



Water hardness zoning of Isfahan Province, Iran, and its relationship with cardiovascular mortality, 2013-2015

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Original Article

Abstract

BACKGROUND: Cardiovascular disease (CVD) is one of the common diseases and today, it is considered as not only an important cause of mortality but also a significant aspect of health geography. The evidence presented in the literature indicates that hard water may reduce the cases of sudden death caused by CVDs because drinking water contains significant amounts of calcium and magnesium, which play a crucial role in the electrical activity of heart. Hence, the present study aimed at investigating the relationship between water hardness and CVD mortality rate in Isfahan, Iran.

METHODS: In this ecological study, the available data regarding the cardiovascular mortality rate and water hardness have been used. Preparation of zoning map has been conducted using the Geographic Information System (GIS) software considering Inverse Distance Weighting (IDW) interpolation models. Moreover, statistical analysis has been conducted using SPSS software.

RESULTS: A reverse relationship was observed between cardiovascular mortality rate and water hardness. However, the observed relationship was not statistically significant (2013: $r = -0.066$, 2014: $r = -0.155$, 2015: $r = -0.051$, $P > 0.050$).

CONCLUSION: The results of mapping with GIS and statistical analysis with SPSS both indicated a non-significant inverse relationship between the water hardness and CVDs. However, lack of a significant relationship highlights the necessity of conducting similar studies involving larger sample sizes and wider areas of investigation to present a definitive and generalizable result.

Keywords: Water, Hardness, Cardiovascular Diseases, Iran

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Introduction

Cardiovascular disease (CVD) is the leading cause of mortality and disability worldwide.^{1,2} Today, in most countries of the world including developing countries, it is recognized as one of the most significant threats to human health.³ In this regard, the World Health Organization (WHO) has estimated that if no measure is taken to improve cardiovascular health, by 2020, 25% of health years will have been lost due to CVD.^{4,5}

Although CVDs are recognized as the leading cause of death in most countries of the world, over the past few decades, the rate of mortality resulted from these diseases has considerably declined in European, American countries, etc. The trend is unfortunately increasing in other countries such as China, India, Pakistan, and Iran.^{4,6}

Accordingly, the occurrence of CVDs is different

in different geographic regions. In this respect, a bulk of epidemiologic studies has identified the factors that could explain it and identified the underlying causes of this disease including diets, genetics, and environmental factors.^{7,8} According to the previous studies, one of the environmental factors which plays a large and important role in CVD is water type, water quality, and its hardness.⁹⁻¹² Water hardness is related to magnesium, calcium, strontium, iron, and other ions, which are soluble in water with bicarbonate anions, carbonate, sulfate, and chlorine.¹³

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Total water hardness is defined as the temporary or carbonate hardness plus permanent or non-carbonate hardness. A good number of studies have been devoted to not only evaluating water hardness by separating dissolved salts from hard water but also examining its relationship with various diseases such as blood pressure disorders, gastric cancer, esophagus disorders, CVDs, etc.⁹⁻¹⁵ Studies have shown that magnesium changes can be of great importance in hypertension (HTN),¹⁶ electrical disorders of the heart and arrhythmias,¹⁷ and cardiovascular system.¹⁸ Moreover, dietary calcium intake can reduce the risk of cardiovascular events associated with high blood pressure, so that the higher the calcium, the stronger the muscle contractions of the heart will be.¹⁷ Hence, as hard water can provide up to 9% of the daily calcium intake, mineral-rich water can significantly contribute to supplementing dietary intake of calcium and magnesium.¹⁹

Despite the existence of studies confirming the association between water hardness and CVD or its mortality rate, many other studies have found no significant relationship between the disease and water hardness or even the direct relationship between water hardness and mortality rate.^{20,21} Therefore, it seems that the existence and the relationship between hardness and mortality due to CVD is still uncertain and further studies in this regard is essential, especially in Iran, as one of the developing countries with a high rate of mortality due to this disease and in areas with specific geological climates.

Nowadays one of those software programs which is wildly used to inform health management systems in research in addressing the zoning of various disease is Geographic Information System (GIS).²²

The selection of Isfahan Province, Iran, as the target area of the study was due to its limestone and chalky land structure, which has led to variation of water hardness level in various areas of this province. This problem has been exacerbated due to the low level of rainfall and occurrence of drought in this region. Hence, the present study provided the mortality zoning of CVDs and water hardness by GIS and statistical relationships between the mentioned variables during the years 2013-2015 in Isfahan.

Materials and Methods

This ecological study was conducted on the rate of cardiovascular mortality in the years of 2013-2015 in 25 cities of Isfahan Province.

The data required in this study were collected in two parts. In the first stage, information on water hardness was studied over a period of three years from the Urban and Rural Water and Wastewater Department of Isfahan Province. To ensure the accuracy of the recorded data, the samples of drinking water were randomly selected and analyzed in three cities and the degree of hardness of water and salts (calcium, magnesium) was extracted. As the test results did not contradict the information recorded in this organization, the water hardness assessed in the organization was assured.

In the second stage, mortality data from CVDs were extracted and recorded from the Registration Department and Provincial Health Center of Isfahan during 2013-2015. In addition, the population of these cities was taken over the past three years by the Bureau of Statistics and Information of Isfahan Province.

Given the following formula for calculating the mortality rate, the mortality rate due to CVD was calculated in each of the three years in each of the 25 cities of Isfahan Province.

$$\text{The mortality rate due to CVD} = \frac{\text{Number of deaths due to CVD in the desired year}}{\text{Total population of the province within the same year}} \times 1000$$

The zoning of the mortality frequency of CVDs as well as water hardness was prepared in GIS software (version 9.9, ESRI, USA) using Inverse Distance Weighting (IDW) models.

According to previous studies, the ideal water hardness was 170 mg/l, so that levels above 170 mg/l had definite relevance for reducing CVD.¹² Also in this study, water hardness went under the rubric of soft, moderate, and hard: soft (161-175 mg/l), moderate (175-300 mg/l), and hard (> 300 mg/l), which is used for zoning water hardness in GIS.²³ Furthermore, to prepare the zoning map of the cardiovascular mortality rate, the total average of mortality rate in the three-year survey (2013-2015), which was 5.8 per 1000, was used.

Collected data were entered into SPSS software (version 20, IBM Corporation, Armonk, NY, USA) and data were represented as mean \pm standard deviation (SD). At the level of inferential statistics, due to the use of mortality rate and its normal distribution, Kolmogorov-Smirnov test (K-S test), one-way analysis of variance (ANOVA), and Pearson correlation coefficient were used. Finally, the results extracted from this software were matched with the results of the GIS zoning map.

Results

Mortality rate and water hardness in each of the three years in each of the 25 cities of Isfahan Province are shown in table 1.

Table 1. Mortality rate of cardiovascular diseases (CVDs) in the years 2013-2015

City	Mortality rate 2013	Mortality rate 2014	Mortality rate 2015
Aran and Bidgol	2.4	2.6	2.8
Ardestan	3.2	3.2	2.8
Isfahan	1.7	1.6	1.7
Borkhar	2.8	3.2	3.2
Boin and Miandasht	2.8	3.6	3.7
Tiran and Karvan	1.7	1.5	1.9
Chadegan	2.1	1.5	2.1
Khomeini Shahr	1.8	1.8	2.4
Khansar	4.8	4.0	3.4
Khor and Biabanak	3.0	3.8	4.2
Dehaqan	3.0	3.0	2.7
Semirom	3.0	1.8	2.2
Shahin Shahr	3.6	3.4	3.2
Shahreza	2.1	2.2	2.0
Fereidan	1.6	1.6	1.5
Fereydun Shahr	2.0	1.5	1.7
Falavarjan	2.4	1.4	1.3
Kashan	2.2	2.0	1.9
Golpayegan	2.8	2.6	3.2
Lanjan	1.5	1.4	1.9
Meimeh	2.4	3.0	4.4
Mobarakeh	2.0	1.7	2.1
Naeen	4.0	2.6	2.6
Najaf Abad	2.4	1.8	2.0
Natanz	3.0	3.0	2.5

The results of the evaluation of cardiovascular mortality rates in 25 cities of Isfahan Province during 2013-2015 indicated that the mean cardiovascular mortality rate in 2013, 2014, and 2015 was 2.57 ± 0.79 , 2.39 ± 0.84 , and 2.54 ± 0.82 , respectively, which had no significant difference in the three years of study ($P > 0.050$) (Table 2).

In addition, comparison of this rate among the 25 cities of Isfahan Province in a total of three years showed that the cities of Lanjan and Fereidan with the mean of 1.60 ± 0.26 and 1.57 ± 0.06 , respectively, had the lowest rate and Khansar and Khor and Biabanak with the mean of 4.07 ± 0.70

and 3.67 ± 0.61 , respectively, had the highest mortality rates due to CVDs. Statistically, the mortality rates were significantly different among the cities under study ($P < 0.001$) (Figure 1).

In the same vein, in figure 2, the zoning map of mortality rate of CVDs in Isfahan Province is presented using the IDW model.

On the other hand, the range of water hardness during the years 2013-2015 in total of 25 studied cities was 161 mg/l to 800 mg/l and the mean value was 280.24 ± 134.73 mg/l, so that 3 cities (12%) (Meyme, Borkhar, Shahin Shahr) were in the range of water hardness of 161-175 mg/l, 16 cities (64%) were in the range of water hardness of 175-300 mg/l, and 6 cities (24%) (Aran and Bidgol, Natanz, Shahreza, Dehaghan, Lanjan, and Falavarjan) were in the range of over 300 mg/l (Figures 3a, 3b).

Moreover, the relationship between cardiovascular mortality rate in three years with water hardness was reversed and poor, equal to -0.062 , which was not statistically significant ($P = 0.769$); in addition, in evaluating this relationship in each of the three years, it was found that the relationship was reversed and negligible ($P > 0.050$). In fact, it can be said that water hardness has a reverse relationship with cardiovascular mortality that in this study due to the evaluation in a limited area and sample size, this relationship is not significant (Table 3).

Discussion

The present study investigated the water hardness zoning and cardiovascular death. According to surveys, the cities with higher water hardness have lower rate of cardiovascular death.

However, there was no significant relationship between water hardness and cardiovascular death in this study. Matching of the two zoning maps (water hardness and cardiovascular death) illustrated that Aran and Bidgol, Natanz, Falavarjan, Lanjan, Dehaghan, and Shahreza had high water hardness (more than 300 mg/l) and cardiovascular mortality rates were lower in these areas than in areas where water hardness was lower (Meimeh, Borkhar, Khomeini Shahr, Khansar). The CVD deaths were even low in the cities with medium range of water hardness.

Table 2. Determining and comparing the rate of cardiovascular mortality in the years 2013-2015

Mortality rate	Minimum	Maximum	Mean \pm SD	P
2013	1.50*	4.80**	2.57 ± 0.79	0.713
2014	1.40*†	4.00**	2.39 ± 0.84	
2015	1.30†	4.40††	2.54 ± 0.82	

* Lanjan; ** Khansar; † Falavarjan; †† Meimeh
SD: Standard deviation

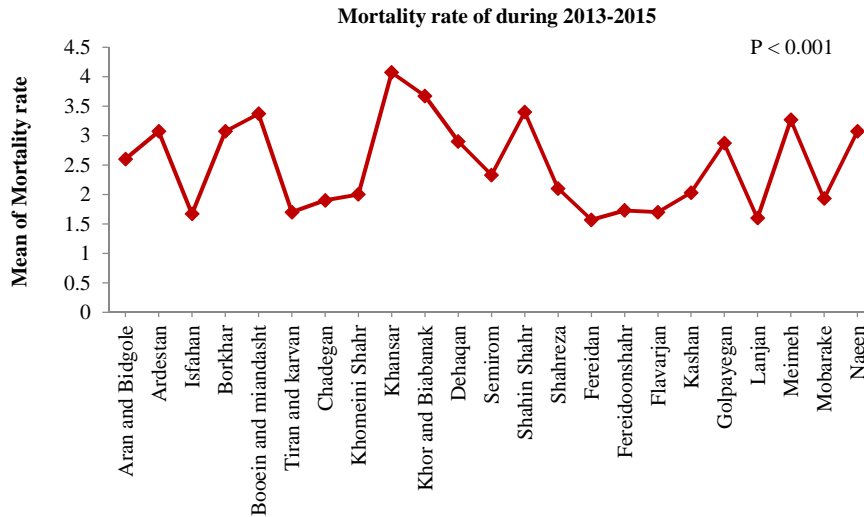


Figure 1. Mean mortality rate of cardiovascular disease (CVD) for a total of 3 years in 25 cities of Isfahan Province, Iran

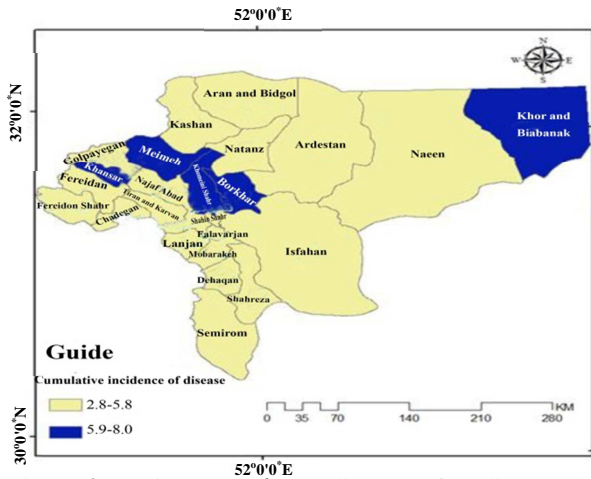


Figure 2. Zoning map of mortality rate of cardiovascular diseases (CVDs) in Isfahan Province, Iran, using the Inverse Distance Weighting (IDW) model

The conducted zoning demonstrated that most of the regions of the province had hard or very hard water. Investigation of the geographical structure effects on water hardness showed that geomorphological factors such as slope, height, and channel directions affected the geographical structure of the studied region and resulted in a situation in which the water hardness was not high in regions with lime soil, because the dissolved lime was transferred to underground water of downstream regions due to high slope and height of the region. That is why in Semirom and Fereyduh Shahr, the water hardness was lower than the downstream regions.

A study was conducted in Japan which showed a significant relationship between the quality of drinking water and CVD deaths.²⁴

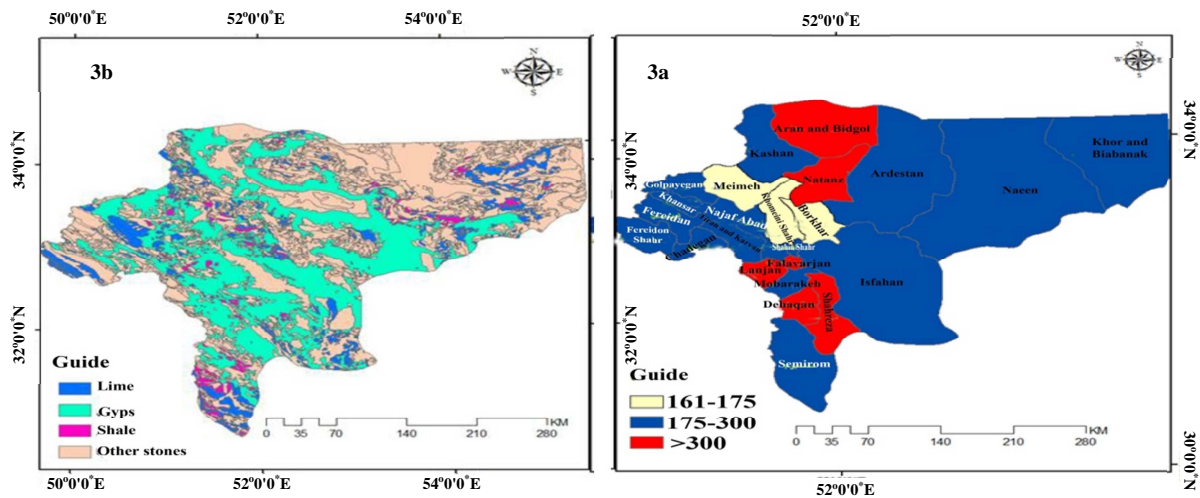


Figure 3. Zoning map of water hardness in various cities of Isfahan Province, Iran; a) According to water hardness, b) According to minerals present in water

Table 3. The relationship between mortality rate of cardiovascular disease (CVD) and water hardness in 2013-2015

Mortality	Water hardness	
	Correlation	P
2013	-0.066	0.755
2014	-0.155	0.459
2015	-0.051	0.807
Total (in three years)	-0.062	0.769

After that, several other studies in different countries revealed negative relationship between cardiovascular death and water hardness.²⁰ Several papers have been published about drinking of hard water and its impact on health but none of them showed correlation. Most of the studies showed a negative and significant relationship between magnesium-containing water and CVD death. Water hardness may be also associated with CVD risk factors; for instance, positive correlations of water magnesium and calcium with blood pressure is documented.²⁵ In 2003, a study in Sweden revealed a significant relationship between calcium level and CVDs.²⁶ Another study in the same year showed a significant relationship between calcium level and CVD, when calcium level was more than 94 mg/l and the protective effect of magnesium was between 4 and 11 mg/l.¹³

In Valencia, Spain, it was said that there was a relation between the mortality rate of CVD and the hardness of drinking water, and this is more related to the concentration of magnesium.²⁷ In 2010, it was revealed that there was no significant relationship between CVD and water hardness; however, there existed a reverse relationship between consumption of magnesium-containing water and death due to cerebral stroke.²⁰

A study was conducted in Khansar, Iran, and the data on water hardness was collected from urban and rural centers, and a comparison was made in 2010 and 2011. It was concluded that the protective effects of water hardness with magnesium were related to CVDs.¹⁹ The results of another showed that water hardness might have a protective role against the early stages of atherosclerosis in children and adolescents.²⁸

In 2014, a study was conducted in Bosnia and Herzegovina (Mostar City) on soft and hard water consumers. It was shown that those who used soft water had CVD prevalence rate of 21.3%, while this rate was 13.7% in hard water consumers.¹² In the same year, a study in Sweden showed a strong relationship between water hardness and CVD and expressed that for having preventive effects, magnesium and calcium

should be considered together.¹¹

Other study has shown that the relationship between magnesium of drinking water and the risk of mortality rate of CVD was considerable in Scandinavia.²⁹

Conclusion

According to the results of this study, there was a non-significant inverse relationship between water hardness and mortality, but it seems that due to the geographical conditions and water hardness in this area and the results of the other study, more advanced studies can produce more accurate results in this regard.

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Conflict of Interests

Authors have no conflict of interests.

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