Groundwater Hardness and Cardiovascular Disease Mortality: Exploring Spatial Association in Bist Doab Region (Punjab, India)

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ABSTRACT

Hardness of groundwater is believed to be an important physical determinant of spatial patterns of cardiovascular mortality. The present paper attempts to examine the role of groundwater hardness in determining the spatial patterns of cardiovascular diseases in rural Bist Doab region of Punjab. The groundwater calcium hardness data was obtained from the website of Central Ground Water Board, India. The calcium content (mg/l) was noted down for 27 observation wells in the study area. Based on the variation in calcium content, the groundwater was classified into five categories of varying hardness. The point data of the observation wells was used to generate a continuous surface using Regularized Spline Interpolation technique in ArcGIS 9.3 software. The data on cardiovascular mortality for the year 2009 was noted down from the village-wise Death Registers of the study area and the mortality figures were aggregated at block level. The method of visual comparison was employed to observe the relationship between groundwater hardness and cardiovascular mortality in different parts of the study area. The results show that the areas of hard underground water, lying in the eastern parts of the study area have recorded low occurrence of cardiovascular deaths, whereas the soft water areas towards the west have higher rates of mortality from cardiovascular diseases.

Keywords
Groundwater, Hard water, Soft water, Cardiovascular mortality, Spline technique

1. INTRODUCTION

Cardiovascular diseases are the largest cause of death in Punjab. They account for nearly fifty percent of all deaths. Cardiovascular disease mortality occurs due to the influence of a number of factors, which can be classified into three main groups – the physical factors, the socio-economic factors and the behavioural factors. Most of the research conducted on the spatial dynamics of these diseases essentially focuses on the traditional socio-economic and behavioural risk factors. However, very few studies have examined the role of the underlying physical environment in determining the geographical distribution of these diseases. Hardness of groundwater is believed to be an important physical determinant of spatial patterns of cardiovascular mortality. Scholars like Foster (1997), Ferrandiz et al. (2004), Calderon and Hunter (2009), Altura and Altura (2009) have examined the spatial association between cardiovascular disease prevalence and groundwater hardness. These studies have revealed that areas with hard water have lower incidence of cardiovascular diseases.

Traditionally, the state of Punjab is divided into three cultural regions, i.e. Majha, Malwa and Bist Doab. Unlike the other two regions of the state, Bist Doab relies heavily on groundwater sources for drinking and agricultural purposes. This is evident from the absence of any major canal network. Though the groundwater is sweet, but it varies markedly in its hardness (Ong et al., 2009). Kumar et al. (2006) have noted a huge variation in hardness and mineral contents of groundwater in Punjab. The present paper attempts to examine the role of groundwater hardness in determining the spatial patterns of cardiovascular diseases in rural Bist Doab region of the state.

2. DATA AND METHODS

The groundwater calcium hardness data was obtained from the website of Central Ground Water Board, India for the year 2005. The calcium content (mg/l) was noted down for 27 observation wells in the study area. Based on the variation in calcium content, the groundwater was classified into five categories of varying hardness. The point data of the observation wells was used to generate a continuous surface using Regularized Spline Interpolation technique in ArcGIS 9.3 software. This technique estimates and interpolates values using a mathematical function, by extruding the sample points to the height of their magnitude and bending a sheet of rubber that passes exactly through the input points, resulting in a smooth surface with minimal overall surface curvature. The data on cardiovascular mortality for the year 2009 was noted down from the village-wise Death Registers of the study area and the mortality figures were aggregated at block level. The method of visual comparison was employed to observe the relationship between groundwater hardness
and cardiovascular mortality in different parts of the study area.

3. THE STUDY AREA

The present study is focused on the Bist Doab region (30°57' N to 32°7' N latitude and 75°4' E to 76°38' E longitude) of Punjab. It is a natural region lying between Beas and Satluj rivers. The former bounds it in the west and the latter in the south. The eastern boundary of the region is marked by the Shiwaliks. As a result the eastern parts are hilly and undulating while the rest of the region has an almost flat surface. The region shares 17.6% (8844 sq. km.) of state’s total geographical area and is one of the three traditional cultural regions of the state, the other two being Majha and Malwa. The climate of the region is of continental monsoon type. The soils are mostly fertile and alluvial in origin. According to 2001 census, the population of Bist Doab is 4,770,477 that accounts for 19.64% of Punjab’s total population. Out of this 71.58% people live in rural areas. The literacy rate of the region is 77.33% and 67.5% of the population is engaged in non-agricultural activities. Administratively, the region consists of four districts namely, Jalandhar, Hoshiarpur, Kapurthala and S.B.S. Nagar, which encompass 30 community development blocks. There are 3528 villages, 35 towns and 2 cities (Jalandhar and Hoshiarpur) in the region. The present study has been conducted for the cardiovascular deaths recorded in rural areas of the region.

4. RESULTS AND DISCUSSION

The cardiovascular mortality patterns (2009) in Bist Doab are shown in Map 1 and have been discussed elsewhere (Saini, 2013). The population of Bist Doab region relies heavily on underground water for drinking and agricultural purposes. In general the water is sweet, however there is a significant variation in the hardness and mineral contents of groundwater (Kumar et al., 2006). The data of Central Ground Water Board for the year 2005 shows that the calcium content of groundwater in rural areas of Bist Doab varies from 87 mg/l at Chohal in Hoshiarpur district to 12 mg/l at Bara Pind in Jalandhar district (Map 2). Based on the amount of calcium content, the groundwater hardness of various observation wells of Bist Doab region can be grouped into five categories, as given below:

(i.) **Soft water** (calcium content between 0 to 20 mg/l): The locations having soft underground water include Bara Pind (12 mg/l), Rampur Bilron (16 mg/l) and Shamilpur (19 mg/l). Bara Pind and Shamilpur lie in Jalandhar district. The areas surrounding these two locations have recorded high incidence of cardiovascular mortality.

(ii.) **Moderately soft water** (calcium content between 20 to 40 mg/l): The observation wells recording moderately soft groundwater include Sujjon (21 mg/l), Dalla (21 mg/l), Paddi (25 mg/l), Khurampur (25 mg/l), Hajipur (27 mg/l), Alawalpur (27 mg/l), Udhopur (31 mg/l), Kaira Majha (35 mg/l) and Chak Ladian (39 mg/l). All these point locations are concentrated in the southern and central parts of the
study area, except Hajipur and Chak Ladian, which lie in the north-eastern parts of the region. The wells of moderately soft water are situated in close proximity to the locations of soft groundwater and have recorded high rates of cardiovascular mortality.

(iii.) Slightly hard water (calcium content between 40 to 60 mg/l): The locations falling under this category are Paddi Jagir (41 mg/l), Jalbhe (41 mg/l), Bahram (43 mg/l), Mawai (45 mg/l), Bahowal (49 mg/l), Rurki (54 mg/l) and Argowal (60 mg/l). Most of these sites fall in juxtaposition to the moderately soft water areas and have also registered high mortality from cardiovascular disorders.

(iv.) Moderately hard water (calcium content between 60 to 80 mg/l): This category includes the observation wells at Bassi Mustafa (61 mg/l), Bhavnaur (62 mg/l), Nangal Bihala (62 mg/l), Karimpur Chhawala (62 mg/l), Rahian (68 mg/l) and Durimiwal (78 mg/l). Almost all these locations of moderately hard water fall in the eastern hilly areas of the study region, which corresponds to low cardiovascular mortality rates.

(v.) Hard water (calcium content of more than 80 mg/l): This category includes only one location of Chohal (87 mg/l), which falls in Hoshiarpur district. Chohal is again situated in the Shiwalik hills, recording very low mortality from cardiovascular ailments.

In order to generate a continuous raster surface from the point locations discussed above, spline interpolation technique was used. The output surface shows that the eastern parts of Bist Doab region have hard underground water (Map 3). Visual comparisons with cardiovascular mortality patterns show that these areas are associated with low cardiovascular mortality. The general trend of hardness goes on decreasing towards the western side of the study area. The areas in central and west-central parts have soft underground water. The rates of corresponding mortality from cardiovascular diseases are high in these parts of the region. Thus it has been found that soft water areas have higher cardiovascular mortality rates, while the areas having hard underground water experience lower cardiovascular mortality.

This observed inverse association between hardness of water and cardiovascular mortality can be attributed to the protective effect of the calcium intake from drinking water (Yang et al., 2005). The deficiency of calcium may lead to development of cardiovascular diseases. Inadequate levels of calcium intake are also associated with higher blood pressure (McCarran and Reusser, 2001) and hence the low hardness of drinking water contributes to higher occurrence of cardiovascular mortality (Sauvant and Pepin, 2000).

5. CONCLUSION

The areas of hard underground water, lying in the eastern parts of the study area have recorded low occurrence of cardiovascular deaths, whereas the soft water areas towards the west have higher rates of mortality from cardiovascular diseases. Thus it has been found that groundwater hardness has a crucial role in determining the cardiovascular health of the people. Therefore, it can be advocated that various components of the physical environment of an area, including groundwater hardness, should be given due consideration while developing preventive measures for this group of diseases.

REFERENCES


