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DOES WASTEWATER PERTURB THE QUALITY OF WATER IN STONE SPOUTS OF KATHMANDU DISTRICT, NEPAL?

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ABSTRACT

The water situation in Kathmandu, Nepal is of concern due to increasing demand and decreasing availability of clean drinking water. Stone spouts, traditional sources of water in the region, are being used to meet this demand, but their water quality is often contaminated and does not meet national or WHO standards. This study aims to assess the status of 30 stone spouts in Kathmandu, Nepal, and classify them into two groups based on their location: Class A spouts in built-up areas and Class B spouts in forest, crop, or grassland areas. The study found that 17 spouts were in built-up areas and 13 were in forest, crop, or grassland areas. Land cover and land change data was also analyzed, and it was found that the built-up areas had experienced significant land cover and land use change (by 41 km2 between 2000 and 2019), potentially affecting the quality of the water in the stone spouts. The water quality of these spouts was tested for various parameters, including pH, electrical conductivity, temperature and the presence of E. coli. The results showed that the water quality of Class A spouts was generally worse than that of Class B spouts, with higher levels of contaminants and lower pH and electrical conductivity. This may be due in part to the improper solid waste management in the built-up areas, which could potentially lead to more contaminants in the water. The water quality of Class B spouts may also be affected by the use of untreated waste water from irrigated land as a source of contamination. The study also found that the water quality of the spouts deteriorated during the monsoon season. In addition, the sources of these stone spouts are shallow aquifers and springs which are recharged by underground water flows, and the possibility of groundwater contamination due to solid waste cannot be ruled out. These findings suggest that the water quality of stone spouts in Kathmandu, Nepal is a concern and that efforts should be made to improve the water quality and ensure that it meets national and WHO standards, as well as addressing the potential contamination of groundwater sources, improving solid waste management in built-up areas, and properly treating waste water used for irrigation.

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INTRODUCTION

Water is not only a resource but also an important symbol of life and death, health and sickness, prosperity and poverty. Nepal holds 2.27 percent of the world's water. The per-capita water consumptions used to be low in Nepal due to the small-scale of population (UN Population Division, 2017). But in the recent years due to increase in urbanization and massive inflow of people moving into cities are increasing pressure on the water resource and its availability (Shrestha, et al., 2022). According to (Timsina, et al., 2020), The Valley has one of South Asia's fastest-growing populations, with a population rise of over 4.8 times since 1971 that has reached 2996,341 in 2021. In the Valley. It was estimated that more than 50% of the water supply came from underground sources such dug wells, tubewells, and stone spouts during the beginning of the twenty-first century (Shrestha, et al., 2022). Along with the increase in population, change in lifestyle of people and attitude of people towards water, demand and per capita consumption of water is increasing. So, with all the efforts, municipal water supply is not being able to meet water demand of urban areas.

From 35.1 MLD (million liters per day) in 1988 (Sah, 2001)to 470 MLD in 2021 (KUKL, 2020), the Kathmandu Valley's water demand has grown to be 472 MLD in 2022 (KUKL, 2022), where Kathmandu Upatyaka Khanepani Limited (KUKL), the only provider of institutional drinking water, provides 126 MLD of water during the months of maximum production and 97 MLD during the months of minimum output (KUKL, 2022). The lack of drinking water is subsequently filled by using traditional stone spouts, spring water, groundwater extraction, and private water sellers' (in jars and tankers) (Shrestha, et al., 2022) (Thapa, et al., 2017) (Udmale, et al., 2016).

Stone spouts were the earliest known hydraulic structure of Kathmandu valley having its recorded existence from 570 A.D (Gha hiti of Patan) (Tripathi, et al., 2018) (U.N Habitat, 2007). Spouts have a significant potential to meet water demand provided they are adequately conserved. Also through the celebration of festivals and other social gatherings, Kathmandu Valley's traditional stone spouts contributed significantly to cultural preservation and the maintenance of social cohesiveness in addition to serving domestic water needs (Spodek, 2002).

There are 165 numbers of stone spouts in Kathmandu (Kathmandu Valley Water Supply Management Board, 2019). Among them they can be classify as traditional (having flow same as at the time of construction), modified (linked with water taps of municipal system) and dry (spouts with no flow). There is a decreasing trend in the discharge of flow within the stone spouts and many of them had completely dried and vanished. The sources of these water bodies which are basically shallow aquifers and springs are recharged by underground water flows coming from cascade of ponds within the valleys (U.N Habitat, 2007). Spout water is regarded as "clean" drinking water, however as shallow groundwater supplies a majority of its sources, it is often contaminated. Majority of the spout water was found to have exceed the WHO standards and sometime national standards also for coliform, E-coli and nitrate and the quality suffered greatly during the monsoon (Shrestha, et al., 2022).

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This study identified the status of 30 water stone spouts located in Kathmandu district of Nepal. Among which the spouts are classified into two sub groups i.e., Class A &Class B. Class A being the spouts located in built up area where infiltration is obstructed by concrete structures and Class B being the spouts located in forest/crop lands /grass land areas. From the 30 spouts, 17 spouts were found to be in built up area and the rest 13 were found to be in forest/ crop land / grass land areas. The objective for this study is to understand the extent to which solid waste contamination is impacting the quality of water sources in the region, and to identify strategies for addressing this issue. This objective could be achieved through a variety of methods, including water quality testing, analysis of the sources, and assessment of the impacts of solid waste on the health and well-being of the local population. By gaining a better understanding of the effect of solid waste on water quality, it may be possible to develop targeted and effective interventions to improve the quality of water sources in the Kathmandu Valley and protect the health and well-being of the local population.

STUDY AREA

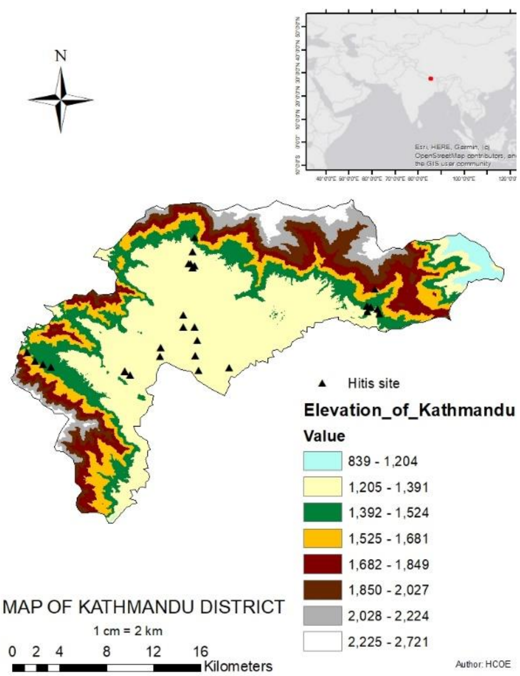

Figure 1: Location Map

One of the major metropolitan centers, Kathmandu is the capital of Nepal which is the study region for this research. The valley has about 2.5 million inhabitants (Udmale, et al., 2016). In the city, the average rainfall ranges from 1500 mm to 1800 mm in the surrounding hills (Thapa, et al., 2017). Which is in decreasing trend, an average of 14mm of rainfall per annum has been found to be in decreasing trend in Kathmandu (Prajapati, et al., 2021). 75% of the total rainfall falls between June and September, which is the monsoon season; 20% falls between March and May, which is the pre-monsoon season; and the remaining amounts fall between October and May, which is the post-monsoon season (Dongol, et al., 2005).

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METHODOLOGY:

WATER QUALITY ANALYSIS:

For the field-based work, we used a portable water quality laboratory. The kit contains a thermometer that is used to measure the temperature of water on the field. It contains an unusual symmetrical tube that is named Jackson turbidity tube to measure the turbidity. A digital ph meter that provides the ph instantly of the test specimen. It also contains an incubator, petri plates, membrane filter, forceps, gloves, and a chemical powder named chromo cult coliform agar. These instrument and chemical is used to detect the total coliform and thermotolerent coliform. Both total coliform and and thermotolerent have same method of detection. At first, we prepare a media using chromo cult coliform agar and it is transferred to petri plate. Then a filtration unit is prepared as shown in figure-2. Next we pour the sample i.e. water from the spout from top of filtration unit and as there is filter paper between the filtration unit, the bacteria of E.coli gets on the filter paper.

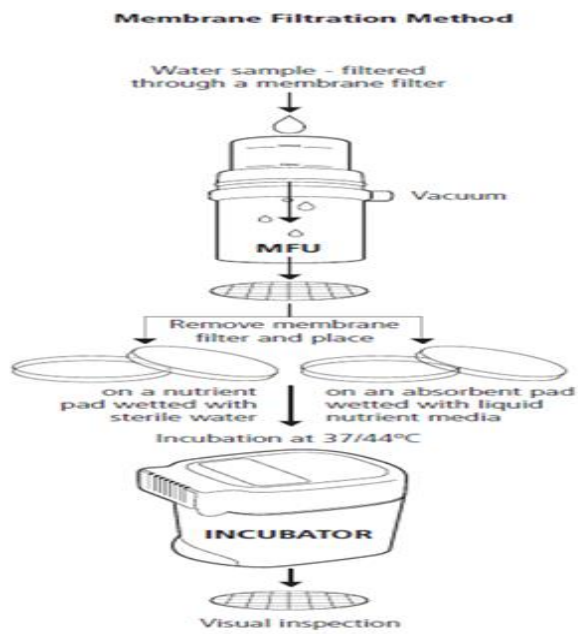

Figure 2: Preparation of Filtration unit

Then the paper is gently transferred to petri plate which is called cell culture dish containing the chromo cult coliform agar, this plate helps the bacteria of E.coli to reproduce on controlled laboratory condition. The plate is sealed with a lid and then it is kept inside incubator for 24 hrs. If the incubation temperature was 37ºC then the yellow colonies represent a count for Total Coliforms. If the incubation temperature was 44ºC then the yellow colonies represent a count for Thermotolerant Coliforms.

Turbidity:

The turbidity test was done according to the lab instrument provided in porta kit, which is named as Jackson turbidity tube which contain the 2-part tube with our unique threaded locking mechanism.

Temperature:

To measure the temperature, thermometer was used.

Discharge:

Discharge was measured using a beaker of 2500ml capacity, the time period was noted till ta beaker is just filled. This process was repeated for three times and average time was used to find the discharge.

$$\text{Discharge} = \frac{2.5*10^{\wedge}-3}{\text{Average time in seconds}} \text{ LPD (Liters per Day)} \qquad (1)$$

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Land cover land change:

Land use land cover (LULC) is the map which helps us to study the changes that are happening in our ecosystem and environment and to know the trend of rapid urbanization. Land use is human use of land (agricultural, residence, industrial, mining etc.) and Land cover is the physical materials at the surface of the earth. Land cover includes grass trees, bare ground, water etc. On the basis of analysis of land cover land change, we will be identifying its relation with infiltration rate of the water. For this, we will be plotting two GIS (Geographical Information System) map with the year difference of about 2 decades from the data obtained from ICIMOD Regional Data Monitoring System. Regional Data Monitoring System is a user-friendly tool for creating maps, charts, and statistics that aid in better understanding change processes and support informed decision. In order to facilitate monitoring and change analysis, it offers yearly land cover mapping and change analysis services. It acknowledges the gaps in land cover data and the irregularities in land cover mapping techniques. The system routinely produces high-quality land cover data to the regional level using state-of-the-art remote sensing science and technology on the Google Earth Engine and a common set of input data sources. By using statistical analysis for comparison of these maps, we will be identifying the percentage change in important classes that impact infiltration. The percentage increase or decrease in these classes could have direct relation with the rate of infiltration.

Table 1: Land covers classes for our study:

Class Name	Description
agriculture	Farmland and cultivable lands, including seasonal croplands.
Built-up	Residential, commercial, roads, suburbs, and construction site.
Water	All types of the water bodies such as rivers, ponds, and lakes
Forest	Land dominated by trees, including natural woodlands and community plantations.
Barren	Areas of silt and sand with very little or no vegetation, such as shores of river.

Results and Discussions:

This study found that traditional stone spouts which had been using by urban poor of Kathmandu rarely fulfils the National Drinking Water Quality Standards ((Government of Nepal, Department of Water Supply & Sewerage, n.d.).The PH range of stone spouts are found at a range of 5.8 to 7.38. Among this 43% of then are out of standard of NDWQS, 2005 (Government of Nepal, Department of Water Supply & Sewerage, n.d.).

The average temperature of stone spouts was 22.27°C with higher value of 25.8C° and lower value of 20.4C°. 97% of stone spouts were found to be contaminated by E. COLI with about 50% of sampled site too numerous not able to count by our kit in 100ml of sampled water. Although, only one stone spout (Bhatbhateni Dhara) was free of E. COLI at the time of assessment, it's PH was found less than 6.5 (i.e.6.4). So, no any stone spots completely fulfill the standards of NDWQS, 2005(Government of Nepal, Department of Water Supply & Sewerage, n.d.)(Table 2).

Table 2: Water Quality Parameters of Stone Spouts During Monsoon Season.

SN	SPOUT NAME	LOCATION	PH	CONDUCTIVITY	TEMP	Discharge	TURBIDITY	E.COLI COUNT	REMARKS
1	PHULBARI	TOKHA	6.46	0.07	23.1	41656.04109	<5	183	CLASS B
2	BAKHAYA HITI	TOKHA	6.63	0.59	23	5660.388497	<5	30	CLASS B
3	CHANDESHWORI	TOKHA	6.35	0.04	22.3	16122.71059	<5	25	CLASS B
4	KOLABI HITI	TOKHA	6.9	0.78	22.6	7541.536023	<5	TNTC	CLASS B
5	BHU HITI	TOKHA	5.8	0.32	23	28789.67005	<5	52	CLASS B
6	CHAGALE HITI	TOKHA	6.36	0.94	22.8	12898.50878	<5	TNTC	CLASS B
7	BHATBHATENI DHARA	KATHMANDU	6.4	0.45	25.8	46990.08525	<5	0	CLASS A
8	THULO KUWA DHARA	KATHMANDU	6.44	0.44	23.6	7932.213322	<5	27	CLASS A
9	RAIBARI DHUNGEDHARA	KATHMANDU	6.71	0.2	21.5	46338.01437	<5	21	CLASS A
10	PANDHERO DHARA	KATHMANDU	6.79	0.68	23.6	12359.35335	<5	5	CLASS A
11	KUMALE DHARA	KATHMANDU	6.82	0.43	24.3	7472.403631	<5	TNTC	CLASS A
12	GYAN DHARA	KATHMANDU	6.53	0.48	24.6	4948.904621	<5	33	CLASS A
13	SIDDHICHARAN DHARA	KATHMANDU	6.39	0.52	22.5	3243.653068	<5	192	CLASS A
14	PAKKU DHARA	KATHMANDU	7.21	1.34	22.9	984.2789894	10	TNTC	CLASS A
15	MARUHITI 1 MAIN	KATHMANDU	6.36	0.89	22.3	31631.50434	<5	TNTC	CLASS A
16	MARUHITI 2	KATHMANDU	6.48	0.92	21.9	11538.1433	<5	148	CLASS A
17	PEPSICOLA DHUNGE DHARA	KATHMANDU	6.08	0.13	22.2	25574.52897	<5	170	CLASS B
18	TRIBHUVAN PARK DHARA	CHANDRAGIRI	6.83	0.52	23	10413.4292	<5	93	CLASS B
19	BUNGACHA HITI	CHANDRAGIRI	7.38	0.52	21.4	15199.43746	8	TNTC	CLASS B
20	THULO DHARA	CHANDRAGIRI	6.66	0.09	20.7	3160.520234	<5	93	CLASS B
21	MATTIKHEL DHARA	CHANDRAGIRI	7.31	0.14	20.4	20020.33313	5 TO 10	TNTC	CLASS B
22	LACCHI HITI	KIRTIPUR	6.91	0.27	20.7	25096.47052	<5	TNTC	CLASS A
23	BARKHA HITI	KIRTIPUR	6.57	0.88	23.1	3227.279663	<5	TNTC	CLASS A
24	SASA HITI	KIRTIPUR	7	0.63	23.1	2210.908753	10	TNTC	CLASS A
25	SIKUCHA HITI	SHANKHARAPUR	6.92	0.44	24.4	2926.435346	<5	TNTC	CLASS A
26	DHULLA MAHADYA HITI	SHANKHARAPUR	6.52	0.12	23.2	16892.34659	5 TO 10	TNTC	CLASS A
27	DUCCHA HITI	SHANKHARAPUR	6.35	0.91	21.5	12073.09073	<5	TNTC	CLASS A
28	SUNTOLE HITI	SHANKHARAPUR	6.7	0.6	22.2	10504.26979	<5	TNTC	CLASS A
29	SALINADI HITI	SHANKHARAPUR	6.18	0.15	23.7	12211.07386	<5	360	CLASS B
30	MALTA HITI	SHANKHARAPUR	6.44	0.23	23.1	3675.465013	<5	94	CLASS B

While conducting an informal survey we found that due to religious values and use of stone spouts from long aged centuries, people are using water from HITI'S without even doubting its quality. In comparison to other parameters, only 4 out of 30 spouts were out of standards in terms of turbidity (Table 2). As turbidity is direct visual representation of quality of water for their household purposes.

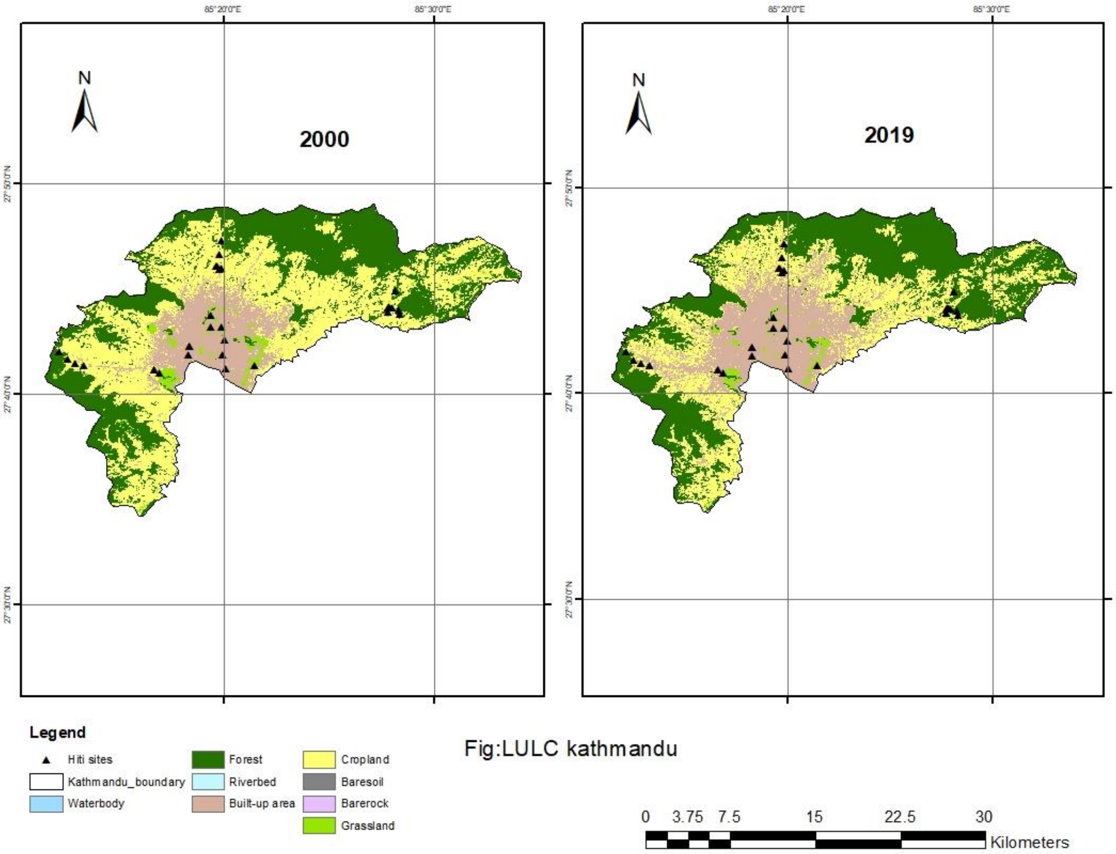
Also, in the study conducted by (Karkey, et al., 2016) among the five stone spouts examined all five spouts exceeded WHO standards for fecal coliform. The findings from the study are similar to what we observed. i.e., almost all the stone spouts contaminated by fecal coliform. The result highlight wide range of discharge from low discharge of 984 liters per day to high discharge of 46,990 liters per day (Table 2). As the sites are accessed during monsoon season, these discharges are expected to decrease in other seasons. Also, when selected, stone spouts are classified by sites near built-up areas as class A and site nearby cropland, grassland, forestland as class B. It was found that 35% of class A (Table 2) and 54% of class B (Table 2) are out of standard of NDWQS in terms of PH. The high percentage of out of standard of PH in class B could be due to infiltration of water mixed with fertilizer in cropland. One of the astonishing findings we found was that one of the stone spouts which was found to have no E. COLI at the time of assessment was nearby built-up area. About 53% of class A spouts and 31.6% of class B are contaminated in a way which E. COLI could not be count numerically. (i.e., formation of excessive colonies nearby) failure of solid waste management by the government authorities and infiltration of water from the site of deposition of those wastes could be one of the reasons of high contamination of water from stone spouts. On comparing the discharge of class, A and class B stone spouts, discharge of class B (i.e.,15,609 LPD) was observed to be more than that of class A (i.e.,14,490 LPD) this could be due to less infiltration in class A than class B. Also, only slight difference was observed in average discharge might be due to assessing in monsoon season.

Table 3: Change in Land Cover from 2000-2019

Land cover class (sq. km.)	2000	2019	Change
Waterbody	0.070694	0.114206	0.043512
Forest	155.046172	170.93386	15.887688
Riverbed	0.030233	0.031595	0.001362
Built-up area	59.008338	99.316381	40.308043
Cropland	188.303516	135.957922	52.345594
Bare rock	0	0.003602	0.003602
Grassland	8.946681	5.732516	3.214165
Other wooded land	2.67236	1.981986	0.690374
Total	**414.077994**	**414.072068**	

The land cover land use (FRTC, ICIMOD, 2022) map when analyzed shows that about 68% of built up area has been increased from 2000 to 2019 A.D(Table 3),(Figure 3). And in built up area points towards more decrease of water in stone spouts in years to come.

Figure 3: Land use changes from 2000 to 2019.



Conclusion:

Stone spouts, which have been perceived as an alternative source of water at the time of crisis and main sources for urban poor area are highly contaminated and drying up with increase of settlement. The sources of these stone spouts are shallow aquifers and springs, which are at risk of contamination due to solid waste. In order to improve the water quality of stone spouts in Kathmandu and ensure it meets standards, it is important to address solid waste management issues in the city. In addition, efforts should be made to properly treat waste water used for irrigation and to prevent potential contamination of groundwater sources.

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