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Changing pattern of water supply system in Jaipur metropolitan (Rajasthan, India)

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Abstract
Jaipur is the capital and largest city of the Rajasthan state with a growing population of 4.008 million in 2021. Jaipur metropolitan is a fast-growing city that attracts the population to migrate from all over the state. Jaipur city is a well-known tourist center and the tourist footfall around the world is very high. The city is developing rapidly (in terms of industrial) and so the population is. This results in the lack of some of the basic necessities to cater to the demands of the population residing here. The major problem nowadays is water scarcity and the crisis that threatens drinking water sources. Due to scorching heat and semi-arid climatic conditions, the surface water sources of dams are drying up resulting in depleting water table. There is no perennial source of surface groundwater in the city. Initially, the Ramgarh dam was the source of drinking water for the city population. In the late 1980s/early 1990s, the major part of Ramgarh dam remained dried and till 2012 the river bed was completely dried. Jaipur city suffered in an acute situation in getting drinking water. Hence, a new source of water was investigated and constructed in 1990 *i.e.*, Bisalpur dam located in Tonk district of Rajasthan over 120 km away from Jaipur, providing water to Tonk, Ajmer and Jaipur. The supply of water from Bisalpur Dam to Jaipur began in 2009. Due to the shortage of water supply from the Bisalpur dam, the government has planned and investigated a detailed feasibility report to link the Bisalpur dam to Chambal and Brahmini Rivers to make Bisalpur dam a sustainable water resource for utilizing excess water off the Brahmini River project. To combat such situation, it is very important for the government to find sustainable solutions. Besides this, public participation is also very significant to attain the solution.

Keywords: Water scarcity, water crisis, sustainable water resource, urbanization, industrialization

Introduction
According to Census 2011, nearly 70 per cent households have access to tap water, out of which 62 per cent have access to treated tap water. Thus, nearly 40 per cent of urban households have no access to public supply, and have to depend on other sources of water. Moreover, not all households that have access to public supply have access to it within the premise. Only 49 per cent of households have access to piped water supply within their premises. There was a gradual increase from 1990 to 2008 in the percentage of households with access to 'improved' drinking water, but then a decline in 2011. However, this decline is due to the availability of fine-grained data. Earlier all tap water was taken as 'improved' whereas disaggregated data has become available in 2011 for treated and untreated tap water categories. Similar is the case with water from wells. If untreated tap water and uncovered wells are included in the improved category, then the proportion of households which have access to improved sources would be 98 per cent in 2011. The need for proper water resource management is the demand of time due to the growing population and limited water resources. It is more important when all the water resources in a basin or nearly all water resources are allocated for various uses [15]. Effective strategies should be made for obtaining more productivity with maintaining or improving the environment. Wastes and nonproductive uses must be carefully examined to identify potential savings. To reduce and resolve conflicts, an effective allocation must be implemented. For the accomplishment of these tasks, better practices are needed to take into account the use and productivity of water resources [15]. It is difficult to communicate about water between professionals and non-water professionals due to widely varying types and scales of use. Policy decisions are often taken without a clear understanding of the consequences on all water users.

As the demand for a limited supply of water increases, it is necessary to communicate to all the water users on how water is being used, and how water resource developments will affect present use patterns [15].

In urban India, especially in the middle-income group and weaker section, the problems related to water quality in piped water distribution systems are more prominent and serious, as they do not have enough water resources to maintain their water supply infrastructure and disinfect residuals. Rapid urbanization in developing countries is often accompanied by overwhelming demands on existing water systems and illegal connections to distribution systems in poor neighborhoods. Many systems have cracks and high leakage [16]. An international survey of water losses as a percentage of water supplied in 1991 reported that water deficits in industrialized countries ranged from 8% to 24%. Water losses ranged from 15% to 24% reported in middle-income or newly industrialized countries and in developing countries like India water loss was estimated at between 25% and 45% (WHO 2001). Frequent power outages to contributes to low or negative pressure in the pipes which allows contaminated water or wastewater surrounding the pipes to be drawn in through any cracks. Equal distribution of water supply is also a major problem as only prestigious people have access to potable water supply and poor people do not receive minimum clean water requirements [16].

Excessive use of water by the consumers is the result of unmetered water supply in the area, due to this, Municipalities/responsible authorities are unable to recover actual costs which lack further investment planning in the expansion and maintenance of water supply infrastructure. This erodes consumer confidence, reliability, and willingness to pay for billed water. Financial viability has declined due to a smaller number of households connected to a piped water supply. The aging of the water supply infrastructure is also a major problem faced by Indian municipalities with aging water supply infrastructure as they do not have enough revenue collection to replace them [16].

Jaipur, the capital and largest city of the state of Rajasthan, India with a population of 4.008 million in 2021. It is the fast-growing city that attracts migration from all parts of the state and is the world's most tourist popular destination. With the increase in the population many advantages and disadvantages also come up with it [4], especially, Jaipur city is presently facing severe water scarcity [7] and a crisis that threatens drinking water sources. It is a challenging issue to the rapidly growing population and rising industrialization of the Jaipur metropolitan. Due to severe heat and semi-arid climatic conditions, the surface water source of dams is drying up resulting in depleting the water table which is not enough for drinking purposes. There is no perennial source of surface groundwater in the city. Initially, the Ramgarh dam was the source of drinking water for the city population. In the late 1980s/early 1990s, the major part of the Ramgarh dam remained dried and Jaipur city suffered from an acute situation in getting drinking water. Depletion of surface water and land-use changes upstream of the Ramgarh dam that increases in agricultural activities and encroachment in the river bed was completely dried in 2012. The alarming rate of the rising population of the city results in huge demand for water, at the current period 600 MLD of water is required to meet the demand of Jaipur city while the city is getting only 440 MLD. Hence, a new source of water was investigated and constructed in 1990 *i.e.*, the Bisalpur dam located in Tonk district of Rajasthan over 120 km away from Jaipur, providing water to Tonk, Ajmer, and Jaipur. The supply of water from Bisalpur Dam to Jaipur began in 2009. Its capacity is 1095 million cubic meters, where the water availability is highly dependent on the annual rainfall pattern which is extremely variable in the catchment area. Due to the shortage of water supply from the Bisalpur dam, the government has planned and investigated a detailed feasibility report to link the Bisalpur dam to Chambal and Brahmini Rivers to make Bisalpur dam a sustainable water resource for utilizing excess water off the Brahmini River project.

Many other cities around the world receive similar or less rainfall, so scarcity of precipitation is not the sole problem contributing to Jaipur's water scarcity. Jaipur's water scarcity is related to water resource management issues. Various strategies could be employed at the household, municipal and regional levels to mitigate Jaipur's water problem and create a much more robust water management system. Presently groundwater is over-exploited and its quality has also degraded the supply of water is minimized to a critical limit and the water crisis rapidly increased. The impacts of rapid urbanization included an increased domestic use of water, especially for hygienic purposes, and the emergence of new water needs due to the expansion of cities and improvements in living standards. Under such conditions, new responsibilities have been created for water resources management, of which the most important are the increased importance of protecting population centers against drought and flood, and the ever-increasing importance of water treatment to provide hygienic water, as well as collection and sound disposal of wastewater and drainage water [3]. Fast-growing urbanization and industrialization have led to too much over-exploitation due to a lack of rules and regulations and monitoring increased the problem, hence extraction of water is unachievable. It is high time to review the policies of drinking water supply, especially for Jaipur city. Jaipur's groundwater table in every fifth well (20%) in the state has gone below the alarming level of 40 mts., making it largely unfit for drinking. In Jaipur, 15.93% of wells are 20-40 meters deep and 41.59% of wells are having more than 40 meters depth.

Study Area

Jaipur is termed as the planned city of the medieval period. Sawai Jai Singh II was a great patron of mathematics, astronomy science and was founded by him on November 18, 1727, in astronomical observatories. The structure of Jaipur bears a testimony to his acumen in town planning; Jai Singh's love for symmetry led to uniformity is well in the meticulous planning of the city. The old Jaipur city was geometrically square-shaped without going up the center-peripheral relationship of a circle. In eastern cultures also the square was utilized in China and Japan, for their ancient capital cities of Changan 6th century, Modern Sian and Kyoto based on the square shape divided straight north-south and east-west road crossing at right angles. Jaipur is surrounded in the north by Nahargarh hills and in the east by Jhalana hills, which is a part of Aravalli hills [11].

Jaipur city is densely populous with 4.008 million in 2021. It is a fast-growing city that attracts migrants from all parts of the state and is the world's most popular tourist destination. It is situated in the eastern part of the state of

Rajasthan having a latitude of 26o 9' N and a longitude of 75o 8' E with an average altitude of 431 mts. The area of the metropolitan city was confined in 1921 to 7.79 sq.km to 64.7 sq.km in 1941, and in 1971 to 206.06 sq.km increased to 980 sq.km in 2001. This areal expansion of the city had a logical bearing upon the provision of civic facilities like housing, water, power supply, sewerage system, and transport.

Climate

Jaipur is located in the semi-arid zone characterized with relatively high temperature from 360 C to 450 C in June, the hottest month of summer and lowest 50 C to 180 C in January, the coldest month of winter, and precipitation of 650 mm annually but a major patch of rains occurs in monsoon months. August is the rainiest month with 84% relative humidity, the higher rainfall occurs during July and August. Overall, it is highly variable from year to year. Rainfall data shows that Jaipur has normal quantity with some fluctuation and varies in between 300 mm to 600 mm. In spite of having normal rainfall, water level is continuously decreasing [17].

Drainage

Dravyawati river originates from Nahargarh hills in the north of the city. The slope of the city has an overall trend from the hills in the north to the plains in the south and then to the east. The Dhund river in the east is ephemeral and flows straight from north to south at a short distance. The river Bandi flows in the northwest about 20 km away from Jaipur. All these streams earlier before independence due to sufficient rainfall during the rainy season were provided water. Ramgarh dam constructed on Banganga river 30 km away from the city flows in the northeast of Jaipur. Later on, these streams dried up with varying temperatures and rainfall. These streams are seasonal.

Objectives

1. To explore the various strategies that could be employed at the household, municipal and regional levels.
2. To assess the possibilities to create a much more robust water management system.
3. To look into the impact of urbanization and industrialization on water resources.
4. To critically analyze the role of existing policies, rules, and regulations in preventing the exploitation of water resources.

Hypothesis

With the rapid growth of population from rural areas, fast urbanization and industrialization, the water demand has increased and hence the supply of water needs monitoring, not implemented policies.

Methodology

The present study intends to see more knowledge about the city's mode and sources of water supply and demand. The strategies for sustainable development management of water supply the relevant data and information were obtained from PHED, RUIDP (Rajasthan Urban Infrastructure Development Project), JDA, RHB, and NGOs connected to private and public bore-well owners for their opinion and observations. Demographic data have been collected from census reports of Rajasthan. Jaipur is currently facing the problem of scarcity of water and diminishing drinking water sources, Bisalpur Dam has shared the supply to some extent. Hence, the government planned to link the river to fulfill the water demand. Water scarcity of Jaipur city is mostly related to water resource management issues which will need implementation of regulations of the policies.

Results and Discussions

The study throws light on the quality of drinking water supplied either by PHED or private bore-wells. Prominently supply of water was through groundwater in the city area, Bisalpur Dam Project is the only source of surface water and its supply is available for a limited area of Jaipur city. Maximum residents use municipality water for domestic and drinking purposes.

Water is a live sustaining substance that is the primary source of life and human existence. Most of the water available on the earth is salty and not suitable for drinking. Only one percent of available water is fresh and suitable for fulfilling human beings' needs, presently facing severe water scarcity and a crisis that threatens drinking water sources. With the rapid rising of population, industrial growth and expanding agricultural activities have increased the water demand. It is estimated that by the year 2025 the demand for potable water is likely to increase by 56% more than the present limit of water use. Hence, water conservation has become the need of the day. The idea of groundwater recharging by harvesting rainwater is gaining importance in the world [2].

Traditional Water System (Decline in use, potential use for future)

Maharaja Man Singh I built Amber Fort in 1592, Maharaja Jai Singh II built Jaigarh in 1726 to protect Amber Fort and Nahargarh Fort. At Jaigarh Fort on the hilltop many wide water channels and three water tanks with 6 million gallons of rainwater to capture and store, are also at present in Amber and Nahargarh Fort [11]. Traditional technologies and systems could not meet the water demand due to the increase in population. Tradition water systems were often kept small enough could easily manage and controlled by the community by porting. Modern technologies are for widespread areas. The forts built around Jaipur and the original layout of Jaipur exhibit traditional water harvesting techniques.

Early History of Water Management of Jaipur

Before the founding of Jaipur in 1727, Amber 9 km away towards the north, was the capital of the state of Kachwahas, due to not enough space for growth and scarcity of water, Maharaja Sawai Jai Singh decided to build a new capital, which is presently known as Old City of Jaipur *(ibid.).* To fulfill water demand Jal Mahal Palace (Man Sagar Lake) was constructed on Dravyawati river surrounded by Nahargarh hill, Maharaja Sawai Jai Singh II commissioned town planning, Vidyadhar Bhattacharya, and the foundation led down in 1728. Tal Katora tank and Raja Mal ka Talav were planned and constructed to fulfill 150,000 people's demand for water. The first water supply system involving to transport of water was initiated for the City Palace through a canal from 100 open wells constructed from time to time to address the growing population.

Due to rises in drought and flood conditions in the first two decades (1896 to 1912), the source of water supply explored a large reservoir Ramgarh Dam on Banganga River constructed 30 km north-east of Jaipur in 1903 and water supply started in 1925. Decennial growth of population from 1961 to 2011 was 38.58 to 49.37 percent with the increasing trend demand for water also rapidly surpassed.

Post-Independence Water Management

During the 1940s, the population of Jaipur began a rapid increase due to the partition of India in 1947, which lead to the immigration of refugees from Pakistan, and the declaration of Jaipur as the capital of the newly merged Rajasthan State in 1949. Hence, from 175,810 to 291,130 population increased between 1941 to 1951. From Ramgarh Dam, the supply of water in 1963 was 27 MLD which was increased to MLD and in 1985 supply of water was increased to 234 MLD. The biggest concern is that most cities do not provide the quantum of water according to existing per capita norms. At the time of Pre- and Post-independence, Ramgarh Dam was the main source of water supply to cater to the rapid increase of the urban population of Jaipur city. The Ramgarh Dam overflowed three times flooded in 1980 and 1983-84 and then after the uncertainty of rainfall, the water level of the dam reduced and became dried up in 2012 due to unauthorized construction and encroachment in the Banganga river basin resulting in depletion of the water table, not enough of drinking water. There is no perennial source of surface groundwater in the city. Therefore, Jaipur city continuously suffered in acute situations to get drinking water.

Explored New Source of Water

A new source of water needed explored and commissioned Bisalpur Dam on Banas River in 1990, 120 km away from Jaipur in Tonk district. Transmission of water from Bisalpur Dam to Tonk, Ajmer, and Jaipur began in 2009. The alarming rate of the rising population (3.628 million) of the city resulted in huge water demand, at the current period 600 MLD of water is required to meet the demand of Jaipur city while the city is getting only 440 MLD indicating a shortage. Its capacity is 1095 million cubic meters, where the water availability is highly dependent on the annual rainfall pattern which is extremely variable in the catchment area. This dam cannot fulfill the demand of the city, Jaipur relies on a single, unreliable surface water source the Bisalpur Dam, as well as a rapidly diminishing groundwater supply, it is highly dependent on annual rainfall, which is extremely variable.

River Linking of Jaipur's Water Management

India faces a number of water-related challenges, including increasing water scarcity and competition for water between different sectors and states. Some of the river basins in the southern and western states are experiencing physical or economic water scarcity. Basins in the east of the country are often perceived as having 'surplus' water and encounter recurrent floods **[21]**. India increases its storage for regulating the vast amount of runoff that otherwise cannot be beneficially utilized. The National River Linking Project (NRLP) water transfers of 178 cubic km will increase utilizable surface water resources by 25 % and improve water accessibility in water-scarce regions [20]. In August 1980, the National Water Development Agency (NWDA) and the Ministry of Water Resources published a report entitled 'National Perspectives for Water Resources Development'. This document outlined a water development plan comprised of the Himalayan and Peninsular components [1]. The National Water Policy 2012 stresses that water needs to be managed as a common pool community resource held by the State, under the public trust doctrine to achieve food security, support livelihood, and ensure equitable and sustainable development for all [18]. The Inter Linking River (ILR) project has been designed such that it will help improve the living standard of people as it will facilitate growth in the Indian economy [8, 10]. The completion of this project would generate a regular supply of water for domestic use, agriculture, and industries, coupled with flood control and improvements in water flow, navigation, food security, etc. [1]. One of the claimed benefits of the interlinking project is that it will provide drinking water to large areas in the country facing drought and water scarcity. The task of providing domestic water supplies, including for sanitation, should obviously receive the highest priority [14]. Shortage of water supply from Bisalpur Dam constructed on Banas River, the government has planned and investigating the detailed feasibility report to link Bisalpur dam from Chambal and Brahmani rivers to make Bisalpur Dam a sustainable water resource for utilizing excess water of Brahmani River project. It is the first interlinking project in the state to address its drinking water and irrigation requirements. Banas and Brahmani rivers are proposed to be interlinked by digging a tunnel between the two. It is estimated that 355 million cubic meters of water every monsoon can be utilized by interlinking with each other otherwise goes wasted [5]. Constructed dam of Brahmani River a tunnel is proposed to be dug ending at Banas some 10 km before Bisalpur dam. It is planned that the tunnel would connect the two rivers at a point closest to the Bisalpur dam to decrease the chances of wastage of water seepage or theft. Many other cities around the world receive similar or less rainfall, so scarcity of precipitation is not the sole problem contributing to Jaipur's water scarcity.

Current Water Supply and Management

The current water supply of Jaipur city primarily depends on tube wells, but estimates of government water supply vary greatly from source to source. There are great distribution losses within the system and water metering is either absent or broken at water receivers. Many of these tube wells are fitted with power pumps, which supply water to the clear reservoir and then to elevated storage reservoirs for distribution to the system [6]. According to PHED total water connections are 390,893 with 352,393 working connections out of which 384,058 metered connections, and 6835 flat-rate connections. There are 329,093 domestic connections, 51,246 non-domestic, 3917 industrial, 1170 public stand posts. However, 60% of the meters are not functioning. General inadequacy in water availability can be found in the circulation of supply and demand that reveals deficit drops in supply duration of depletion of groundwater affecting pressure in tube wells issues, and issues with water metering and fees.

Bisalpur dam is currently supplying about 320 million litres per day of water, estimated water supply and demand (462 million litres) consistently show a supply deficit of 90 MLD became distribution losses in the water supply system. It is

highly concerning the water scarcity issue to a city with a sustainable water supply for the future.

There are many issues with the tariff system for water consumption. The tariff is not well defined and charges are generally not based on actual consumption in the majority of the homes, but based on an average consumption value in the household based on past reading, which leads to great losses of revenue.

Jaipur's water scarcity is related to water resource management issues. In addition to water scarcity, degradation in the quality of both surface and groundwater resources is of great concern. Various strategies can be employed at the household, municipal and regional levels to mitigate the Jaipur water problem and create a much more robust water management system. Recently the government, of Jaipur has looked to re-employ traditional water harvesting techniques. Currently, it is mandatory for all houses with more than 300 sq. mts. to have rainwater harvesting structures. Further investigating to enforce more widespread and reliable strategies of traditional rainwater harvesting.

Originally the groundwater resources of Jaipur exhibited a high-water table and good quality. Presently, groundwater is over-exploited and its quality is also degraded and supply of water is minimized to a critical limit, and the water crisis rapidly increased. Fast-growing urbanization and industrialization have led to much over-exploitation due to a lack of rules and regulations and monitoring of tube wells have been increased the problem. Hence, the extraction of water is unachievable. It is high time to review the policies of drinking water supply, especially for Jaipur city. It can also be done by adopting and employing technology that makes more efficient use of water [22].

Recommendations

1. Increase of open areas- For recharging of trenches/shafts, more open areas are required.
2. The trend of rainfall in all over Rajasthan state is unprecedented and unpredictable so it is better to make conservation of surface water percolation of rainwater to recharge aquifers.
3. For decades, the farmers in the Sanganer Tehsil of Jaipur district have been irrigating their fields from a feeder of Dravyavati River containing toxic discharge from the Sanganeri print and dye industries located nearby. It is recommended to establish a water treatment plant at Sanganer.
4. Minimize the use of fresh water in industries- wastewater treatment plants should be installed to reuse industrial wastewater or recycle them to sustain freshwater.
5. Educating the public- it is more important to educate the public to save rainwater and minimize the use of potable water.
6. As the population increases the demand for drinking water also increases which leads to drilling the borewell where government supply water is not available. So, it is necessary to ban drilling and registration should be made mandatory to conserve groundwater.
7. The mandatory rooftop of rainwater harvesting- making it mandatory for people, government should give some subsidy on rainwater harvesting to promote it amongst the population.
8. Civil society organizations such as WaterAid and the Water Integrity Network are calling for more accountability and equity by strengthening citizens' voice and control over service provider performance, for example by introducing report cards and score cards, and exposing corruption and mismanagement **[12]**.
9. Review of traditional rainwater harvesting techniques- It is clear from the studies brought about the master planning of Jaipur city during its establishment that Sawai Jai Singh's planning of water harvesting was tremendous. So, we must review traditional rainwater harvesting techniques.
10. Recycling and reuse of water [9], treatment of sewage and industrial wastewater [13] can use in irrigation, lawns, crops, gardens, industrial cooling, etc.
11. Loss of water checking regularly- It is necessary to keep an eye on the irregular and irresponsible use of water which led to the loss of gallons of water.
12. Monitoring of system- With the help of new techniques and technologies of land use and remote sensing, the quality of soil moisture, content in the soil, and the water table should be studied.
13. The metering system must be for all consumers, penalize them, update the distribution system, implementation of comprehensive metering policy must be necessary
14. Optimum use of water in irrigation- sprinkler/ drip irrigation must be there.
15. As a fast-growing population, it is difficult to keep many areas open for recharging of water and also difficult to cater to the need for water. So, it is recommended to make artificial recharge sites along roads, and footpaths to recharge trenches and shafts.

Future Challenges

1. Comprehensive metering is a necessary policy for government and water supply agencies so that the maintenance, installation, operation, and management of water supply targets can be achieved at their own cost.
2. Training courses must provide to service provider workers in the field and ensure adequate educational preparedness.
3. The government must pass and enforce legislation to curb the over-exploitation of groundwater and avoid deterioration of groundwater quality.
4. Government must put in place legislation or incentives to promote the reclamation, and reuse of sewage after treated water in horticulture, flushing of sewers, toilets, lawns, cooling, etc.
5. Conservation of fresh and potable water by industries so the environment can save from pollutants in receiving by water bodies.
6. The government must open platforms for dialogues for the public, experts, and leaders of various communities who actively participate.

Conclusion

Arid and semi-arid climatic conditions prevail over the unevenness and uncertainty of rainfall in the Rajasthan state. Water availability from various sources is fast depleting and deteriorating as a result Jaipur city is facing a tremendous problem with drinking water supply. Presently water demand is deficient. There is an urgent need to research new

sources of groundwater availability for sustainable development through integrated resource management, rainwater harvesting, water audit for domestic purposes, and reuse of treated wastewater are technical water-saving measures that can be adopted. Higher tariffs may change consumption habits. People are ready to reduce the consumption of water. The need is to implement water conservation techniques by concerned authorities.

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