Cheese | 25 g/day | 60 |
| Eggs[2] | ¼ egg | 3.6 |
| Sea foods | 15 g/day | 0.9 |
| Bread | 143 g/day | 37.8 |
| Rice | 107 g/day | 2.86 |
| Tomatoes | 33 g/day | 0.50 |
| Cucumbers | 33 g/day | 0.99 |
| Potatoes | 107 g/day | 4.82 |
| Green leaves | 33 g/day | 0.99 |
| Legumes | 33 g/day | 1.98 |
| Cauliflower | 17 g/day | 1.70 |
| Citrus | 107 g/day | 8.56 |
| Apples | 33 g/day | 2.97 |
| Banana | 33 g/day | 0.50 |
| Water[3] | 0.5 L/day | 0.51 |
| Juices | 0 | 0 |
| Drinks | 0.25 L/day | 0.43 |
| Coffee | 0.25 L/day | 0.26 |
| Soups | 0.25 L/day | 6 |
| Total | | 293.62 mg/day′ |

[1] Calcium intake = (75 g) × (0.2 mg/g) × 0.15 = 2.25 mg calcium
[2] The average weight of an egg is 84 g.
[3] Home RO water

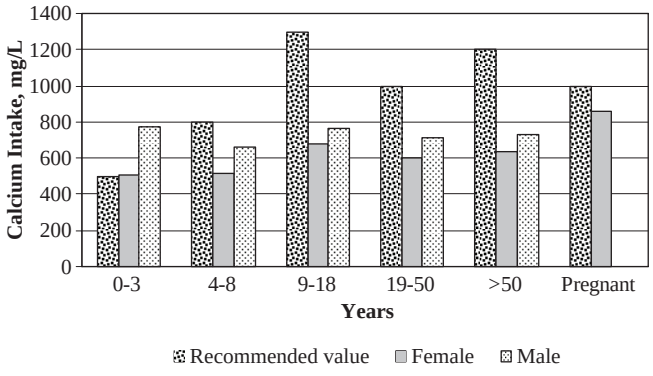


Fig. 2. Calcium intake based on age and sex compared to the recommended values.

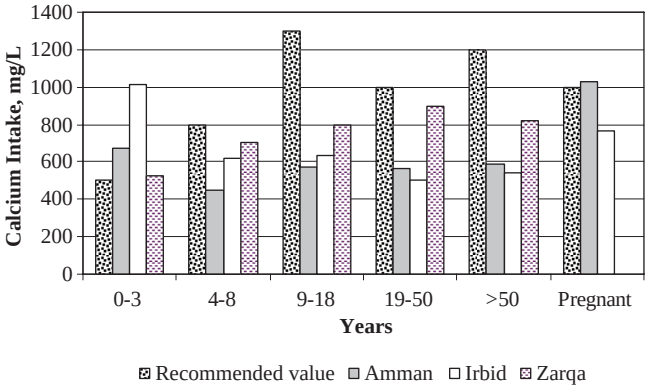


Fig. 3. Calcium intake based on age and sex compared to the recommended values in the three cities studied.

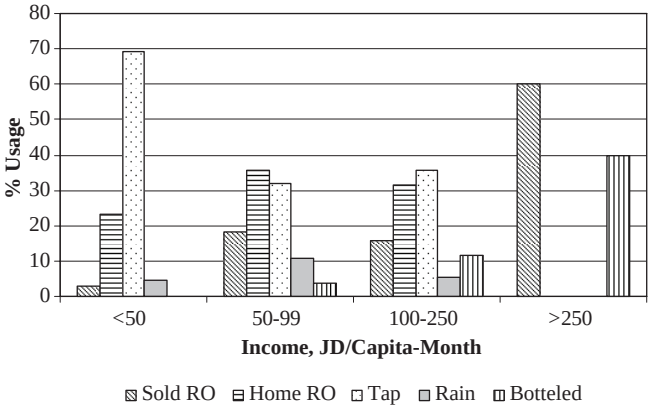


Fig. 4. Percent water usage based on the income.

Table 6
Percent use of the different sources of water by Jordanians live in Amman, Irbid and Zarqa.

| Type of drinking Water | Percent of water source | | |
|---|---|---|---|
| | Amman | Irbid | Zarqa |
| Sold RO water | 18 | 16 | 10 |
| Home RO water | 45 | 27 | 20 |
| Tap water | 25 | 37 | 61 |
| Rain water | 2 | 17 | 4 |
| Bottle water | 10 | 3 | 5 |

jeopardize the health of more Jordanians living in these cities.

## 4. Conclusions

Based on the study the following points can be stated:

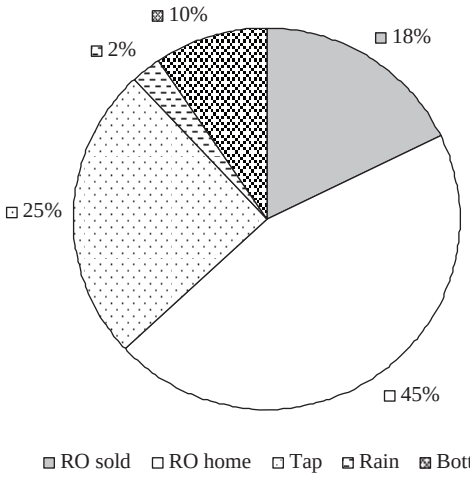


Fig. 5. Percent use of the different sources of water by Jordanians live in Amman.

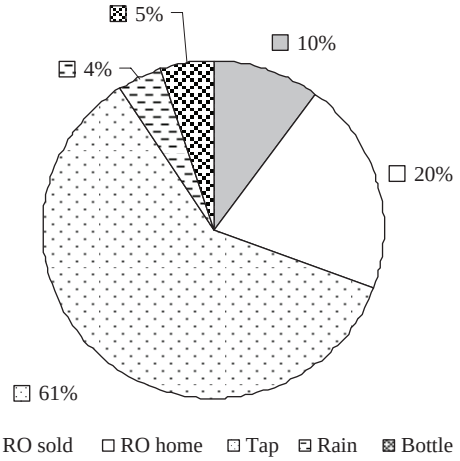


Fig. 7. Percent use of the different sources of water by Jordanians live in Zarqa.

1. Many factors such as type of water, type of food, family income play a key factor in determining the calcium intake for Jordanians.
2. The above study showed that calcium intake for most Jordanians was below the internationally recommended amount except for those whose age is 0–3 years. The problem was obvious for those who rely on RO water since it contains very low calcium content. People who rely on tap water were in better situation in terms of calcium intake since tap water contains higher calcium content compared to other types of drinking water.
3. Jordanians who use tap water (mainly live in Zarqa) had a better calcium intake compared to those who live in Amman and Irbid. Twenty five percent of the Jordanians living in Amman, 37% living in Irbid and 61% living in Zarqa use tap water.

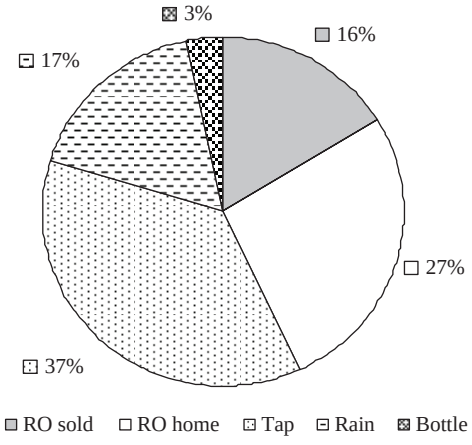


Fig. 6. Percent use of the different sources of water by Jordanians live in Irbid.

4. The study covered more than 70% of the Jordanians who live in the largest three cities, namely Amman, Irbid, and Zarqa. It was concluded that a large proportion of the population will suffer from some sort of calcium shortage and precautions need to be taken into account to make up such shortage in calcium ion by drinking more calcium-rich foods such as dairy products.
5. The above study still needs further investigation. To make a solid conclusion in this regard, larger number of people needs to be questioned and careful monitoring of their daily food and drink intake is required.

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