THE STATUS OF TRADITIONAL STONE SPOUTS IN THE KATHMANDU VALLEY, NEPAL

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***Abstract*—An icon of the Kathmandu Valley civilization, 'stone spouts' are traditional water supply systems that originate from ancient canals (Rajkulos), natural springs or shallow aquifers. These stone spouts are either dry or on the verge of extinction today. Despite cultural and economic significance, these stone spouts are overlooked in various water management strategies and baseline data is scarce. As a result, its regular monitoring and management remain a challenge. The main objective of this research was to identify the status of 250+ stone spouts of the Valley mobilizing university students as citizen scientists during the 2018 post- and 2019 pre-monsoon. All data were recorded in an Android application called Open Data Kit (ODK) Collect. Out of the 287 stone spouts surveyed, in post-monsoon period, there were 146 flowing and 141 non-flowing stone spouts. When the season changed, in pre-monsoon, there were 112 flowing and 175 non-flowing stone spouts. Also, the flow rate was higher in the post-monsoon than pre-monsoon, except for some of the exceptions. This could be due to various factors including urbanization, overpopulation, depletion of shallow groundwater aquifers, reduced surface infiltration capacity, destruction of state canals, excessive groundwater extraction, and obstructions to subsurface flow areas. Management of these ancient spouts is hence crucial to preserve our historical ambiance and reduce the water stress of the Valley.**

Keywords—stone spouts, Kathmandu Valley, citizen scientists

I. INTRODUCTION

Over the past decades, global freshwater use has shown an exponential growth mainly due to rapid population growth and economic development. Groundwater resource depletion, surface water pollution, over withdrawals and climate change effects have threatened the availability and sustainability of freshwater resources. Despite being rich in water resources, both urban and rural areas of Nepal face severe water quality and quantity crisis.

Kathmandu, one of the most populated and urbanized cities of Nepal, is characterized by its deteriorated water quality and acute water shortage [8]. In the Kathmandu valley, population growth from 1.65 to 2.53 million between 2001 and 2011 has led to water demand escalation from 155 to 370 million liters a day (MLD) between 2000 and 2015 [8]. However, as of 2015, Kathmandu Upatyaka Khanepani Limited (KUKL) is supplying only 115 MLD and 69 MLD in wet and dry seasons, respectively [4]. Due to this growing imbalance between water demand and supply, core areas of the Kathmandu Valley are facing severe water shortages [6][8][10]. The conversion of agricultural land to built-up areas from 62% to 42% from 1984 to 2000 has declined the recharge of stressed underlying groundwater aquifers [8]. In such a case, the importance of cost-effective and efficient traditional water supply source i.e. stone spouts can be highlighted.

The stone spouts (also known as Dhunge Dhara in Nepali and Hiti in Newari), developed in the 6th century AD, served as the only communal drinking water source for the urban dwellers living in the Kathmandu Valley [12]. The concept of stone spouts initiated during the Kirat period, developed further during the Lichhavi period and its construction then extended during the Malla regime [1]. The recharge of the stone spouts is a local shallow aquifer (10m below the ground) which is further recharged by conveyance canals called state canals (Rajkulos). The operating system of the traditional water supply system is illustrated in Figure 1. Back in history, the integrated network of state canals, ponds and water conduits provided sustainable water supply to the Valley's population.

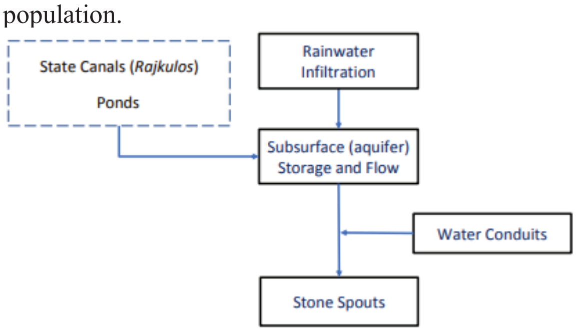

Figure 1: Flowchart showing the traditional water supply system in the Kathmandu Valley [3]

An icon of the Kathmandu Valley civilization, these stone spouts are historically and culturally significant. However, with the development of the modern water supply system and lack of attention and priority, the medieval ones are being discarded. Many of the stone spouts have already dried up, while many others have reduced flow. According to UN-Habitat, the introduction of piped water supply system after 1950 A.D. is the reason for the destruction of the traditional water sources in the Valley [11]. Before the introduction of piped water supply system, stone spouts were the main source of drinking water for the people residing in the Valley [6]. Nowadays, people choose private and personal water taps over stone spouts for domestic and household purposes. Concurrently, the reasons for the declination of these ancient stone flow are: increase in developmental activities, destruction of source, decrease in open spaces, modern construction, digging of deep boreholes, and deforestation [9]. The state canals which supply water to these spouts have been destroyed. For instance, the *Sundhara Hiti* ran dry because of the destruction of its source which was located in the area where Kathmandu Mall was built [7]. Out of the total 389 recorded stone spouts, 34, 4 and 7 had already disappeared in Kathmandu, Bhaktapur, and Lalitpur, respectively. Many of the remaining are not working and not fully functional [7]. Human footprint continues to expand at an alarming rate, and competition among the priorities of conservation actions tends to increase. In the priority list, the study of stone spouts (in terms of its status) is scarce.

Past studies in stone spouts doesn't have temporal studies and very less spatial one. So, this study will thus help in defining existing conditions of the stone spouts, and continuing data collection will show any changes that occur over time. Also, the research aims to increase awareness among the university students and locals about the importance of traditional water supply system, here in this case, stone spouts.

II. METHODS

A. Study area

Located between 27°32'13" to 27°49'10" North latitudes and 85°11'31" to 85°31'38" East longitudes in the central region of Nepal, Kathmandu Valley (Valley) (Figure 2) is one of the rapidly urbanized mountain basins of the Himalayas. The Valley is a circular intermontane basin with an area of 644 km2 encircled by mountains in its peripheries. The Valley comprises three districts; Kathmandu, Bhaktapur, and Lalitpur with a total population of 2.53 million according to the 2011 census [8]. The elevation ranges from 1100 to 2700 meters above the sea level (masl) with a mean of 1300 masl. Within a small geographical area, the Valley has complex topography [8]. The Valley has a mild southerly slope and has fertile soil deposits that favor agricultural production of rice, corn and vegetables from northern to southern parts. The subtropical cool temperate climate is influenced by South Asian monsoon altering the precipitation pattern and wind direction [13]. More than 80% of the annual rainfall occurs from June to September. Within the Valley, the highest and least amount of precipitation falls in the north-western and southern parts, respectively. The monsoon season is followed by winter, spring, and summer. The average annual temperature and rainfall are 18.1°C and 1407 mm, respectively.

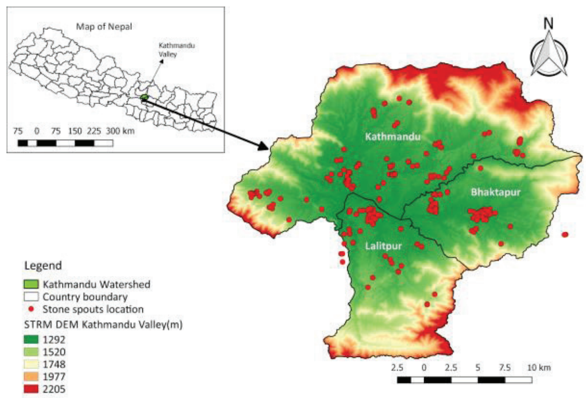

Fig. 1: Kathmandu Valley Watershed map showing the stone spouts location

B. Data Collection

From 15 to 27 September (2018; post-monsoon) - and 22 to 26 March (2019; pre monsoon), each group of 6 Bachelor's in Environmental Science student citizen scientists from various academic institutions of Nepal joined Smartphones For Water Nepal (S4W-Nepal) two-weeks-long Dhunge Dhara and Land Use Classification (2D-LUC) Campaign. This research was done within the project of S4W-Nepal. Theoretical orientation and field-training were given to the students citizen scientists for data collection. All measurements were recorded in an Android application called Open Data Kit (ODK) Collect. For each sampling location, stone spouts flow, quality and land use classifications were performed using a customized ODK form. The date, time and GPS locations were recorded using the same form and collected data were transferred into S4W Aggregate server via Wi-Fi or cellular network.

For stone spouts discharge measurement, a measuring bucket of known volume and a stopwatch timer were used. The bucket was held under the stone spout, timer was started, and the time taken to fill up the bucket was recorded and hence, flow was measured. For example, if the 12 litres bucket takes 25 seconds to fill, the flow rate (in litres per second i.e. lps) would be 0.48 lps. For quality, electric Conductivity for all the flowing stone spouts were recorded. The Tusa Hiti located at Mangalbazaar of Lalitpur district is one of the examples of flowing stone spouts. The image was captured by the citizen scientists during the campaign.

Fig. 2: The Tusa Hiti located at Mangalbazaar of Lalitpur district

III. RESULTS AND DISCUSSION

A. Status of stone spouts

We surveyed a total of 287 stone spouts in both the seasons i.e. post-monsoon 2018 and pre-monsoon 2019. In post-monsoon, we recorded 146 flowing and 141 dry stone spouts. For the flowing stone spouts, the flow ranged from 0.004-11.488 lps with a mean and standard deviation of 0.255 and 0.429, respectively. However, in the pre-monsoon, the number of drying stone spouts increased to 175 while the flowing one decreased to 112. The flow ranged from 0.002 to 1.464 lps with a mean of 0.036 and a standard deviation of 0.11. The number of flowing stone spouts and their respective flow was mostly dependent on the rainfall with post-monsoon having a higher flow range and more number of flowing stone spouts. A similar study done in Kathmandu Metropolitan City showed 73% and 27% continuous and seasonal flow of the stone spouts, respectively. The findings revealed the reason for comparatively high volume of water in the rainy season is because of rain-water infiltration and recharge of the underlying shallow aquifers (Khadge and Tiwari, 2014).

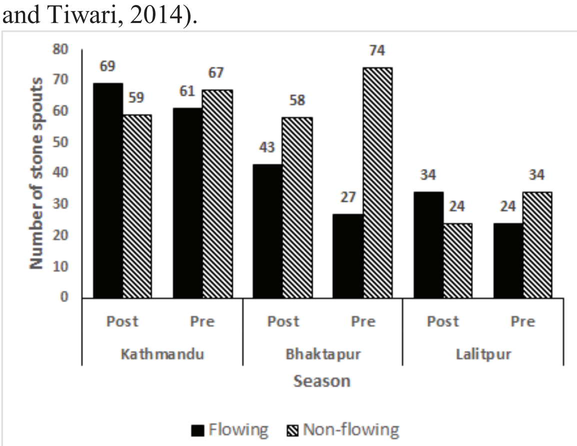

Fig. 3: District-wise variation in Stone Spouts Flow from post- to pre- monsoon

Dividing the 287 stone spouts into three districts (Figure 3), we found altogether 128, 101 and 58 stone spouts in Kathmandu, Bhaktapur, and Lalitpur, respectively. The number of non-flowing stone spouts exceeded the flowing one when from post-monsoon to pre-monsoon. In Kathmandu, out of 128 stone spouts, 69 were flowing and 59 were dry. The number of non-flowing stone spouts increased from 59 to 61 during the pre-monsoon. The highest number of non-flowing stone spouts were more in the Bhaktapur district. According to Manna (2016), the massive earthquake of 2015 and haphazard urban expansion are the reasons for the stressing stone spouts in the Bhaktapur district [5]. There are other stressors in the Valley besides the mentioned above; destruction of state canals, depletion of groundwater table, road constructions, land encroachments, and modern constructions are to name a few. For instance, the tall buildings require deeper foundations which not only disrupts the flow but destroys the entire channel supplying water to the spouts [3]. Land encroachment for the establishment of buildings like colleges, clubs, and organizations was seen in the Kathmandu Valley. Nepal Bank Limited construction over *Pako Pukhu* and Sajha Bhandar Building over *hiti* at *Bhotahiti* are few examples [11].

From Figure 4, we can see that high flow was observed in Lalitpur district compared to Kathmandu and Bhaktapur districts. In Patan, Lalitpur, various stone spouts like *Kwont Hiti, Elahne Hiti, Sundhara Hiti, Taapa Hiti*, and *Amrit Hiti* were constructed and revitalized after several protests for its conservation [11]. Today, these stone spouts are supplying continuous water which might be the reason for high flow in that area [11]. However, less variation was observed in Bhaktapur followed by Kathmandu which might be because of the seasonal effect.

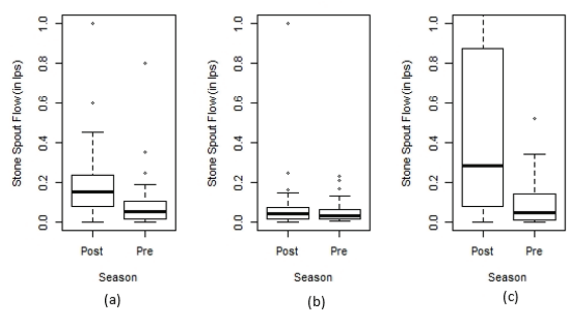

Fig. 4: District-wise variation in Stone Spouts Flow from post- to pre- monsoon where, (a), (b) and (c) are Kathmandu, Bhaktapur and Lalitpur, respectively.

The EC of all the flowing stone spouts were compared with National Drinking Water Quality Standard (NDWQS) and World Health Organization (WHO) standards. Out of 142 post-monsoon samples, 11 samples exceeded the NDWQS i.e EC was more than 1500 while for 111 pre-monsoon samples, all were within the guidelines. EC is the most important water quality parameter because it is highly correlated with other drinking water quality parameters [2]. So, it can help determine the potability of water for drinking water uses. The samples within 1500 µs/cm can be used for drinking water purposes after minor treatments like disinfection. However, other drinking water parameters needs to be taken into consideration for determining its quality.

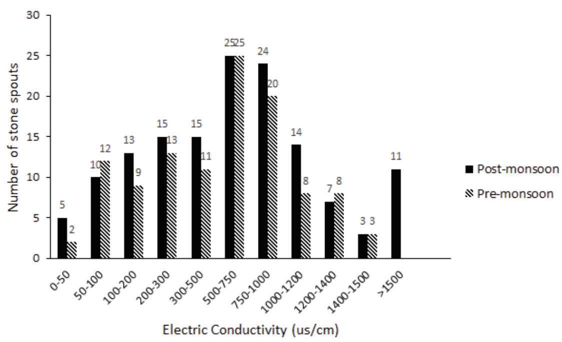

Figure 5: Electrical conductivity variation in the sampling locations

From local people's perception residing in the Valley, springs were the source for 205 stone spouts followed by state canal, piped supply and others (ponds, tanks, unidentified, and other). A similar result was obtained by a study conducted by Tripathi (2016) in the Bhaktapur area which showed that most of the stone spouts were fed by springs followed by state canals. Springs of the valley being recharged by the monsoonal rainfall, the stone spouts are mainly dependent on rainfall for its recharge.

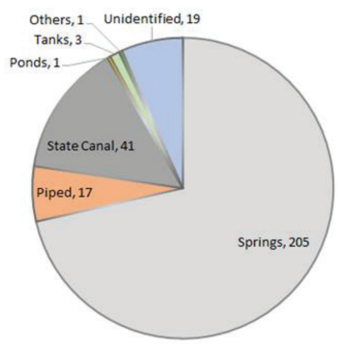

Fig. 6: Local's perception on the sources of stone spouts

The status of stone spouts in terms of flowing and non-flowing, flow variation, EC variation and stone spouts source were illustrated from this study. Also,

IV. Conclusion

Stone spouts, an important cultural heritage, and water delivery system of the Kathmandu Valley, have been neglected and impacted by developmental activities initiated by humans. In the changing timeline, many stone spouts have stopped functioning and some are on the verge of extinction. Out of the 287 stone spouts surveyed, in post-monsoon period, there were 146 flowing and 141 non-flowing stone spouts. When the season changed, in pre-monsoon, there were 112 flowing and 175 non-flowing stone spouts. Also, the flow rate was higher in the post-monsoon than pre-monsoon, except some of the exceptions. So, the seasonal drying of stone spouts observed in the study indicates the depletion of groundwater aquifers, disruption of supply mechanisms, and/or lowering groundwater tables. This could be due to various factors including urbanization, overpopulation, depletion of shallow groundwater aquifers, reduced surface infiltration capacity, destruction of state canals, excessive groundwater extraction, and obstructions to subsurface flow areas. From local people's perception, springs were identified as main water supply source to these stone spouts followed by state canal and pipeline source. Management of these ancient spouts are crucial to preserve our historical ambiance and reduce the water stress of the Valley.

V. ACKNOWLEDGEMENT

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