Evaluation of Water Quality Based on Hardness Parameters in Selected Drinking Water Sources

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Abstract:
The study assessed the drinking water quality of selected sources based on total hardness, calcium hardness, and magnesium hardness. Water samples were collected during the pre-monsoon and monsoon periods to observe variations affecting overall quality. Total hardness ranged from 97.6 ppm (Banjaravas SMC, monsoon) to 362 ppm (Banjaravas Boring, pre-monsoon). Calcium hardness varied between 21.48 ppm (Ambedkarnagar, monsoon) and 59.69 ppm (Banjaravas SMC, pre-monsoon), while magnesium hardness ranged from 4.738 ppm (Morarji Vasahat, monsoon) to 65.642 ppm (Banjaravas Boring, pre-monsoon). Most of the values remained within permissible limits according to BIS and WHO guidelines. A reduction in total and magnesium hardness was observed during the monsoon period, mainly due to rainfall dilution. The borewell sources exhibited greater hardness variation and tended to exceed permissible levels; municipal-supplied water comparatively showed uniform and safer levels of hardness. These findings highlighted the need for an increase in public access to treated municipal water among informal settlements to meet public health and drinking water standards compliance.

1. Introduction
Drinking water quality is critical in protecting public health as well as supporting sustainable community development. Of all the factors affecting water quality, hardness is most relevant because it influences taste, scaling characteristics, and use in household and industrial applications directly. Hardness is largely due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, which can be from geological sources, from interactions between groundwater and rocks, and from human activities [1,2].

While moderate hardness is not found to be detrimental and can even supply good minerals to the health of human beings, high hardness causes pipe scaling, decreased efficiency of soaps and detergents, and alters taste[3]. Total hardness of drinking water should not exceed as per the Bureau of Indian Standards [4] and the World Health Organization [5] for safe use.

Different researchers had monitored hardness in water sources. In the study that of hydrogeochemical assessment in a semi-arid area of Telangana, focusing on groundwater suitability, findings indicated that the total hardness (TH) was generally higher than favourable levels (ranged from hard to very hard), and the study attributed this in terms of Ca^{2+} and Mg^{2+} from dissolution of granitic aquifer rocks, which is the same geological source effects[6]. Subba Rao et al. narrated that in the Yellareddygudem watershed, Telangana, post-monsoon recharge altered Ca^{2+} and Mg^{2+} concentrations through greater mineral dissolution and water–rock interaction—repeating seasonal hardness patterns in their study [7]. Most of those study were, however, region-specific or season-specific, with comparatively few reporting on the comparative investigation of total, calcium, and magnesium hardness of drinking water sources within the same region.

This gap was addressed by the research in assessing water hardness parameters in the selected sources of drinking water compared to the standards of drinking water quality. In addition to the determination of total hardness, the research accounted the contribution of calcium hardness and magnesium hardness to ascertain their contribution towards general water quality. Secondary factors affecting those parameters, including seasonal changes (pre-monsoon and monsoon), were also investigated to achieve a complete assessment applicable to drinking water quality management.

2. Materials and Methods

The study was designed to compare and assess the Hardness of water from a few selected slum pouches of Surat City, India. Five locations were chosen for the study: Govalak, Morarji Vasahat, Banjaravas, Halpativas, and Ambedkarnagar.

Water samples were collected in a systematic way from Surat Municipal Corporation (SMC) supply and borewell sources. In view of obtaining extensive coverage and to capture spatial change, five sampling points were chosen within each site, thus totalling 30 samples in the study area. Twenty-five of them were sampled from SMC-supplied piped water and five from borewell water in Banjaravas.Analysis was carried out following standard protocol[8].

Pre-monsoon and monsoon sampling was carried out to study for possible seasonal trends in water quality. The observed values were compared with BIS (IS 10500:2012)[4] drinking water quality permissible limits as well as those proposed by WHO[5].

3. Results and discussion

3.1 Total Hardness

The total hardness values ranged from 97.6 ppm (Banjaravas SMC, monsoon) to 362 ppm (Banjaravas Boring, pre-monsoon). A clear seasonal decline was observed in all sampling locations during the monsoon period (Fig. 1).

3.2 Calcium Hardness

Calcium hardness varied from 21.48 ppm (Ambedkarnagar, monsoon) to 59.69 ppm (Banjaravas SMC, pre-monsoon). Seasonal changes were inconsistent, with certain locations experiencing an increase during the monsoon (Fig. 1).

3.3 Magnesium Hardness

Magnesium hardness exhibited considerable variation, ranging from 4.738 ppm (Morarji Vasahat, monsoon) to 65.642 ppm (Banjaravas Boring, pre-monsoon). A general reduction was noted during the monsoon season (Fig. 1).

3.4 Implications for Drinking Water Quality

The average Total Hardness during the pre-monsoon season in Banjaravas Boring (362 ppm) and Halpativas (200.396 ppm) exceeded the 200 ppm standard limit. However, during the monsoon, all locations recorded total hardness values well within the acceptable limit. Average calcium hardness values for both seasons and all locations consistently remained below the 75 ppm standard limit, indicating good compliance. In the pre-monsoon season, magnesium hardness in Banjaravas Boring (65.642 ppm) exceeded the 50 ppm standard limit for magnesium. All other locations and all monsoon samples were below this limit.

In the current study, it was found that both municipal-provided drinking water sources and borewell (groundwater) contained different levels of hardness in different seasons. Total hardness in water samples was lower in municipal sources than in borewell sources, as follows the treatment practices adopted by water supply utilities, like sedimentation, filtration, and lime softening, the concentration of the calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions gets lowered according to the regulatory regulations [4,5]. However, seasonal hardness reduction was noted in all locations, including municipal supplies, during the months of rainy season mainly because of dilution effects from rain.

Subba Rao and his co-workers noted that seasonal recharge enhanced groundwater quality by reducing hardness in the Yellareddygudem watershed, Telangana. The results confirmed the geogenic processes and recharge function to control levels of hardness in raw water sources [7].In Punjab, regional studies from Bathinda District indicated total hardness levels ranging between approximately 164–314 mg/L and showed seasonal and spatial variability influenced by geology and recharge patterns. In their study, 56 groundwater samples were collected during pre-monsoon and post-monsoon. The mean total hardness (TH) was around 250 mg/L (pre-monsoon) and 270 mg/L (post-monsoon). Approximately 75% of pre-monsoon and 79% of post-monsoon samples exceeded the WHO maximum permissible limit for TH (150 mg/L)[9]. Gupta et al compared total hardness against BIS/WHO standards. The study highlighted numerous districts where hardness, along with nitrate and fluoride, exceeded the drinking water limits, especially during dry or pre-monsoon conditions [10].

It was found that municipal water supply facilities in Surat controlled hardness prior to distribution. According to U.S. Geological Survey (2018), the hardness of treated drinking water in most instances is within acceptable limits where proper treatment processes are applied by water utilities. The results thus affirm the conclusion that municipal treatment is in fact effective in sustaining hardness at Bureau of Indian Standards (BIS) and World Health Organization (WHO) levels even in regions where groundwater hardness is higher.

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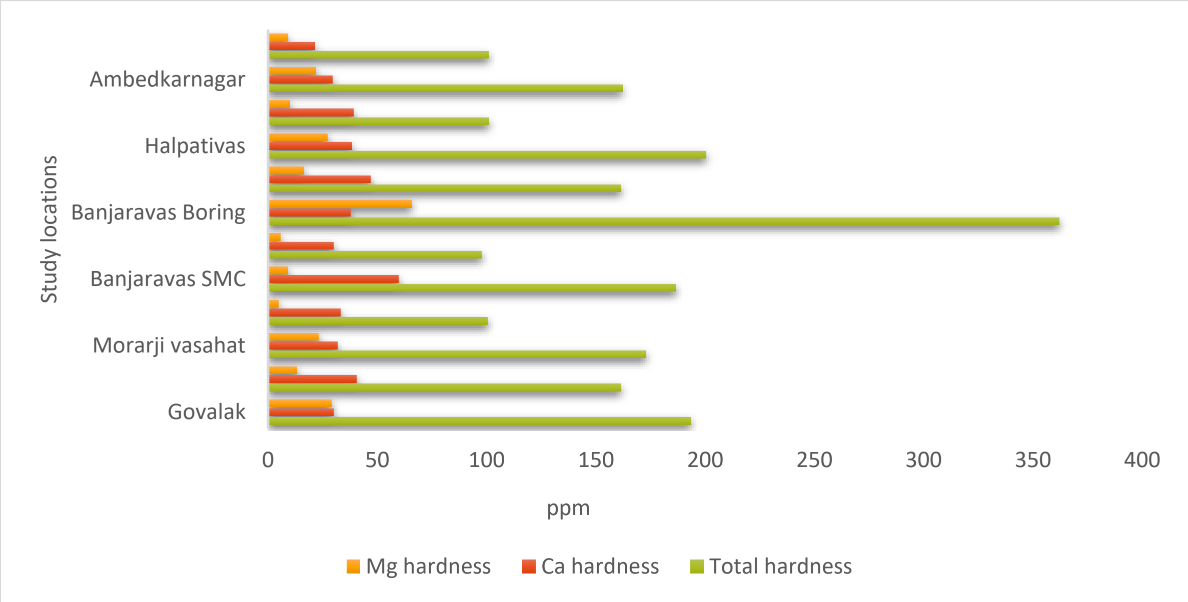

Fig.1 Variation in concentration of Total hardness, calcium hardness and magnesium hardness

5. Conclusion

The assessment of drinking water quality based on hardness parameters showed that most samples met the required standards for safe consumption. Seasonal variations, although present, did not compromise water quality but emphasised the need for ongoing monitoring, especially during the pre-monsoon period when hardness levels peak. Overall, while borewell sources exhibited greater hardness fluctuations and tended to exceed permissible levels, municipal supplies offered comparatively uniform and safer hardness levels. These findings emphasise the importance of increasing public access to treated municipal water in informal settlements to ensure compliance with public health and drinking water standards.

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