Study of Relationship of Potential Kidney Stone with Water (Consumption and Quality) and Dietary Habits of People in Urban Thanjavur using GIS

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Abstract: Kidney stone formation in Thanjavur district population has been identified in the recent years. There is a common belief that kidney stone forms due to intake of high Calcium content present in groundwater and improper dietary regulations of the people. Literature review on kidney stone studies reveals that there are no exact correlations of factors that causing kidney stones such as high/low Calcium and Sodium contents in groundwater in addition to other factors including common dietary and water intake by the patients over period of time and hereditary causes coming in family traditions. The present work is to study the relationships between the kidney stone formation and pH, Calcium, Sodium contents of groundwater while considering dietary regulations and quantity of water intake by the people of urban Thanjavur. Finally ArcGIS 10 is used to demarcate the high/low Calcium and Sodium zones in Thanjavur city.

Keywords: Kidney Stone, Ground Water Quality, Gis, Calcium, Sodium and Thanjavur

1. Introduction:

Among urinary disorders, stone formation is of paramount importance. The incidences of kidney stones are rising in rural and urban societies in India. A large population of the country suffers from kidney stones which are formed due to deposition of calcium, phosphates and oxalates in kidneys and later moving to urinary tracts and bladders (Madhvi Awasthi et al, 2011). The chemicals start accumulating over a nucleus, which ultimately takes the shape of a stone (Misra and Kumar, 2000). The occurrence of renal stone disease is related to food habits of individuals. Dietary factors include a high intake of animal proteins and oxalates and a low intake of potassium containing citrus fruits and fluids (Tur et al. 1991). Intake of sodium is also associated with increased risk of stone formation presumably because of increased urinary calcium excretion (Carbone et al. 2003; Vasanthamani and Sushmitha, 1997). Inadequate fluid consumption decreases total urinary volume thereby increasing the concentration of stone forming salts. The present work is an attempt to study the relationship among dietary habits & quantity of water intake by patients and water quality parameters in incidence of stone formation based on selected kidney stone patients in urban Thanjavur, Tamil Nadu, India.

Thanjavur city population was provided drinking water from the nearby Vennar River and Vandavur River (distributaries of river Cauvery diverted after Grand Anicut). To meet present population water demand, the Thanjavur Municipality has been augmenting the existing supply by using 32 new bore wells located in various locations of the city. This ground water is not given adequate treatment before supplying to city population for consumption and domestic purposes (TNUIFL, 2007). By consuming this bore well water there are many evidences of people affected with Kidney stones in Thanjavur city in recent years. Kidney stone patient histories are found in various Urology hospitals including Thanjavur Medical College Hospital (TMCH), KDR Hospital and SB Hospital.

This work is done beginning with visiting hospitals treating kidney stone patients (for past few years) for recording patient details including their name, age, gender and address. Secondly, using questionnaire prepared specifically, visiting the patients’ houses for collecting water intake and common dietary habits of the patients, collecting water sample in 1 liter water bottle for water analysis at laboratory for estimating various water quality parameters and measuring latitude & longitude of the location of the house using Geographical Positioning System (GPS) for geo-referencing in GIS. Finally, Geographical Information System (GIS) is used for preparing base map and various thematic layers based on Calcium, Sodium and pH contents for preparing spatial distribution of these contents in Thanjavur polygon for comparing their
inter-relations in formation of kidney stone. Building the queries to understand the most possible relationship among various water quality parameters, water intake and food habits causing kidney stone formation. Some of the findings from the work include water having Calcium content >75 mg/lit as well as <75 mg/lit (BIS desirable limit), both effected patients in kidney stone formation. Thereby, it can be said that not only Calcium content is the main cause but also other causes responsible for kidney stone formation. Calcium and Sodium are interrelated. Even moderate amount (>50 mg/lit) of Sodium present (BIS desirable limit) in drinking water or food increases Calcium in the kidneys even if water has less Calcium thereby stone formation is possible. Drinking less than 3 liters water per day (62 out of 66 patients have been identified) could be the main factor in formation of kidney stone.

2. Study Area:
The present study area is urban Thanjavur, having Latitude of 10.8°N and Longitude of 79.15°E. The Urban Thanjavur is headquarters of the Thanjavur taluk and which is also the seat of the district administration. It is situated at the head of Cauvery delta, at a distance of 314 kilometres (195 mi) south-west of Chennai and 56 kilometres (35 mi) east of Tiruchirappalli. Though most of Thanjavur District is a level plain watered by the Cauvery tributaries, the taluk of Thanjavur is made up mostly of barren uplands sloping towards the east. The Grand Anaicut Canal and Vadavuru river flow through the city. Thanjavur's economy is mainly agro-based. The city acts as a focal point for food grains transported from the adjoining areas of the Cauvery Delta. Previous integrated Thanjavur district was known as the Rice bowl of Tamil Nadu as major crop is paddy throughout the year. Other major crops other than Paddy are Blackgram, Banana, Coconut, Gingelly, Ragi, Redgram, Green Gram, Sugarcane, Maize. The present study area is shown in figure 1.

3. Data and Water Samples Collection:
The study was conducted on a total of 66 kidney stone patients (gone through the treatment in the period 2010-2011), comprising 44 males and 22 females, selected from KDR Hospital, Thanjavur, Tamil Nadu. A comprehensive and exhaustive questionnaire was formulated specifically keeping in mind the objectives of the study. This sample questionnaire was presented to 4 urologists (doctors) and was then evaluated for response of the patients. The necessary improvements/alterations/modifications were incorporated on the basis of collected information, thus making the questionnaire more functional. The data were collected during the months of January-February, 2012.

Each patient was interviewed by visiting their houses to collect information regarding the quantity of water intake per day, source of their drinking water, type of home treatment given to water before consuming, dietary habits especially vegetarian and non-vegetarian with added information about his/her food likes/dislikes and preferences/intolerances (if any). Table 1 show the colonies and the number of patients interviewed in urban Thanjavur.

Table 1: Patients Interviewed in different Colonies of Urban Thanjavur

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Colony Name</th>
<th>Code</th>
<th>No. Of patients interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Medical College Road</td>
<td>MC</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Madakottai Road</td>
<td>MR</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Nanjikottai Road</td>
<td>NK</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Yagappa Nagar and Arulanand Nagar</td>
<td>YPR</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ARL</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BS</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>M.Chavady</td>
<td>MCV</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>New Bus Stand</td>
<td>NBS</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>Old Bus Stand</td>
<td>OBS</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: Queries and the Number of Sample Stations That Falls With in the Query Criteria Given

<table>
<thead>
<tr>
<th>Definition of Query</th>
<th>Number of Sample Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I) Water consumption &lt; 3 liters and Ca &lt; 75 mg/lit</td>
<td></td>
</tr>
<tr>
<td>Query (1) : Na&lt;50 mg/lit and Veg</td>
<td>8</td>
</tr>
<tr>
<td>Query (2) : Na&lt;50 mg/lit and Non-Veg</td>
<td>11</td>
</tr>
<tr>
<td>Query (3) : Na&lt;50 mg/lit and Veg</td>
<td>6</td>
</tr>
<tr>
<td>Query (4) : Na&gt;50 mg/lit and Non-Veg</td>
<td>7</td>
</tr>
<tr>
<td>(II) Water consumption &lt; 3 liters and Ca &gt; 75 mg/lit</td>
<td></td>
</tr>
<tr>
<td>Query (5) : Na&lt;50 mg/lit &amp; Veg</td>
<td>6</td>
</tr>
<tr>
<td>Query (6) : Na&lt;50 mg/lit &amp; Non-Veg</td>
<td>8</td>
</tr>
<tr>
<td>Query (7) : Na&gt;50 mg/lit &amp; Veg</td>
<td>9</td>
</tr>
<tr>
<td>Query (8) : Na&gt;50 mg/lit &amp; Non-Veg</td>
<td>11</td>
</tr>
</tbody>
</table>

Drinking water samples (all are groundwater samples) also collected from each patient in 1 liter bottles to analyze for estimating physical and chemical parameters including Calcium and Sodium contents. Additionally, latitude and longitude of the house location of each patient is recorded using the Trimble Global Positioning System (GPS). 66 sample station locations are shown in figure 2.
3.1 Water Analysis:

Water samples were analyzed using Systronic Water analyzer 371 for water quality parameters such as pH, DO (ppm), Conductivity (µS), Salinity (ppt), TDS (ppm) and Temperature (°C). Calcium contents were estimated by the standard titration method whereas Sodium contents were estimated using digital flame photo meter. According to BIS, pH desirable limit is in between 6.5 to 8.5 whereas permissible limit is in between 6.5 to 9.2; DO desirable limit is >3 ppm; TDS desirable and permissible limits are <500 ppm and <1000 ppm; Calcium desirable and permissible limits are <75 mg/l and <200 mg/l; Sodium desirable and permissible limits are <50 mg/l and <200 mg/l.

4. GIS Mapping: Spatial Distribution of Calcium and Sodium:

4.1 Base Map Preparation and Geographical Features Creation:

Village polygons in Bhuvan administrative layers were (developed by ISRO, India) obtained for Thanjavur city region and its corresponding latitudes and longitudes at four locations were noted (Bhuvan, 2012). A base map for the study area is prepared by using tools in ArcGIS 10. Line features and polygon features of Thanjavur city were downloaded by connecting to Open Street Map (OSM, 2012) open source website. Line feature is representing National Highway, State Highway and village roads whereas polygon feature is representing new Thanjavur boundary of populated area and other important buildings and institutions. In addition to these available features, point features are created for selected 66 sample stations. Attributes are defined and their estimated values are entered for all chemical parameters of water samples and corresponding patient details as well.

4.2 Contour Map Development of Calcium and Sodium:

Using Inverse Distance Weighting (IDW) method, interpolation surfaces were generated for Calcium, Sodium and pH data for entire city. Using these raster layers, contour maps (as vector layers) were generated separately for Calcium and Sodium to observe their distributions over Thanjavur city.

4.2.1 Spatial Distribution of Calcium:

Calcium variation in the contour map given is figure 3 depicts some of the patterns. As contours move from North to South, Calcium values are gradually increasing up to the centre of the map and again decreasing towards South. Similar observation is made from West to East. Contour values are increasing up to the centre of the map and again decreasing towards the East.

4.2.2 Spatial Distribution of Sodium:

Sodium has been following the similar pattern as Calcium, showing the maximum values (around 70 mg/lit) at the centre of the map and deceasing values as contours move towards the four directions (shown in figure 4).

4.3 Building Queries Using Attributes:

It is observed from the water consumption of the patients that many (63 out of 66) patients were consuming ≤3 lit/day. Drinking less water could be the main cause for crystal formation and further led to stone formation in kidneys over period of time. So, this is taken as constant query while other queries on other parameters were changing according to the BIS desirable limits of the parameter. Patient’s gender and age, type of water consumed, treatment given to water for consumption are not considered in the queries as these are not the direct factors of the kidney stone formation. Following Table 2 gives queries used to find the number of sample stations falling in the query and their distribution. Two sets of queries are designed. In first set of queries, water consumption <3 lit and Ca>75 mg/lit were kept constant whereas Na (in mg/lit) and patient diet were varying. In second set of queries, water consumption <3 lit and Ca>75 mg/lit were kept constant whereas Na (in mg/lit) and patient diet were varying as in first set.

5. Results and Discussions:

Spatial distribution of given water quality parameter over given space gives the understanding of it’s spread, it’s high, low and intermediate quantities can be observed in the locations where actual quantities are not available. This will provide the information of entire spatial distribution of given water quality parameter. From the observation of spatial distribution of Calcium, Sodium and pH of 66 water samples reveals that they are interrelated each other and causing kidney stone formation as discussed below. In addition, drinking water quantity and diet of the patients are also identified as main factors influencing kidney stone formation.

1. The main factor that may be cause of kidney stone formation is least daily water consumption. Answers to the questionnaire reveal that 63 patients were consuming ≤3 lit/day. This may lead to gradual
formation of crystals and later on increases to measurable kidney stone over period of time.
2. There is common belief that drinking more Calcium water (>75 mg/lit) is the causing factor in kidney stone formation but this study reveals that even drinking less Calcium water also causing kidney stone problem. 25 water samples were estimated with Calcium > 75 mg/lit and remaining i.e. 41 samples were estimated with Calcium ≤ 75 mg/lit. This means not only water having more Calcium can cause Kidney stone formation but less Calcium can cause Kidney stone problem.
3. Some of the literatures revealed that Sodium present in water also indirectly causes increasing the content of Calcium in the body and further assists in formation of kidney stone. In another way, even though Calcium content is less (compared to desirable limit), its counterpart Sodium can increase Calcium in the body. There are other studies (Madhvi Awasthi et al, 2011) quoted taking more salted food also increases salt content in the body there by increases Calcium content in the body. If not from water, substantial amount of Sodium from salt food consuming more than the prescribed limit also increases Calcium in the kidneys.
4. 47 water samples are having pH ≤ 7 and remaining 19 samples are having pH > 7. This reveals that acidic water may cause kidney stone formation rather than alkaline water.
5. As far as overall comparison of diet of the patients is concerned, non-vegetarians are more prone to kidney stone formation than vegetarians. As meat food contains more proteins that causes more acids generation in the body and leads to kidney stone formation. Protein increases uric acid, calcium, and oxalate levels in the urine, and reduces citrate levels. Diets high in protein, particularly meat protein, have been consistently connected with kidney stones. Meat protein has higher sulfur content and produces more acid than vegetable protein.
6. Contour maps of Calcium and Sodium are overlapped to compare the interrelation between them and shown in figure 5. Both Calcium and Sodium are having directly proportional relationship West, North and East directions of city. Only South direction, both Calcium and Sodium are indirectly related to show that both are having influencing factors on formation of Kidney stone.
7. Table 2 provides the information on number of samples matching with the various criteria considered under attributes query field. Non-vegetarians are facing more kidney stone problem than vegetarians. Following combinations were identified as possible potential combinations compared to other combinations in forming kidney stones: (a) water consumption ≤ 3 lit, Ca > 75 mg/lit, Na > 50 mg/lit and Non-Veg (b) water consumption ≤ 3 lit, Ca ≤ 75 mg/lit, Na ≤ 50 mg/lit and Non-Veg. In above two combinations, observed samples are 11 in each combination and more than other combinations.

6. Conclusions:
As many factors involved in kidney stone formation, combination of proportions of each factor has to be understood to diagnose the root of the problem. This study has been considered various factors such as daily water consumption by patients and their dietary habits, groundwater quality parameters such as pH, Calcium, Sodium to evaluate the combined effect kidney stone formation. Following are the conclusions derived from this study:
1. Drinking very less water is the main cause for kidney stone formation.
2. Calcium and Sodium are directly related in entire Thanjavur. This means even though Calcium is less in water, salt food consumption can increase the content of Calcium in the kidneys and leads to stone formation. Or if Sodium availability is more in water then it can also increase acidic formations and Calcium content in the kidneys.
3. Non-vegetarians are more prone to kidney stones than vegetarians since meat food can increase acidic content in the body there by acidic stones may form.
4. pH having less then 7 also increases acidic quality in the body and lead to acidic stone in the kidneys.
5. Combination of less water intake and non-vegetarian food in addition to inversely proportioned Calcium and Sodium are the most possible criteria for formation of kidney stones.

7. Acknowledgements:
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8. References:


Figure 1: Study Area of Urban Thanjavur
Figure 2: Sample Stations in Study Area
Figure 3: Spatial Distributions of Calcium and its Contours in Study Area
Figure 4: Spatial Distribution of Na and its Contours in Study Area
Figure 5: Combined Contour Map of Calcium and Sodium