Water Conservation in Nepal

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Abstract Since the last decade, Kathmandu has been immensely crowded by many populations migrating from different places. One of the significant issues in Kathmandu valley today is water management. Nepal is considered the second most prosperous country for water in the world. Despite this, 8.4% of the population of Nepal (2015) do not have access to safe drinking water. Nepal has a high annual rainfall of 1200 millimeters but still faces substantial challenges in ensuring water security. The primary purpose of the new design for the Sport and Recreation Centre project is to conserve the water by reuse, recycling, and systematic utilization of water to create a sustainable water-efficient building and site. The research literature indicates the feasible way to fulfill water needs is by using rainwater harvesting systems in the center. Nepal historically has had rajkulos, canals, human-made ponds and sunken water conduits which are among the oldest techniques of maintaining the water supply. In the Sport and Recreation Centre, historic design techniques have been combined with rain gardens, ponds for groundwater recharge, pervious pavements, and grate inlets to manage the stormwater on the site. Also, treating the greywater through the Reed Bed Treatment System can help and conserve water for the site and project. In the landscape design, specific native plants will be used that conserve water. The buildings will have low flush and composting toilets, sensor taps, rainwater collections, and use. Overall, with the conservation of water on the site and creating a water-saving building design, this can be one of the most effective ways to promote other public buildings to do the same. The people can have adequate residential drinking water. This can help to reduce the scarcity of water in society and teach us to use rainwater and greywater more efficiently in all future new projects.

1. Introduction
Nepal, one of the Asian countries with southern slopes of the Himalayan mountain ranges, lies between India to the east, south, and west and China's Tibet to the North. It is a landlocked country and elongates roughly 500 miles (800 kilometers) from east to west and 90 to 150 miles from north to south. It includes some parts of the Indo Gangetic Plain [1]. It is geographically divided into three belt mountain regions, i.e. the north, mid-hills in the center, and a lower plain belt to the south covering 147,516 sqkm (56,956sqmi). The climate of Nepal is affected by elevation and its position in a subtropical latitude. It extends from subtropical monsoon conditions in the Terai regions through a warm temperate climate between 4,000 and 7,000 feet in the mid-mountain area. At altitudes above 16,000 feet, the temperature is freezing with snow and ice [2]. According to the world meter data, the total population of Nepal is 29,124,951. As reported by the World Bank Nepal, 42% of the people live below the poverty line and only 27% with improved sanitation. Being a developing country, Nepal has several health facilities, education, job, economic, social, and environmental issues.
2. The Research Region in Kathmandu

Kathmandu, the capital and main political and economic center of Nepal (Figure 1), is a valley. It spans an area of 50.7sqkm (19.6sqmi). The valley includes four main cities: Kathmandu, Bhaktapur, Lalitpur and Kirtipur. The climate is a sub-tropical cool temperature, characterized by a slightly hot summer and cold winters. According to the climatic data, the annual maximum and minimum temperatures are usually between 29°C in June and 2°C in January [3]. The summer has heavy monsoon rain, whereas winter is dry. The average annual temperature is 18 °C/64.5F, and about 1505mm/59.3inch of precipitation falls annually.

Precipitation is lowest in November, with an average 7mm 0.3 inch. The most significant amount of rainfall occurs in July, with an average of 379mm/14.9inch. Figure 2 shows that the highest amount rain will occur during June, July and August. While January, March, November and December are completely dry. On average, July has the rainiest days throughout the period (climate in Kathmandu, Nepal). Since the valley lies at an altitude of 1350 meters, it experiences all four seasons: summer, autumn, winter, and spring. According to the world meter, the total population of Kathmandu valley is 1,442,271 with an annual growth rate of 4.63%. People from different parts of the country migrate to the capital city in the hope of having job opportunities, better life and higher education. Also, the sociological, cultural and heritage has affected a lot in sustainable lifestyles. With the advancement of urbanization in the city, various infrastructure, economics, and social benefits have changed lifestyle [5].

![Figure 1. Map of Nepal [4]](image_url)

3. Problems

The problem of urban management in Kathmandu city is at a severe stage. The primary issue being environmental sustainability which includes solid waste management, drinking water, dust, drainage, parking, congested roads, street shops, public toilet, and unemployment. One of the significant issues in Kathmandu valley is related to drinking water even with the richness of Water in Nepal, considered the second most prosperous country for water in the world. According to the International Institute of water management, Nepal has 2.7% of the available fresh water on earth after Brazil. 8.6million cubic meters of water flows from the Himalayan peaks through the Nepali valleys every year and can provide each person an annual availability of 9000 cubic meters. This can be considered as one of the highest rates in the world, yet the residents are deprived from safe drinking [6]. According to the world meter data, 6% of water dependency is from outside the country.8.4% of the population of Nepal (2015) does not have access to safe drinking water Nepal has high annual rainfall but still faces substantial challenges in ensuring water security. Even with more water resources, access to a nine million population has become a severe problem. Almost a quarter of the population of Kathmandu suffers due to a lack of infrastructure...
management and a burgeoning population. Water is an important issue and without solving the problems of water, it would be challenging to address the issues of sustainability. Although there are available water supplies, it is inadequate in quantity and quality for the city's demands for household purposes. In addition to this, there is a scarcity of water supply in public buildings too. [3]

![Graph showing water demand and deficit](image)

**Figure 2.** KUKL Service Area: Water Supply, Demand and Deficit, based on [7]

Figure 2 shows the water demand estimated using BIS guidelines (338MLD for 2016) gives a supply deficit of about 187 MLD in KUKL service areas. The supply deficit in KUKL service areas in 2021 is estimated to be 322 MLD and 294MLD, by KUKL and BIS guidelines, respectively, against the present maximum supply capacity of 151.19MLD and without considering the impact of leakages and the MWSP [7]. From the research, the current scenario of Kathmandu Valley, besides the polluted river, is in the form of underground water extracted by all the sectors, including individuals, hotels, commercials, and government, for the sustainable water supply [7].

![Graph showing mean water consumption](image)

**Figure 3.** Mean water consumption in household types and proportion water consumed from different sources based [6]

As shown in figure 3, people who don't have the governmental piped network and private well use the least amount of water of 36lcd during dry season. Those who have private wells used 69lcd and those with government connections use 42lcd. Those who have both water supply used maximum water with 97lcd. [6]

4. **Different Sources of Water**

Water can be used for different purposes like drinking and household needs, recreation, industry and commerce, agriculture and thermoelectricity energy. One of the traditional Nepali water resources called stone waterspouts is used in Kathmandu and works as a tap water (Figure 4). The people of Kathmandu used to get water mainly from these traditional waterspouts and ponds and wells. It has been reported
that there are 400 traditional stone spouts in the Kathmandu Valley. [8] mentions stone spouts came into existence since ancient time and believes that Licchavi Kings constructed followed by Kirat rulers connecting them. If we review the history a series of numerous small canals, rajkulos, manmade ponds and sunken water conduits from the peripheral higher ground to the lower settlements area were developed [5].

![Figure 4. Waterspouts in Nepal][1]

**Figure 4. Waterspouts in Nepal [PC: Nirakar KC]**

5. **Reasons behind the scarcity of water**

But with the rise in population and the lack of attention, many of the spouts have dried up while the others have a significantly reduced water flow. There were parks, kitchen gardens for the recharge, and green areas, which are now mostly converted into built-up regions, which can be another reason for water heritage to dry [9]. UN Habitat (2008) mentioned that the destruction of traditional water resources in the Kathmandu Valley started in 1950 when piped water supply systems was introduced. The supply system of such spouts was structured and methodical, but the burgeoning population and uncontrolled urbanization created pressure destroying which caused them to dry out (Figure 5 and 6).

![Figure 5. Water tank in public places][2]

![Figure 6. Unmanaged Stone Spouts][3]

**Figure 5. Water tank in public places [PC: Nirakar KC]**

**Figure 6. Unmanaged Stone Spouts [PC: Nirakar KC]**

6. **Possible Solutions**

Despite knowing all the issues and problems, the government hasn't taken significant steps to provide drinking water to its residents and other public buildings in most parts of the Kathmandu valley. With the groundwater level decreasing, water prices being controlled by water vendors, and the irregular supply of Kathmandu Upatyaka Khanepani Limited (KUKL), there is no other option than relying on rainwater harvest. This method can be cost-effective and easy to use. It is also clear that no workable water sources are around the city that could be tapped and supplied. The only feasible way to fulfill water needs is by installing rainwater harvesting systems which can be done for individual buildings or any governmental, commercial, or public buildings.
7. Potential of Rainwater Harvest in Kathmandu

Water conservation has always been an important topic not only in Kathmandu but all around the world. Water conservation can be defined as the minimization of loss or waste, care, and protection of water resources and the efficient and effective use of water to be available for an extended period. To confirm the availability of water for the future, removing fresh water from an ecosystem should not exceed its natural replacement rate. For the conservation of water, some approaches are appropriate to building design and water-related issues. Firstly, efficient use of freshwater should be introduced. Second, rainwater and greywater should be recycled and effectively used where it is possible. Lastly, adequate disposal of grey, black and rainwater should be effectively sought. Water pumps and wastewater treatment facilities consume a notable amount of energy. The history of Nepal, particularly in the city, shows that people never had a piped water system and depended on the self-reliant water system and stone waterspouts with a water conduit system using groundwater recharge during rainfall. The piped water system that has been introduced these indigenous systems are no longer functioning. The importance of rainwater collection can be submitted with the use of modern techniques.

The current water demand of a family of 5 members is about 170 Cu. M. per year. But a building of 100 sqm can collect 200 cum per year if almost 80% of the total rainfall on a particular building is organized [5]. The water supply in the Kathmandu valley is 60% from the tube well and 40% from surface sources. According to [10] Water from the Melamchi River through (26 km tunnel) has initiated since 2018 but have not produced any result from increasing water. Also, the groundwater table is dropping by 2.5 meters per year. Practically, it is impossible to store the exact potential water needed, so the rest of the rainwater can be artificially recharged to the groundwater aquifer. Out of the total 640 sq km of Kathmandu valley, only 10% of the total area can be used for rainwater harvest, then 128 million cum rainwater per year could be recharged [11]. Practical action, suitable recharge techniques, and proper investigation are required to implement plans efficiently [5].

The key factors for addressing sustainable water use are as follows:

- Minimizing the need of water
  - Use composting toilets
  - Use rain gardens
  - Use ponds for the water table recharge
- Efficient use of water
  - Install water-saving spray or automatic taps on basins and showers
  - Installing dual or low flush water closets.
- Recycle used water
  - Installation of grey water collection systems to flush water closets or water gardens
- Recycle rainwater
  - Install rainwater recycling system
  - Installing catchment for the collection of rainwater for many daily purposes.

Also, the building water can be reduced through installing various equipment, which includes dual flush closets, low flush water closets, waterless toilets such as composting toilets, or using minimal water. Composting toilets can save 40% of domestic water use [12]. For basins and showers, aerated taps keep water as aerated showerhead can use 9 liters instead of the usual 20 liters per minute. Automatic basin taps can limit the use of water. Also, for the outdoor activities to conserve water and minimize the use of water in the site, rain gardens, ponds for groundwater recharge and pervious pavement can be used. Also, in the landscaping portion, specific plants such as khair, a spring tree with yellow flowers and flat pods, Shorea Robusta, Devdar, Jacaranda (famous), Bougainvillea, Silky oak and Grevilea Robusta, Solandra, Pink Siris, Orchid Tree, Coral Tree, and Erythrina [13] can be planted that can conserve a lot of water. To save groundwater resources, rainwater harvesting can be an excellent option. Rainwater harvesting and greywater treatment systems can be used in any building, whether residential, commercial, institutional, or public. Also, rainwater and grey water can be used for non-potable uses and if treated properly, it can be used for drinking purpose also. Reuse of rainwater,
greywater can assist in reducing sewage and stormwater pollution. Also, stormwater can be filtered on site through underground retention tanks, pervious pavement and creating like water catchment areas like ponds and swales are primarily used in large-scale projects for proper drain management. Wastewater that comes out from the laundry showers, basin and sinks can be conveyed through the plant-based filtration plant, which can be reused for house cleaning, toilet flushing, gardening, car washing and many more things. Then plant-based treatment plant needs to be checked to ensure all the water remains below the ground level during treatment. The technology that is used is constructed wetlands, which is a well-tested method for the treatment of different forms of wastewater [10].

A separate greywater treatment system is to be included for treating greywater from sinks, basin, showers, cleaning, and washing clothes. The greywater recycling system used was vertical subsurface. Flow of the reed bed treatment systems (RBTS) or constructed wetland systems which are designed specifically for wastewater treatment as shown in figure 7. Effluent (resulting wastewater) is transported through pipelines and applied to the basin via inlet arrangement [10]. It is a type of constructed wetland that consisted of a rectangular bed (4.8sqm) filled with 20 cm of gravel (25 to 30 mm) at the bottom, 1 cm of small gravels in the middle, and 60 cm of coarse sand on the top. The filter process supports the growth of vegetation like Phragmites karka (Narkat in Nepali). Wastewater usually passes through the roots of vegetation formed between the particles of filter zone. The bed is on a slope and lined with impervious material such as a plastic to prevent infiltration of wastewater in the ground.

The water is distributed 1 to 2 times a day through a 50 mm diameter perforated pipe fixed above the surface level of the bed and connected to the feeding tank. As the wastewater flows through the bed, it is treated through a process by mechanical filtration, chemical transformation, and biological consumption of potential pollutants in the wastewater stream. The plants grown in the wetland offer the root mass of filtration and provide oxygen and carbon for wastewater treatment. It is also one of the cost-effective systems for Kathmandu besides other mechanical systems [10].

| Water use          | Amount (Liters) |
|--------------------|-----------------|
| Drink during exercise | 0.5             |
| Toilet Flush        | 13.6            |
| Shower/Bath         | 34.4            |
| Dishwash            | 65              |
| Wash hands          | 0.6             |
| Drink per person    | 3               |
| Washing machine     | 100             |
| Lap pool            | 122647          |
| Leisure pool        | 73929           |
| Hot tub             | 34750           |

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In a recreation center, the following is an estimate of the amount of water used (Table 1):

Calculations of tank capacity for greywater recycling system:

Total number of occupants:100
Water per person =80 liters
Size of sedimentation tank= 80X200 (V1) =16000 liters
Size of feeding tank=2/3 of V1 (V2) =5333.3 liters
Size of vertical flow reed bed area=2m² per 1m³ of sedimentation = 4.8 m²
Size of storage tank=2/3 of V1(V3) =5333.3 liters

During the rainy season, the rainwater could be harvested for different purposes. Water continuously relied upon therefore is reduced, reducing the water dependency. For this, usually, the catchment system for rainwater is a CGI roof. The first 10 to 15 minutes of rainwater is used for flushing dust, leaves, and other materials. This water can be used for watering the plants or used in the garden or it can also be stored in the underground stormwater. The water can be collected and stored in an underground tank. Designing a recreational center, water is for drinking, shower, toilet flush, laundry, cleaning, indoor swimming, and kitchen needs. The amount of rainwater always depends on the type and quality of the catchment area. According to the survey done by [10], 85%of the concrete roof, 12% have a tile roof and only 3% have the CGI (Corrugated Galvanized Iron Sheet) roof in figure 8. However, a metal roof is best preferred for the water catchment area. Compared to the other roofing materials, metal roofs especially galvanized metal roofs, have a much lower concentration of dissolved organic carbon and other bacteria, which means the rainwater collection system will produce less of the disease-causing microorganism. Galvanized metal roof is preferred, coated with zone, prevents rust, and prevents the collection of iron in the water.

8. Calculations:
The total amount of the water to be harvested based on the above assumptions is calculated as below:

Catchment area= 4675sqm
Water Consumption=80 ltrs
Number of people= 200
Period of Water to be stored= 15 days
Size of the tank= 80x200x15=240000=240m³
Block A=4675sqm
The minimum rainfall required to fill the tank= 240/4675X1000=51 mm per month
Block B=7095sqm
The minimum rainfall required to fill the tank = 240/7095X1000= 33.82 mm per month
blocks-1377sqm
The minimum rainfall required to fill the tank=240/1377X1000=174 mm per month
Block D- 1613
The minimum rainfall required to fill the tank=240/1613X1000=148.79 mm per month
Block E- 1430
The minimum rainfall required to fill the tank=240/1430X1000= 167.83 mm per month
Figure 9. Master Plan illustrates different water conservation activities

Figure 10. Rainwater treatment system

Figure 11. Grey water treatment system
Figure 9 shows the master plan with the water conservation activities performed on the site. The site includes pervious pavements in different paths, rain gardens for stormwater management, ponds for underground water recharge, grate inlets for the parking area, and a reed bed treatment system for greywater management. Figure 10, figure 11, and figure 12 show the rainwater treatment, greywater treatment process, and composting toilet in different blocks. It also shows how these various activities work in the building.

9. Results and discussions

Therefore, the size of the tank for the rainwater harvesting is 240,000 liters which is designed underground. The water is then pumped to the reserve tank for gravity flow in restrooms, showers, laundry. For safe potable water to drink, additional filtration should be done with the treatment and technology. Rainwater access after filling could also be charged to the ground. Rainwater could be harvested for at least a period of four months. The use of water can be minimized in the building by following activities:

- Use of the composting toilets.
- Installing of dual or low flush water closets or plumbing fixtures.
- Installing water-saving spray or automatic taps on the basins and showers.
- Installing the water meters.
- Combining the water-absorbing surface and planted areas to suit the local environment.

10. Conclusions

Sports and Recreational Centre needs a lot of rainwater. Firstly, in developing countries like Nepal these methods are the most cost-effective method. Secondly, using these techniques in the buildings and site can serve a range of non-potable uses, including irrigation, toilet flushing, washing, and cooling. Using the old methods of recharging the water balance the ecosystem, conserve the landscape. Using the methods discussed above, the new recreational Center for Nepal will save 800k Gal of Water. The center will save as much water through rain gardens, ponds, recycling water in the swimming pool impervious pavements and recharge pits. Also, the treatment of the greywater system saves a lot of water.

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