Coping mechanism during erratic rainfall, frequent drought and challenge to supply potable water to millions, a case study of Jaipur City

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KEYWORDS

Erratic rainfall, Drought, Ground water depletion, Water quality, Bisalpur

ABBREVIATIONS

ADB	Asian Development Bank
ASCI	Administrative Staff College of India
BCM	Billion Cubic Metre
CGWB	Central Ground Water Board
CWRS	Clean Water Reservoirs
GPS	Global Positioning System
INR	Indian Rupees
JDA	Jaipur Development Authority
JICA	Japan International Cooperation Agency
KMS	Kilo Metres
mg/l	Milligram per litre
MC	Municipal Corporation
MLD	Million Litres per Day
MM	Mili Meters
MOHUA	Ministry of Housing and Urban Affairs
MOU	Memorandum of Understanding
NEERI	National Environmental Engineering Research Institute
NRW	Non-Revenue Water
OTP	One Time Password
PHED	Public Health Engineering Department
Sq. Km	Square Kilometre
STP	Sewage Treatment Plant
RWH	Rain Water Harvesting
TDS	Total Dissolved Solid
ULB	Urban Local Body

ABSTRACT

Jaipur, the Pink City of India and capital of the biggest state of India has approximately 3.5 million population as we just approached 2020. With an average rainfall of around 500 mm against the national average of almost 1100 mm, Jaipur started facing the crunch of water scarcity as it is largely dependent on ground water. In last two decades the average annual rainfall has decreased considerably. As of 2019 all the 13 blocks of Jaipur city are in dark zones as per survey by central ground water board, which means the recharge is just half of the total exploitation. Water table has gone more than 25 metres below in last one decade leading to extreme deterioration of ground water quality with higher concentration of TDS, fluoride, nitrate and salinity a common feature across whole Jaipur. With severe scarcity of rainfall in 2018 the average water supplied was just 15 minutes in most of the area with very low pressure. In other areas the water supply was just once in 2 days or once in three days. The situation has been critical in last 20 years. Infact the water supply scheme of historic city is almost a century old, which was initially taken care by open local wells and later in 1918 the increasing population was served through large diameter open wells with tap water at common points. In 1952 Ramgarh dam was used as key surface source supplying 7 MLD water which was further augmented to 27 MLD in sixties. Same time drilling of new tube wells came into existence as surface water was not enough. With urban population increasing and expansion of concrete jungles, new colonies and residential complexes mushroomed the city and the ground water started depleting. With intense deforestation and reduction in greener area the surface runoff is a big challenge for recharging due to loss of top soil. Looking to key challenge in water supply Rajasthan state government initiated in 2009 a very costly arrangement of bringing and supplying drinking water from distant source Bisalpur dam which was almost 120 kms away from Jaipur. Bisalpur dam supply to Jaipur city was reduced to 307 MLD before August 2019, which was 450 MLD in 2018 and 540 MLD in 2017 and the dam is used to supply water to half of Jaipur population. The demand supply deficit is almost 125 MLD which is further aggravating the vulnerability. The monitoring and regulation of extraction of ground water through almost 20,000 private tube wells and 2000 tube wells managed through Public Health Engineering Department is almost difficult. With increasing population and urbanization there has been inundating task of supplying water to 3.5 million urban population of Jaipur. Being a big tourist hub with huge floating population due to administrative and educational centre the time is to effective implement the various initiative's. This paper will focus on key challenges and effective measures for the continuity of water supply to an emerging city.

1 INTRODUCTION

India is one of the emerging global economy and presently it is suffering from the worst crises of drinking water availability. This crises of acute water scarcity is giving a huge impact on lives and livelihood of millions of residents (Chari, 2019). With population growth beyond control, the condition will be worst by 2030 as demand for water will be doubled which will be impounding the lives of hundreds of millions population due to severe water scarcity. As per (MOHUA, 2019) 255 districts or 756 ULBs in the country are severely water stressed. Almost 17% of notified towns and cities in the country are facing extreme scarcity of water, among them Jaipur is one of the most affected one besides Hyderabad, Bengaluru, Delhi, Puducherry, Chennai, Mumbai and Amravati.

With a geographical area of 342,239 square kilometers (Census India 2011) and uncertain, erratic rainfall pattern Rajasthan is among the driest state of India. The state is comprised of Thar Desert and Aravalli mountainous ranges. State is divided into 236 blocks (Central Ground Water Board), out of which 204 blocks are in dark zone, 26 districts out of 33 districts are in drought like situation. 140 blocks are over exploited, 50 blocks are in critical stage and 14 blocks in semi critical stage. There are six major river basins available in the state (SANDRP), from these six river basins Chambal and Mahi are the only perennial rivers. With net annual ground water availability of 10.38 BCM, the annual

ground water draft is 12.99 BCM. Due to very poor rainfall in 2013, out of 724 dams in the state majority of their catchment area remained dry. Only 7 dams received water with full capacity, 250 received partial rain water and 467 were total empty. Monsoon rains comes from late June to September and delaying of monsoon rains is a regular feature in the state. In June 2013 as monsoon was delayed, 23 districts in the state received very less rainfall during the month (The Economic Times), as state received just 130 mm of rainfall in comparison to 280 mm of rainfall in the corresponding months.

Jaipur city being part of the semi-arid zone of the country, is the capital of Rajasthan state, has a population of 3.1 million as per 2011 census. City is now reaching almost 3.5 million population as we reached 2020. The city is characterized by high temperature and low rainfall. Average rainfall of city is around 504 mm (CGWB) comparing to national average of around 1100 mm. In 2011 Jaipur recorded a yearly growth rate of about 5% comparing to 2001 and ranked tenth among India's megacities (Sogani and Vyas, 2019). The city has been included in the Smart City Program and is expected to undergo massive urban restructuring. Wards and zone maps were obtained from Jaipur Development Authority (JDA, 2020) and were digitized. Figure.1 shows the different wards and zones of Jaipur city. Table 1 gives key statistics of Jaipur city.

Figure. 1: Wards and Zones of Jaipur City

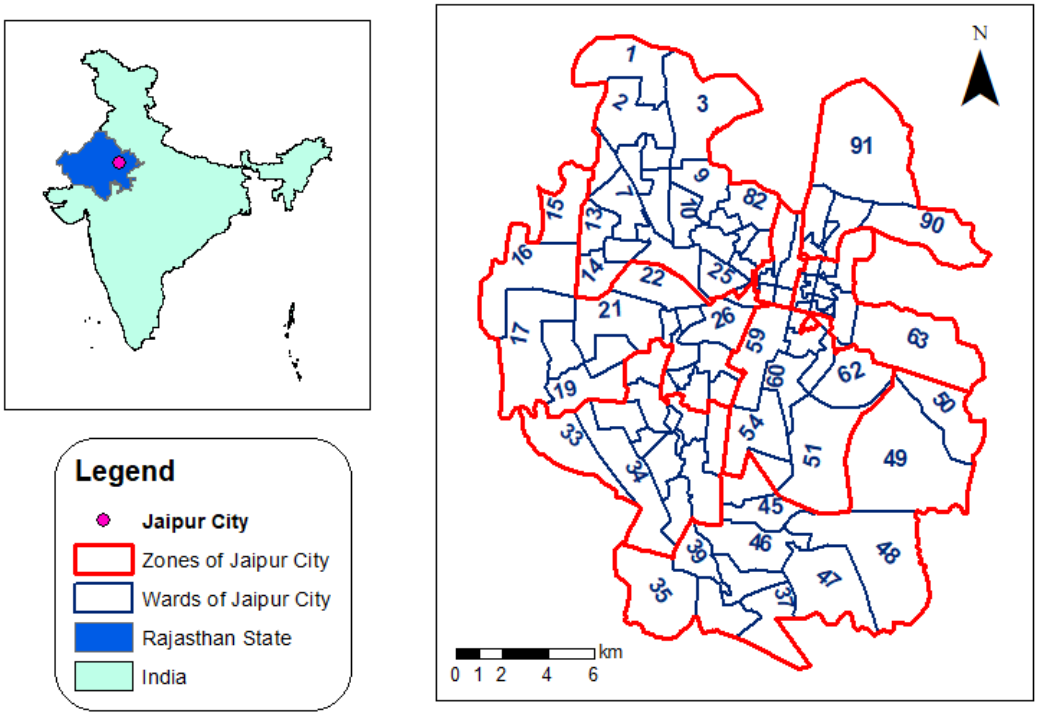


Table 1: Key information about Jaipur City

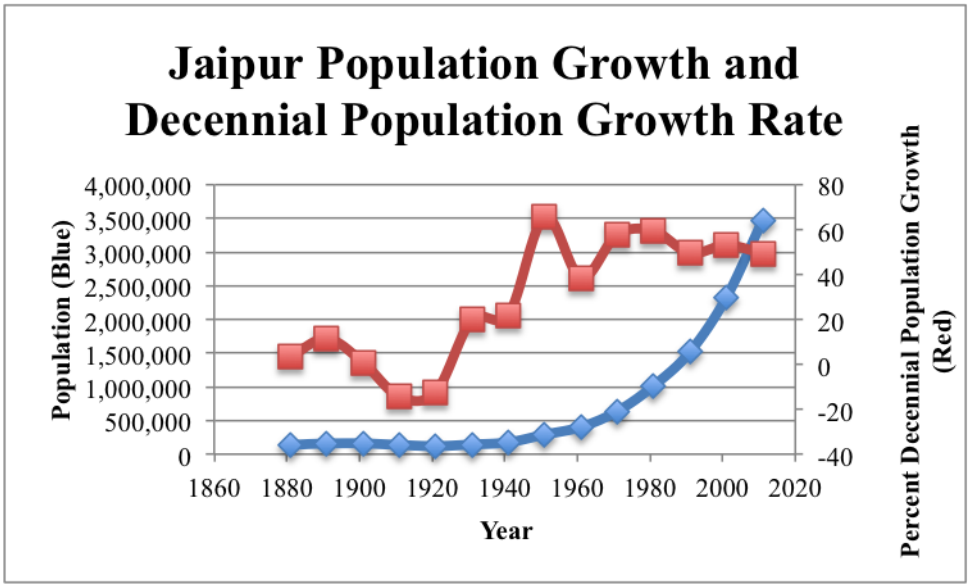
Study area city name	Jaipur City	
Study Area	467 Sq.Km	
City Zones and wards	8 zones and 91 wards	
No. of households	737179	
Total Population	3046185 (According to 2011 census)	
	Male	1603136

	Female	1443048
	Sex Ratio	900 Females per 1000 Males

(Source: City Profile, JMC)

In December 2019 as per The Pink City Post city was reclassified into two parts. 91 previous designated wards were redistributed into 250 new wards. One is Greater Jaipur Municipal Corporation which has 150 wards and other is Heritage Jaipur Municipal Corporation which has 100 wards and covers old city area. Since this is a relatively new division, not much information is available about this reclassification as JMC invited objections on demarcations in December 2019. This study was done pertaining to how the drinking water is supplied to almost 3.5 million residents as we reached 2020 in spite of severe shortage of water, an attempt has been made to identify key challenges the utilities are facing and identifying remedial measures. Figure 2 shows how the population growth has taken place in Jaipur in last 140 years.

Figure 2: Jaipur Population Growth



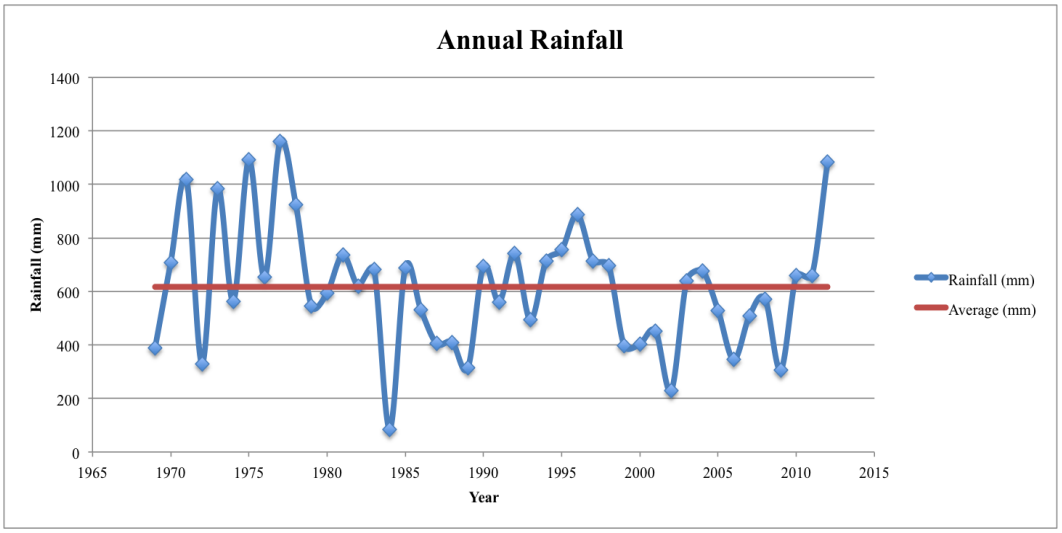
(Source: Census of India)

Jaipur Drinking Water Scenario:

Jaipur today receives drinking water mainly from Bisalpur dam which is situated at 120 kms from the city. Along with Bisalpur supply there are public and private tube wells and through hundreds of water tankers plying around the city. A few percentage of population have their own personal bore wells. With almost 125 MLD deficit of water in the whole distribution system, the present water demand is almost 500 MLD whereas supply is 375 MLD. Out of this total 500 MLD demand 275 MLD of water is supplied from Bisalpur dam (Jain, 2020). Around 100 MLD is supported through more than 2000 tube wells which have already depleted the groundwater level in the city by more than 25 meters in last one decade as per state ground water department. All the 13 blocks in Jaipur city are over-exploited as per Central Ground Water Board (CGWB, 2013), as over exploitation varied from 117% to massive 364%. Rampant construction and concrete flooring have blocked all the process of natural recharging, combined with the withdrawal rate of 100 to 110 MLD created an alarming situation. With urban population growing the city boundaries are expanding and the demand for drinking water is also increasing manifold times. Situation is getting worse due to new colonies and real estate developers are drawing groundwater for drinking and construction purposes. Quality of water has

deteriorated severely. A study on Jaipur water quality by Jain et al., (2014) projected high TDS in drinking waters, which varied from 400 to 1800 mg/l. Almost 95% samples were exceeding the permissible limit. A study done by Jal Bhagirathi Foundation et al., (2013) predicted that in last two decades Jaipur has passed through downward rainfall trends with high variability. It has also predicted that by 2040 median annual rainfall is going to decrease and climate change would be the most important influencing factor except in the monsoon season. Climate change, as one of the major influencing factor, is giving a huge impact and major stress on the city's drinking water supply. During mid 1900s due to extreme population rise and rapid growth of the city, it created substantial issues in water supply. As per Times of India, India's lead newspaper residents across the city have been regularly complaining about the low water supply. For example in one of the area Barkat Nagar there are severe problems related to low pressure which has worsen the situation as residents receive water for around 10 to 15 minutes. Due to low pressure most of the residents use boosters which further decreases water pressure and residents are forced to order water tankers once a week, which is again a costly affair for urban poor. Residents of Kartarpura gets water every alternate day where almost all the houses have boosters. This has significantly lowered the pressure of water and the timings of water supply have been also cut short to 15 minutes. PHED due to the scarce rainfall in 2018 and water level going down in Bisalpur Dam, already reduced the city's water supply by 15%. A study was done by Elizabeth et al. (2017) on household survey in Jaipur city to examine conservation behavior and residential water end uses. How the demographic factors influence, what are the beliefs about water, about water sources and how social pressures effect on these behaviors were tested in the study. The study indicated that majority of the participants do recognize the importance of conservation of water, but on the other side they were not conserving water at their own. This brings out the importance of user education before adopting water conservation techniques for the public. Kumar et al. (2016) conducted a survey to determine water use pattern and the applicable water conservation strategies for Jaipur city. Water conservation techniques like bucket bathing, low flow faucets and dual flush toilets were part of the study to combat the growing water deficit of the city.

Figure 3: Jaipur annual rainfall



(Source: Rainfall Data)

2 METHODS

The methodology was to study and analyze the various challenges the city was facing in terms of demand and supply of drinking water for almost 3.5 million residents along with the coping mechanism.

Major Challenges in supplying potable water:

a) **Non-revenue water:**

Non-revenue water is one of the major issue Jaipur city presently facing like any other city of developing nations. Based on few studies it has been found that city is having NRW in the range of 40-50%. Water audit which was initiated in 2011 was to study and analyze complete accounting of water quantity from all the available sources to user's end. This audit brought NRW to 32% from initial NRW of 42% (Jain, 2020). Although groundwater reliance of Jaipur has improved from 97% to about 25% (Shah, 2015) the quality of water supply services is still relatively low.

b) **Water abstraction through tube wells:**

With increase in population the dependency on groundwater has increased tremendously in Jaipur city. In some of the areas there has been almost 500% over exploitation of ground water which has severely degraded the ground water quality. Rapid urbanization, extension of concrete jungles, decrease in agriculture and forest lands, less areas for recharge are major issues Jaipur city is presently facing like any other city in developing nations. In absence of effective regulation and monitoring of drilling of new tube wells, illegal mining of water has aggravated the problem drastically. On the other side number of tube wells are very high as it has become difficult for PHED to maintain the performance. It has been estimated that there are 20,000 to 30,000 tube wells in the whole Jaipur which are un accounted (Shodhganga), whereas as per PHED there are around 20,000 private tube wells and 2000 public tube wells. The over exploitation of groundwater has given serious issues of Fluoride, Total Dissolved Solids and Nitrate in the ground water of Jaipur city.

c) Nonfunctional of metered connections:

About 60% metered connections out of 384,058 metered connections in Jaipur city are nonfunctional Sharma (2019). One of the reason attributed is shortage of staff at PHED which is resulting low repair rate of meters. This is also hampering the revenue collection which is not systematized.

Table 2: Water Metering

Total Connections	390893
Total connections (Metered)	384058
Connections (Domestic)	329093
Connections (Non domestic)	51246
Connections (Flat rate)	6835
Connections (Working)	352393
Connections (Industrial)	3719

Public stand post	**1170**

c) **Illegal Water Connections:**

As per various provisions of Notification by Public Health Engineering Department, (2018) Rajasthan, PHED has imposed "PENALTY FOR TAKING ILLEGAL WATER CONNECTION FROM DISTRIBUTION MAIN". For All water supply {1210. 00 and 5 times estimated charges for water schemes in the State consumed subject to a minimum consumption of 30 KL per month for a minimum period of 12 months }. In spite of strict norms and regulations there are no concrete steps by PHED department to curb the menace of illegal connections. In absence of enforcement team, they do not have exact numbers and there are huge protest by residents whenever PHED team goes to cut the illegal connections. There is lack of political motivation and many times local ward leaders support the illegal connections.

d) **Ground Water Contamination/ Water Pollution**

A report by India water portal says almost 70% of Jaipur piped water supply has high TDS or has bacterial contamination or both the issues. This is based on a report from NEERI and PHED Rajasthan. On the other side due to extreme abstraction of ground water the concentration of Fluoride and Nitrate has increased in Jaipur ground water. In fact all the 33 districts of Rajasthan are partially or fully affected by fluoride contaminant. Jalore, Jaipur, Ajmer, Nagaur, Pali, Jodhpur and Sirohi districts are worst affected by fluoride with average concentration of 2 mg/l (Singh et al., 2011). When the amount of rainfall is low as it generally happens in the state and mainly in Jaipur, there is always high concentration of nitrate as ground water gets less water for dilution. (Saxena et al., 2014). The state of Rajasthan and especially Jaipur is severely affected by nitrate contamination of groundwater. Ayyasamya et al. (2009) study projected that nitrate concentration in the whole state is ranging from 40 to 1000 mg/l. A study done by Hansa and Goyal (2017) assessed the groundwater deterioration using GIS and multivariate statistical techniques for Jaipur district. The study found that geogenic processes are attributed for high fluoride concentrations in ground water similarly excessive use of fertilizers along with discharge of domestic sewage is responsible for high nitrate in ground water of Jaipur district. Higher concentration of bicarbonates and Chlorides were responsible for higher pH, higher alkalinity levels in the study. A study done by Sharma et al (2019) projected that the total waste water treatment capacity of sewage treatment plants in Jaipur city is only 62 %. Out of total 378 MLD waste water generated only 235 MLD waste water is treated. This high level untreated liquid waste finds its way back to reservoirs leading to bacterial contamination of drinking. The study also found that about 36% of the population have piped or underground sewerage connections, 25% rely on on-site sanitation systems and 39% still practice open defecation as per census 2011.

Besides the narrated issues, there are several other issues which Jaipur water supply system is presently facing. These include not only inappropriate collection of revenue but also nominal rates of water consumption from the consumers. On the other side substantial increase in the number of multistory buildings is also requiring higher water consumption.

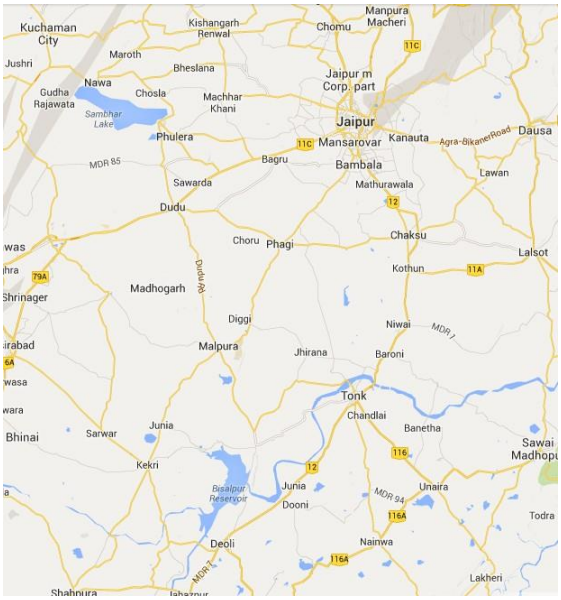
Coping Mechanism:

a) Bisalpur project:

With a huge water demand deficit, Government of Rajasthan took one major initiative of bringing drinking water supply from Bisalpur dam, situated 120 kms away from Jaipur. This was a very costly affair as all other nearby sources were found in sufficient to meet the future demand of a major city. The

project was initiated in 2006 by PHED through the support by Government of Rajasthan. Water distribution from Bisalpur dam started to Jaipur city in 2009. It has two phases, one transmission system where raw water is transferred up to Surajpur where it is filtered and chlorinated. This phase was sanctioned by Asian Development Bank (ADB). The second phase is transfer system where water is transferred to Jaipur city and various other places using pipelines. This phase was sanctioned by Japan International Cooperation Agency (JICA) loan of 8.88 billion yen at 1.3% interest rate for 30 years.

Figure 4: Map of Jaipur and Bisalpur Reservoir



(Source: Jaipur Google Maps)

b) Water supply through tankers

Water distribution through tankers in Jaipur city started mushrooming when demand deficit started increasing. Almost 2.9 million population was connected through piped water network by PHED from 3.1 million census population of city with base year 2011. The challenge came when low water deficit started grooming and people were getting water with low pressure. In many places people were getting water once in two days. All existing water sources including Bisalpur dam were found insufficient and the abstraction of ground water was at maximum. The peri urban poor living on the outskirts of the city and new regularized/non-regularized colonies faced the maximum crunch. Water through tankers was transported round the year in the city which included both connected and unconnected areas. On the other side PHED initiated to make adequate improvements in the water distribution system and the process was completed by 2016 in many localities. Number of tanker trips running during summer time was about 2800 till the year 2010. This number finally reduced to 1000 tankers in the year 2016. Out of these 300 tankers were running in the outer areas which were not connected and rest were in the network areas. In order to reduce the corruption in exaggerated tanker trips, GPS based tanker tracking system was introduced in March 2012. This has enabled the payments as per trips recorded in GPS. On the other side there has been an increment of water mafia who were indulged in water trafficking without keeping any records in government books. In present scenario to remove black marketing “One Time Password” (OTP) system was introduced. One tanker trip cost is around 300 to 500 INR for 4000 litres of water (Times of India, 2018).

c) Water quality assurance:

Disinfection by chlorination is a routine feature in the drinking water treatment systems in the developing nations. In Jaipur city usage of bleaching powder was done at all pumping stations by (PHED). Bisalpur project pumping stations were provided with gas chlorination at all the places. On the other side 100 online chlorination plants were installed on tube well along with 12 electro chlorinators at pump houses. In order to have an effective water quality surveillance and ensuring water is safe from bacterial contamination water samples are collected on daily basis for testing of residual chlorine.

d) Artificial recharge structures :

In continuation to various coping mechanism to augment the surface water storage and ground water recharge the necessity of artificial recharge structures was also emphasized. More than hundred roof top artificial recharge structures were installed by JDA in public parks and government buildings. These structures were also constructed at depressions along the road side which are places of water accumulation mainly during monsoon season. Similarly in the year 2011/12 (PHED) constructed more than hundred artificial recharging structures on tube wells which were in abandoned stage.

e) 24 by 7 drinking water supply in four pilot areas :

PHED through Government of Rajasthan signed a MOU with a Malaysian based company Ranhill Co Malaysia. This MOU was to commission 4 pilot projects for 24 by 7 water supply in four zones of Jaipur City. The major focus was to have an effective NRW strategy and to study the consumption behavior.

3 RESULTS

Results and Suggested Remedial Measures:

Water audit: This is the first step to understand the flowing water quantity and quality even in a complex scenario. In 2011 PHED conducted water audit and brought the water loss to 32%. A regular systematic audit may yield good results when problems are identified and solutions are found out.

Illegal water connections: This is a major challenge ULBs and MCs are facing in developing nations, especially in India. In Jaipur PHED has to face lots of challenge when unauthorized connections are taken from the rising main and the department has to face anger of the communities. Time is to make awareness programs and strict penalties to be imposed.

Reduction in water loss: With almost 32% NRW and other substantial losses, there is need to reduce the water losses. There has been four pilot projects (Mansarovar sector 1, 3 and 9 and Malaviya Nagar sector 9) for reduction in NRW which needs to be scaled up.

Unauthorized private tube wells: This is the biggest issue city of Jaipur facing. There should be complete ban on drilling of new bore holes. Due to shortage of staff, PHED is unable to curb the menace of illegal tube wells. These tube wells owners than sell the water to water tankers. This has to be stopped through strict actions and regular monitoring.

Strengthening the distribution network: There is always a scope of addition of new pipe lines in order to strengthen the distribution network. In order to increase the revenue department needs to curb the issues of NRW and regularize the tariff system.

Rain water harvesting structure: It is mandatory to have RWH for every plot size of 300 square metre but this policy has not been adopted strictly. RWH is one of the best solution by capturing every drop of water in a water scarce state.

Roof top water structures: The houses in western Rajasthan used to construct traditional roof top water structures made up of stone and lime. The housing complexes in Jaipur city and institutional buildings have larger spaces which has to be sparingly used for roof top water structures.

Minimizing contamination: In these circumstances installation of a flash mixer at treatment plant is one of the remedial measure. In order to have safe drinking water, there is need for regular cleaning of CWRS, regular cleaning of treatment plant, checking of existing water supply pipelines, increasing the frequency of water quality checks at all the levels.

Conserving surface water: with huge inflow of surface runoff, there is need to conserve surface water. The areas which are still left and not come under urbanization can be useful for collecting water and recharging depleting aquifers

Regulation on industrial water: Flow and sewage mixing in the open nallahs (channel) has to be strictly monitored and at any point it should not finds its way to drinking water sources and leaking networks.

Tariff system: For water consumption there is need for well-defined tariff system as charges made are not done as per consumption of water in majority of the housing colonies (Jethoo et al). This has to be regularized as charges for water consumption are very nominal, it has to be revised so as to make the system sustainable.

Conclusion

Jaipur city is one of the emerging mega city of India. With almost 3.5 million population the supplying of safe drinking potable water is one of the biggest challenge for PHED Rajasthan. With floating population and big tourist hub the need for equitable water is another issue. The most severe sufferers are urban poor who ends up paying higher cost for deteriorated water quality. PHED Rajasthan in coordination with Rajasthan State Government has made this task possible, though there are huge hindrances and challenges. Communities are willing to pay more for drinking water if quality and quantity is better and improved. Lots of measures has to be taken strictly including saving every drop of rain water. There is a need for strong political will in the core interest of common man with strict measures. With present state government focusing more on users end that is last mile, it looks like if there is political stability it can deliver to the needs of the community. Government of India's new merged ministry "Jal Shakti" is very ambitious to bring water by tap to every end user by the year 2024. An effective coordination is the need of the time between federal ministry and state government in the core interest of common man.

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