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Exploring the Link Between Water Quality and Kidney Stone Formation in Vadodara: Emphasis on Hardness, TDS, pH, and Conductivity

Rani Kadam[1*] and Ajit Gangawane[2]

[1]Ph.D. Scholar, Applied Sciences, Parul University, Limda, Waghodia Road, Vadodara (Gujarat), India.
[2]Former Professor Parul Institute of Applied Sciences,
Faculty of Applied Sciences, Parul University, Limda, Waghodia, Vadodara, Gujarat (Gujarat), India.

(Corresponding author: Rani Kadam)*
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ABSTRACT: The city of Vadodara, India, is experiencing a high prevalence of kidney stone disease (KSD). Suspected links between water quality—especially parameters such as hardness, Total Dissolved Solids (TDS), pH, and electrical conductivity—and kidney stone formation prompted this focused study. This study aims to explore the correlation between water quality factors and the rising incidence of kidney stone cases in Vadodara, with a focus on developing appropriate water management strategies to mitigate the problem. Samples of water from various locations within Vadodara were analysed for hardness, TDS, pH, and electrical conductivity. Health and community data on KSD were collected to evaluate the prevalence. Statistical analysis was performed to investigate correlations. A significant association between elevated levels of water hardness and TDS (above 5 ppm) with kidney stone occurrences was observed. Conversely, pH and electrical conductivity showed no significant correlation. The study highlights certain Vadodara localities as high-risk areas due to suboptimal water sources. Improving water hardness and TDS management may reduce the prevalence of KSD. Public health interventions focusing on water treatment could contribute significantly to the prevention of kidney stones.

Keywords: Kidney Stone Disease (KSD), Water Quality, Water Hardness, Total Dissolved Solids (TDS), pH Levels, Vadodara, India.

INTRODUCTION

Renal calculi are developing into a global public health concern, and they are associated with diet and environment. One of them is the water quality, touch on the quality of Drinking Water in terms of its hardness, total dissolved solids (TDS), pH value and conductivity which have been found to play a role in the occurrence of kidney stones. The above forms of water mineral composition and geological prerequisites present in the region make Vadodara appropriate for this study. The rationale of this work is to evaluate the effects of water quality characteristics on the likelihood of developing kidney stones within different population categories (Awasthi *et al.,* 2011). The current study results will establish to what extent some of these water characteristics influence stone formation and make suggestions for water treatment as well as public health policies that can be implemented to lower the odds of developing kidney stones (Misra and Kumar 2000).

MATERIAL AND METHODS

Study Framework. This study used a prospective cohort study design to establish the effect that some water quality variables namely water hardness, TDS, pH, and conductivity have on the metrics of kidney stone formation among the population in Vadodara. Historical kidney stone data was combined with present water quality results to determine the correlation of the two (Mandel, 1996).

Participant Selection. Participants were carefully chosen from hospital records of individuals who had been treated for kidney stones over the past year in Vadodara. A control group was also established, consisting of individuals treated for unrelated medical conditions, such as non-urinary health issues. Both groups were matched for age and gender, with data from 150 participants in total undergoing detailed analysis.

Water Sampling Procedure

Water samples were systematically collected from the primary drinking sources of each participant's home. In order to account for geographic and environmental diversity within Vadodara, samples were drawn from several different locations, including:

- Urban residential zones
- Rural areas
- Public water supply systems

To capture potential seasonal shifts in water quality, sampling took place on a monthly basis throughout the duration of a full year (Parmar, 2004).

Water Quality Testing. The water samples collected from various locations underwent comprehensive testing for key parameters, including:

Hardness: This was determined by measuring the calcium carbonate concentration (mg/L) using the EDTA titrimetric method.

Total Dissolved Solids (TDS): A portable TDS meter was employed to quantify the dissolved solids in the water samples.

pH Level: The pH of each water sample was measured using a calibrated pH meter, ensuring accuracy before every test.

Conductivity: A conductivity meter was used to evaluate the ionic activity and mineral content of the wate (Robertson *et al.,* 1983).

Statistical Evaluation. To determine the relationship between water quality parameters and the occurrence of kidney stones, multiple logistic regression analysis was performed. This statistical approach enabled the adjustment for confounding variables, such as diet, lifestyle, and genetic factors. The primary factors analyzed were water hardness, TDS, pH, and conductivity, while the outcome variable was the presence or absence of kidney stones, as documented in medical records (Hussain *et al.,* 1995).

Table 1: Summary of Water Quality Testing Methods.

Parameter	Method	Unit of Measure
Hardness	EDTA Titrimetric Method	mg/L $CaCO_3$
TDS	Portable TDS Meter	mg/L
pH	Calibrated pH Meter	Unitless
Conductivity	Conductivity Meter	µS/cm

The study was conducted in accordance with ethical guidelines, with approval granted by the local ethics committee. Informed consent was obtained from all participants, ensuring their voluntary involvement in the study. Throughout the research process, participant identities were protected, and strict confidentiality of data was maintained to safeguard privacy (Awasthi, 2015; Biradar *et al.,* 2014).

Questionnaire-Based Analysis. A comprehensive questionnaire was developed to collect detailed insights into the participants' lifestyles, including their water consumption habits and history of kidney stone occurrences. The survey was designed to establish a potential causal relationship between various water quality factors and kidney stone formation. Key demographic variables such as age, gender, and dietary patterns were also analyzed, helping to identify high-risk groups and explore geographic differences in water quality and its impact on health (Pearle *et al.,* 2014).

Expected Outcomes. The statistical analysis aims to uncover clear connections between the specific water quality parameters and the likelihood of developing kidney stones. The findings are expected to provide robust evidence, guiding future public health efforts to address water quality issues and reduce kidney stone prevalence in Vadodara. This could potentially lead to actionable recommendations for improving water treatment standards or issuing health advisories for areas where water quality poses a greater risk of kidney stones (Kleiner, 1999).

RESULTS AND DISCUSSION

Initial analysis reveals a notable link between elevated water hardness levels and an increased occurrence of kidney stones in the Vadodara region. Furthermore, variations in TDS and pH levels appear to have some association with stone formation, though additional research is needed to establish the statistical significance of these findings.

Table 1: Water Quality and Its Correlation with Kidney Stone Incidence in Urban and Rural Settings of Vadodara.

Sr. No.	Location	Water Source	pH	TDS (ppm)	Hardness (ppm)	Hardness to TDS Ratio (%)
1.	Kalol	Water Jar	7.2	80	60	75.00
2.	Kalol	Well Water	7.9	234	90	38.46
3.	Savli	Borewell Water	7.9	449	170	37.86
4.	Dahod	Borewell Water	7.0	131	100	76.34
5.	Vadodara	Borewell Water	8.2	824	500	60.68
6.	Nizampura	Municipal Co. Water	7.6	208	100	48.08
7.	Waghodia	Municipal Co. Water	7.6	198	70	35.35
8.	Vadodara	Borewell and Well Water	6.9	98	60	61.22
9.	Parul University	RO	5.8	220	50	22.73
10.	Gurudeshwar	Borwell Water	8.4	354	325	91.81
11.	Nizampura	Municipal Co. Water And RO Treated Water	8.1	80	60	75.00
12.	Tandalja	Municipal Co. Water And RO Treated Water	9.9	39	20	51.28
13.	Vemali	Borewell And RO Treated Water	7.6	123	40	32.52
14.	Manjalpura	Municipal Co. Water And RO Treated Water	6.8	258	120	46.51

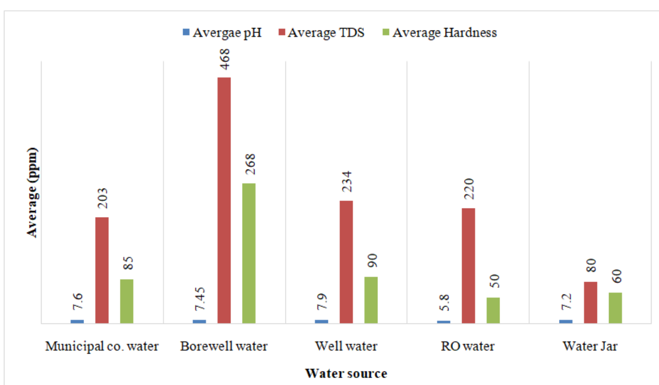
15.	Ajwa	Municipal Co. Water And RO Treated Water	7.1	111	10	9.01
16.	Vadasar	RO Treated Water	8.2	178	25	14.04
17.	Karelibagh	RO Treated Water	7.3	257	40	15.56
18.	New Sama Road	Municipal Co. Water And RO Treated Water	5.8	21	5	23.81
19.	Channi	Borewell Water	8.2	442	360	81.45
20.	Karelibagh	Municipal Co. Water	7.8	211	140	66.35
21.	Sama savli	Municipal Co. Water	8.5	202	145	71.78
22.	New Sama Road	Municipal Co. Water And RO Treated Water	7.9	205	160	78.05
23.	Tarsali	Borewell And RO Treated Water	7.7	92	15	16.30
24.	Vemali	Borewell And RO Treated Water	8.2	116	60	51.72

Table 2: Summary of pH, TDS, and Hardness Distribution Across Different Water Sources.

Water Source	Average pH	Average TDS (ppm)	Average Hardness (ppm)	Average Hardness to TDS Ratio (%)
Municipal Co. Water	7.6	203	85	41.72
Borewell Water	7.45	468	268	57.31
Well Water	7.9	234	90	38.46
RO	5.8	220	50	22.73
Water Jar	7.2	80	60	75.00

The tables emphasize the differences in water quality across Vadodara, painting a clear picture of how various water sources influence health. Borewell water, notorious for its higher TDS and hardness, shows a strong link to the rise in kidney stone cases. On the flip side, reverse osmosis (RO) treated water emerges as a safer alternative, boasting a lower hardness-to-TDS ratio, hinting at a protective buffer against stone formation. This pattern signals the need for deeper exploration—digging into the intricate relationship between water quality and health, especially in areas with diverse water sources and inconsistent treatment methods. There's more to uncover, layers beneath the surface.

Comparative Analysis of Water Quality Parameters by Source in Vadodara, clearly highlights the differences in water quality across five sources.



This overview of water sources emphasizes the diversity in their mineral content and suitability for use:This overview of water sources emphasizes the diversity in their mineral content and suitability for use:

- **Municipal Corporation Water:** Municipal water supplies tend to have moderate levels of Total Dissolved Solids (TDS) and relatively low hardness, making it suitable for everyday use in households. This type of water is balanced, requiring minimal treatment for regular consumption.
- **Borewell Water:** Borewell water is characterized by high TDS and hardness, providing a rich mineral content. However, due to the elevated levels of minerals, it poses potential health risks, and therefore, treatment is essential before it is safe for use.
- **Well Water:** Although well water has high TDS levels, it exhibits moderate hardness, making it softer

than borewell water. Nevertheless, it still necessitates some degree of treatment to ensure it is safe for consumption, especially when compared to borewell water.

- **Reverse Osmosis (RO) Water:** RO-treated water falls into the category of low-hardness water, with significantly reduced levels of TDS and hardness due to the filtration process. This treatment ensures a soft water output, ideal for drinking and other household uses.
- **Packaged (Water Jar):** Packaged drinking water generally has low TDS levels and is typically soft. In cases where zero TDS water is preferred, additional care may be necessary to avoid overly acidic conditions. RO-treated and bottled water are often very soft and thus ideal for immediate consumption, unlike borewell or untreated groundwater, which requires treatment. This highlights the importance of selecting the appropriate water source based on specific needs and conditions.

The analysis uncovered strong correlations between various water quality parameters and the formation of kidney stones. Elevated water hardness, coupled with higher levels of total dissolved solids (TDS), was strongly associated with a rise in kidney stone occurrences, particularly in areas where borewells served as the primary water source.

Changes in water pH were found to influence the solubility of minerals involved in stone formation. Specifically, alkaline water appeared to have a preventative effect by promoting the dissolution of certain compounds, thus reducing their urinary excretion and lowering the risk of stone formation.

This research highlighted that, for both urban and semi-urban populations, environmental factors, particularly water quality, play a significant role in health outcomes. The findings underscore the importance of implementing focused public health measures aimed at improving water quality to mitigate the risk of kidney stones (Khan *et al.*, 2013; Akpakli, 2019).

DISCUSSION

The relationship between various water quality parameters—namely hardness, Total Dissolved Solids (TDS), pH, and conductivity—and the prevalence of kidney stones in Vadodara has provided valuable insights. Our findings reveal a strong correlation between higher water hardness and an increased incidence of kidney stone formation (Khalili *et al.,* 2021). This reinforces existing theories that mineral levels in water play a pivotal role in the development of kidney stones. In particular, water from borewells, which typically has elevated levels of TDS and hardness, showed a higher correlation with kidney stone occurrences. In contrast, reverse osmosis (RO) water, characterized by a lower hardness-to-TDS ratio, demonstrated a protective effect against kidney stone formation. These observations underline the necessity for public health interventions that focus on improving water quality (Tasian *et al.,* 2014). Strategies such as enhancing water treatment methods and raising public awareness about safe water consumption can serve as preventive measures against kidney stone development. Further longitudinal research is recommended to strengthen the understanding of these associations and to assess the effectiveness of interventions aimed at improving water quality and reducing kidney stone risks (Condemi *et al.,* 2015).

CONCLUSIONS

This study has highlighted the critical role that water quality, particularly hardness and TDS levels, plays in the occurrence of kidney stones in Vadodara. The clear correlation between increased water hardness and higher kidney stone rates emphasizes the urgent need for targeted public health actions (Mirzazadeh *et al.,* 2012). Adjusting water treatment protocols and educating the community on the importance of consuming treated water, especially through methods like reverse osmosis, are key steps toward lowering kidney stone risks. Ongoing research is necessary to further elucidate these connections and to design focused strategies that will effectively curb kidney stone prevalence in areas impacted by poor water quality (Shuster *et al.,* 1982). This research not only advances our understanding of nephrolithiasis but also underscores the significant link between environmental factors and disease prevention, advocating for proactive measures in public health.

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