Impact of Fragile Water Management Stratergies and Mitigation - a case study of Pune City, India

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IMPACT OF FRAGILE WATER MANAGEMENT STRATERGIES AND MITIGATION – A CASE STUDY OF PUNE CITY, INDIA

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ABSTRACT

The aim of the study is to know about the impact of water management system on the city of Pune due to the fluctuating monsoon. To achieve this, research study was carried out in exploring the factors which are contributing for this variation in amount of precipitation. For instance, improper urbanization and industrialization in the states such as that of Maharashtra is happening in a haphazard manner owing to the uncontrolled burst in population in the cities and town. To ascertain the impact caused due to heavy rainfall this study was initiated. Data of population of Pune city was collected as it is our study area for research. Based on the analysis it was clear that there is a drastic increment in last three decades. A survey was conducted and responses from people across the city were collected regarding the management of rain water as well as the issues faced during peak rainfall and it was analysed to evaluate the impact.

For analysis and identifying the regions that were most affected, SPSS (**S**tatistical **P**ackage for the **S**ocial **S**ciences) tool has been used. The survey responses collected were analysed using SPSS and various parameters have been compared to identify the relevant ones. Based on the analysis of the data obtained from the survey it is concluded that in many regions proper rain water management strategies are not adopted and also rain water harvesting technique is not installed. This results in various problems like water logging, traffic congestion and improper drainage.

The output obtained is conclusive on identifying the parameters that have crucial impact on the city during monsoons and if corrected, can bring a change in the rain water management strategies adopted and make Pune a better city to live in.

Keywords: Water management system, rain water harvesting, SPSS.

1. INTRODUCTION

During the last few years, increased attention is given on the issue of sustainability of urban water systems from ecological, social and economic point of views. In metro cities of India like Pune, it is a difficult challenge to provide a sustainable underground storm water management system due to space constraint**.**The rain water should be managed properly and diverted effectively toward catchment or basins to reduce the waterlogging problems in peak rainy seasons.

Due to improper urbanization and industrialization the development in the states such as that of Maharashtra is happening in a haphazard manner owing to the uncontrolled burst in population in the metro cities and town and even due to growing migration of population from the villages **(Magnus U. Igboekwe et al., 2011).** All these factors are resulting in the environmental degradation which affects the season cycle of our planet. Therefore, it leads to adverse effects such as rise in temperature, fluctuation in monsoon, heavy rainfall, etc.

This study focus on how the variation in North-East monsoons is affecting the normal people living in the city, what problems they are facing during rainy season and suggesting remedial measures to mitigate it. There are many techniques and measures that has been implemented by the government authorities to manage rain water during peak rainy seasons but these measures are not sufficient or may be not efficient as predicted **(S. Beecham et al., 2011).** Therefore, it is now the responsibility of each and every individual living in the city to take some serious action against this issue for controlling the factors which affect the environment and also to conserve water for building a sustainable environment for living **(Kumar P Sundara et al., 2015).**

As urbanization is increasing in most of the cities in India rapidly including Pune city, paved areas in the city is also increasing which leads to less infiltration of the rain water. During past few years amount of rainfall is varying significantly as given in Figure 1.3. Therefore, increasing the load on the storm water drainage network of the city. This improper draining of runoff water results in accumulation of water on roads and different parts of the city. **(Akinchan Singhai et al., 2019)**

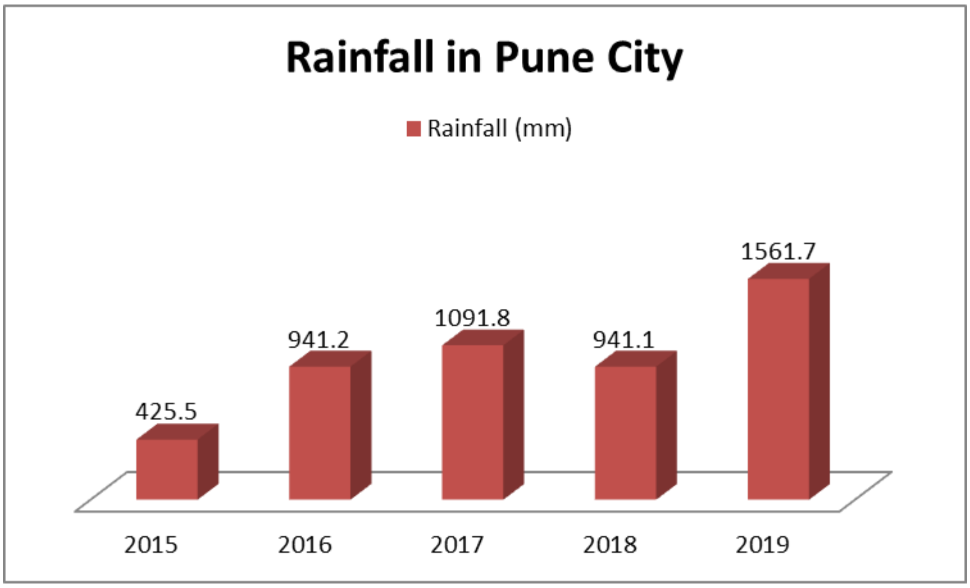

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Figure 1 Amount of rainfall in Pune City

According to an article in Hindustan Time, Pune Municipal Corporation faced huge difficulties in 2018 to manage the rain water as they were not prepared for the heavy pre-monsoon rains. Roads were water logged in many areas of the city due to which residents faced lot of problems. People faced many issues like traffic congestion, choking of drains, areas were flooded and water entered into the houses. **(S. Satheesh kumar et al., 2017)**

In Pune (Maharashtra) population has increased three-folds in last three decades resulting in increased paved areas which leads to increased runoff. The city, on the other hand receives heavy rainfall causing huge runoffs because of lack of pervious surfaces and insufficient drainage system resulting in water logging. **(Rajat Agarwal et al., 2013)**

The fluctuating amount of rainfall in past few years in Pune put additional pressure on the storm water management system as represented in figure 1. Also due to significant rise in population there is a substantial rise in siphoning of underground water which brought about diminishing the level of ground water table **(Viavattene C. et al., 2008).** Pune authorities are continuously struggling to control this problem of mismanagement of rain water. **(Rejani R.**

et al., 2015). So, the main purpose of this study is to study impact of monsoon in Pune city due to fragile management of authorities and suggesting suitable remedy for the same.

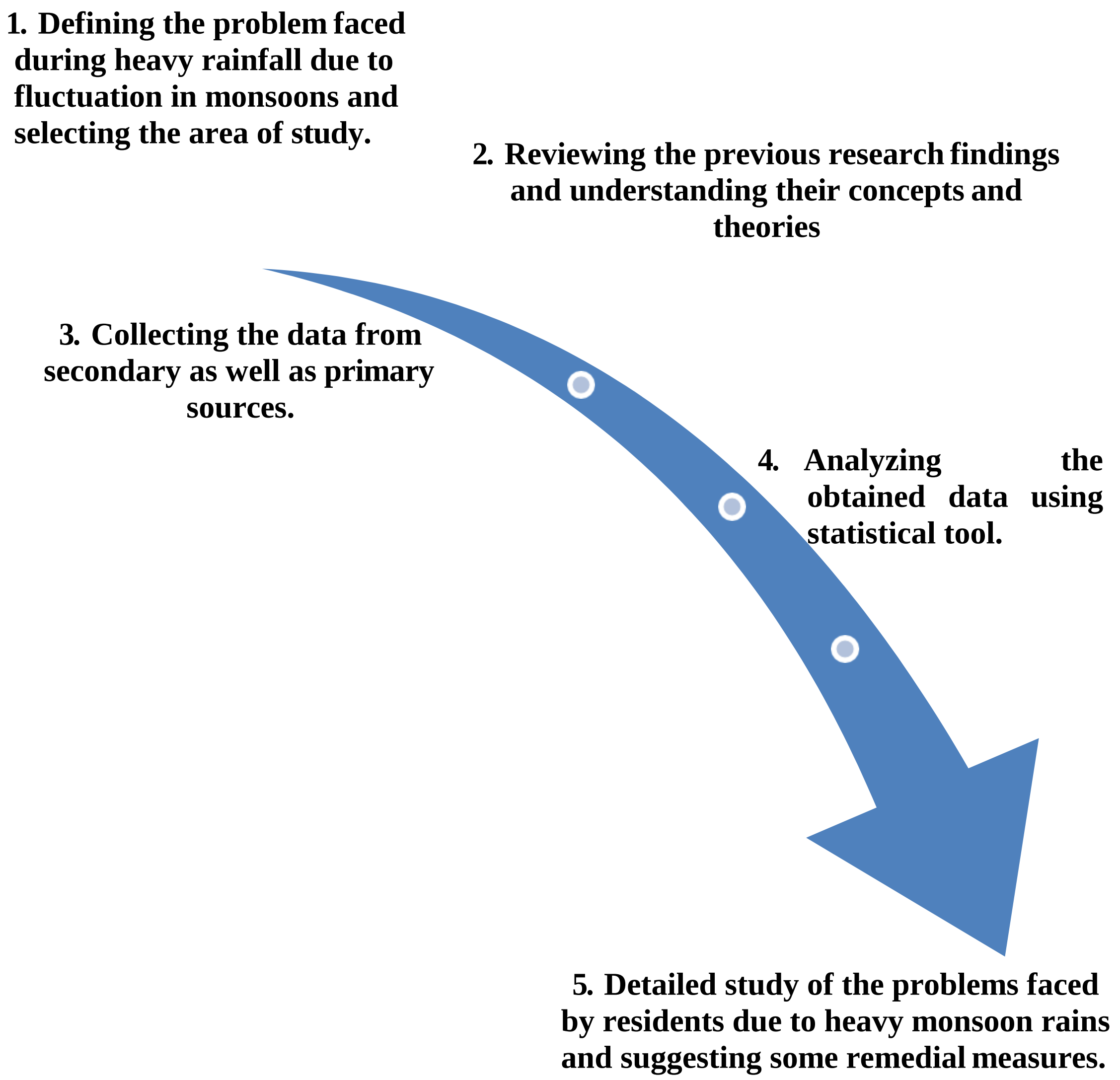
2.1 METHODOLOGY

The methodology adopted in this work is determining various factors responsible for various environmental changes such as monsoon fluctuation and its impact on the people living in the city. Thus, the objective of current study is to analyze the variation in amount of rainfall happening in past few years and due to this what all problems are arising. Also suggesting some of the remedial measures as stated in Figure 2.1.

1. Since last few years lot of variations can be observed in the pattern of rainfall in various regions of the country. There are several reasons for this change like pollution, global warming and other human activities that disturbs the environmental as well as geological conditions. Due to urbanization more and more industries are established in past few years, attracting more people for immigration. This swiftly expanding urbanization in various parts of India has led to generation of enormous quantity of air and water pollution causing global warming. All these factors causing negative environmental impacts like change in monsoon pattern, deteriorating the quality of fresh water, increasing temperature, varied rate of precipitation, and most vital is declining the ground water level.

   Most of the states in India are growing rapidly like Maharashtra, due to which paved areas in the state is also increasing leading to less infiltration of the rain water. Growing construction activities increases the pollution and also allows the rain water to flow directly into the drainage or streams rather than infiltrating into the soil which in turn is reducing the level of ground water table.

   The Areas which are highly affected during monsoon. In case of primary source, we have conducted a socio-economic survey in different areas of Pune city. In this survey we have prepared a questionnaire and approached to the people living in different areas of Pune city like Aundh, Baner, Pashan, Shivajinagar, etc. Goal of conducting the survey is to know that what type of problems occur due to heavy rainfall and up to which extent people living in an area is suffering.
2. After collecting sufficient number of reliable responses, we have segregated the data based upon the area in which an individual live. We have used SPSS (Statistical Package for the Social Sciences) tool for analysing the data. We conducted the Chi-Square test to obtain the relationship between the selected parameters for each region which helped us to reach to our desired results.



(Source: Compiled by author)

Figure 2. 1 Research Methodology

3. Based upon the obtained results by analysing the primary data as well as taking the reference from the secondary data we have done a detailed research that how the tremendous rainfall has affected the residents of Pune city. How the people of the city are suffering due to different problems like traffic congestion, water logging and floods. They are still fighting with these issues and trying to find an efficient solution for it. We studied about what measure have been taken till now to mitigate these problems during rainy season and we have also suggested some remedial measure as well that can help to improve the situation.

3.1 STUDY AREA DESCRIPTION

Pune district occupies a strategic position within western Maharashtra. The district headquarters in Pune city. Pune is the second largest city in the Indian state of Maharashtra, after Mumbai. It is the ninth most populous city in the country with an estimated population of 3.13 million. Along with its extended city limits Pimpri-Chinchwad and the three cantonment towns of Pune, Khadki and Dehu Road, Pune forms the urban core of the eponymous Pune Metropolitan Region (PMR).

Pune city's total area is 15.642 sq. km. By road Pune is 1,173 km (729 mi) south of Delhi, 734 km (456 mi) north of Bangalore, and 149 km (93 mi) south-east of Mumbai. Pune lies on the western margin of the Deccan plateau, at an altitude of 560 m (1,840 ft.) above sea level. Pune has a hot semi-arid climate bordering with tropical wet and dry with average temperatures ranging between 20 and 28 °C (68 and 82 °F). Pune experiences three seasons: summer, monsoon, and winter.

Typical summer months are from mid-March to mid-June, with maximum temperatures sometimes reaching 42 °C (108 °F). The warmest month in Pune is May. The city often has heavy dusty winds in May, with humidity remaining high. Even during the hottest months, the nights are usually cool due to Pune's high altitude. The highest temperature recorded was 43.3 °C (109.9 °F) on 30 April 1897.

The monsoon lasts from June to October, with moderate rainfall and temperatures ranging from 22 to 28 °C (72 to 82 °F). Most of the 722 mm (28.43 in) of annual rainfall in the city falls between June and September, and July is the wettest month of the year.

Demographic

The city has a population of 3,124,458; while 5,057,709 people reside in the Pune Urban Agglomeration as of the 2011 census. The latter was 4,485,000 in 2005. According to the Pune Municipal Corporation (PMC), 40% of the population lived in slums in 2001 The number of people migrating to Pune rose from 43,900 in 2001 to 88,200 in 2005. The sharp increase in population during the decade 1991-2001 led to the absorption of 38 fringe villages in and around Pune city.

4 RESULTS AND DISCUSSION

Primary Data Collected

Primary data has been collected by means of a socio-economic survey that was circulated in both software and hardware form. Printed forms were circulated and filled by people from various locations. Google form link was shared via email to people to collect responses. Social media such as WhatsApp was used to circulate the google form to various people.

The target people for this survey were strictly people living in the city of Pune under PMC from various locations.

A total of 60 responses were obtained and used for further analysis as represented in the figure 4.1,4.2.

Location	No. of responses
St. Joseph (Aundh)	16
Pashan	13
Magarpatta	12
Shivajinagar	18
NDA	1
Total	60

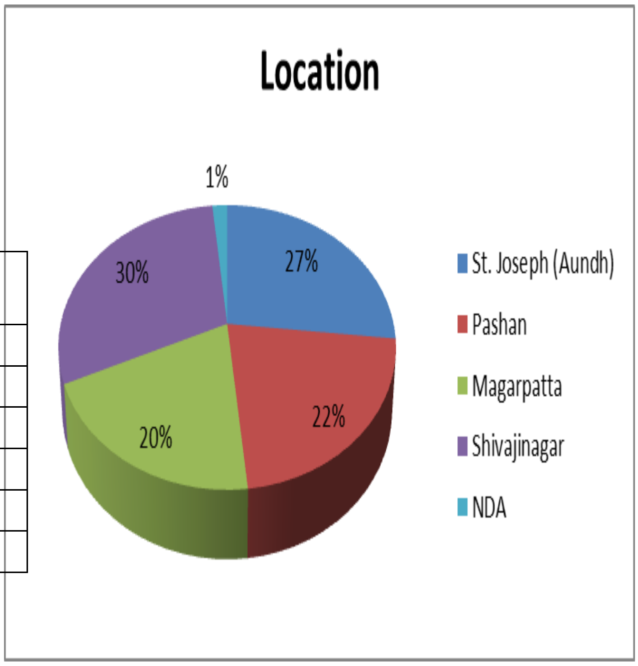


Table 4.1 Location wise Responses

Figure 4.1 Location wise Responses

Type of residence	No. of responses
Housing Society	46
Single High rise	6
Bunglow	4
Single storey flat	4

Table 4.2 Responses as per type of residences

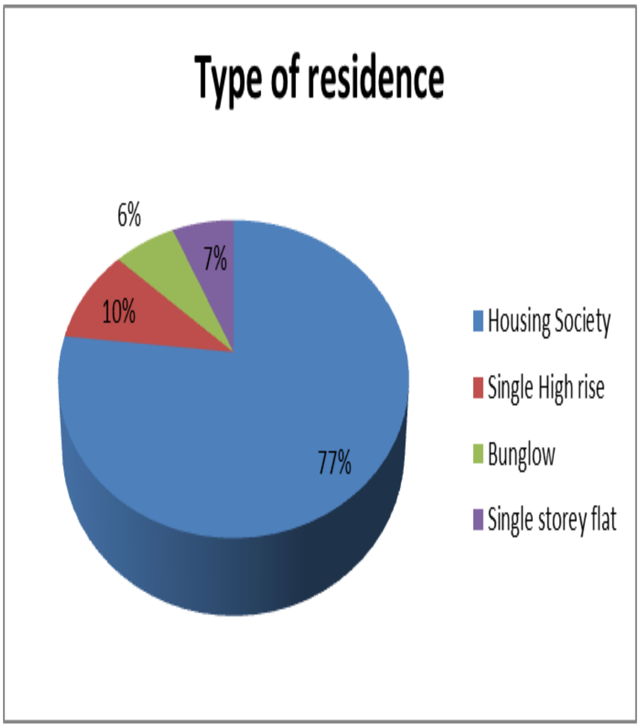


Figure 4.2 Responses as per type of residences

Based on the data collected only two locations (Aundh and Pashan) were selected for further discussion and analysis as these locations are highly affected.

Observations:

- It has been a dwelling area in Pune from a long time and is still developing. Around 30% of the people are living here for more than 10 years and another 30% of the people are new dwellers in the area.
- It is a well-developed area with demand for living here as 75% of the homes here are in housing societies. This reflects a very high population density in this area.
- However, only around 30% of the societies have rain water harvesting system installed in their Apartments.
- Water logging is not a usual occurrence in this area, however, close to 60% people experienced water logging this monsoon. 75% of the population faced various problems due to several factors.
- Approximately 20% of the area gets cleared of water logging within 24 hours whereas 40% of the area faces water logging for more than several hours.

SPSS Analysis:

Test1: To check the relation between rain water harvesting facility available or installed and experiencing water logging in the area.

Null hypothesis -There is no relation between rain water harvesting facility available or installed and experiencing water logging in that area.

Alternate hypothesis -There is relation between rain water harvesting facility available or installed and experiencing water logging in that area.

TABLE 4.10 Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Is rain water harvesting facility installed/available in your residence? * Did you experience water-logging in your area?	16	100.0 %	0	0.0 %	16	100.0 %

TABLE 4.11 Is rain water harvesting facility installed/available in your residence? * Did you experience water-logging in your area? Cross tabulation

			Did you experience water-logging in your area?		
			No	Yes	Total
Is rain water harvesting facility installed/available in your residence?	No	Count	3	8	11
		Expected Count	4.8	6.2	11.0
	Yes	Count	4	1	5
		Expected Count	2.2	2.8	5.0
Total		Count	7	9	16
		Expected Count	7.0	9.0	16.0

TABLE 4.12 Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.883[a]	1	.049		
Continuity Correction[b]	2.036	1	.154		
Likelihood Ratio	4.035	1	.045		
Fisher's Exact Test				.106	.077
N of Valid Cases	16				

Inferences:

Since the Pearson Chi-Square value for Test 1 (=0.049) is less than 0.05, hence null hypothesis is rejected and the alternate hypothesis is accepted as per above TABLE 4.12

Therefore, it is inferred that there is relation between rain water harvesting facility available or installed and experiencing water logging in an area

Test 2: To check the relation between rain water harvesting facility available or installed and time required for the water logging to subside.

Null hypothesis – There is no relation between rain water harvesting facility available or installed and time required for the water logging to subside.

Alternate hypothesis – There is relation between rain water harvesting facility available or installed and time required for the water logging to subside.

TABLE 4.13 Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Is rain water harvesting facility installed/available in your residence? * How long does it take for the water-logging to subside?	16	100.0%	0	0.0%	16	100.0%

TABLE 4.14 Is rain water harvesting facility installed/available in your residence? * How long does it take for the water-logging to subside? Cross tabulation

			How long does it take for the water-logging to subside?				
			24 - 48 hours	48 - 72 hours	Less than 24 hours	More than 72 hours	Total
Is rain water harvesting facility installed/available in your residence?	No	Count	2	4	0	5	11
		Expected Count	2.1	2.8	2.1	4.1	11.0
	Yes	Count	1	0	3	1	5
		Expected Count	.9	1.3	.9	1.9	5.0
Total		Count	3	4	3	6	16
		Expected Count	3.0	4.0	3.0	6.0	16.0

TABLE 4.15 Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.018[a]	3	.029
Likelihood Ratio	10.649	3	.014
N of Valid Cases	16		

Inferences:

- Since the Pearson Chi-Square value for Test 1 (=0.029) is less than 0.05, hence null hypothesis is rejected and the alternate hypothesis is accepted as per above TABLE 4.15
- Therefore, it is evident that relation between rain water harvesting facility available or installed and time required for the water logging to subside.

Pashan

Observations:

- It is a relatively new dwelling location for the people of Pune with around 75% people living here for less than 5 years duration in this location.
- It is a rapidly developing area with around 75% of the residences being housing societies-based data collected.
- Around 50% of the residences do not have rain water harvesting facility installed Derived from the data collected.
- This location does not usually experience water logging but 55% of the people experienced water logging this monsoon and faced various problems.
- Around 50% of the area is relieved of water logging within 24 hours whereas the other half requires more than 72 hours. This indicates absence of proper drainage system in the other half and can be relieved of this problem by providing a proper drainage system.

SPSS Analysis:

Test1: To check the relation between rain water harvesting facility available or installed and experiencing water logging in the area.

Null hypothesis – There is no relation between rain water harvesting facility available or installed and experiencing water logging in that area.

Alternate hypothesis – There is relation between rain water harvesting facility available or installed and experiencing water logging in that area.

TABLE 4.23 Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Is rain water harvesting facility installed/available in your residence? * Did you experience water-logging in your area?	13	100.0%	0	0.0%	13	100.0%

TABLE 4.24 Is rain water harvesting facility installed/available in your residence? * Did you experience water-logging in your area? Crosstabulation

			Did you experience water-logging in your area?		
			No	Yes	Total
Is rain water harvesting facility installed/available in	No	Count	1	5	6
		Expected Count	2.8	3.2	6.0

your residence?	Yes	Count	5	2	7
		Expected Count	3.2	3.8	7.0
Total		Count	6	7	13
		Expected Count	6.0	7.0	13.0

TABLE 4.25 Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.899[a]	1	.048		
Continuity Correction[b]	2.006	1	.157		
Likelihood Ratio	4.162	1	.041		
Fisher's Exact Test				.103	.078
N of Valid Cases	13				

Inferences:

- Since the Pearson Chi-Square value for Test 1 (=0.048) is less than 0.05, hence null hypothesis is rejected and the alternate hypothesis is accepted based on TABLE 4.25
- Therefore, it is clear that relation between rain water harvesting facility available or installed and experiencing water logging in an area.

Test2: To check the relation between rain water harvesting facility available or installed and time required for the water logging to subside.

Null hypothesis – There is no relation between rain water harvesting facility available or installed and time required for the water logging to subside.

Alternate hypothesis – There is relation between rain water harvesting facility available or installed and time required for the water logging to subside.

TABLE 4.26 Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Is rain water harvesting facility installed/available in your residence? * How long does it take for the water-logging to subside?	13	100.0%	0	0.0%	13	100.0%

TABLE 4.27 Is rain water harvesting facility installed/available in your residence? * How long does it take for the water-logging to subside? Crosstabulation

			How long does it take for the water-logging to subside? Less than 24 hours	More than 72 hours	Total
Is rain water harvesting facility installed/available in your residence?	No	Count	1	5	6
		Expected Count	2.8	3.2	6.0
	Yes	Count	5	2	7
		Expected Count	3.2	3.8	7.0
Total		Count	6	7	13
		Expected Count	6.0	7.0	13.0

TABLE 4.28 Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.899[a]	1	.048		
Continuity Correction[b]	2.006	1	.157		
Likelihood Ratio	4.162	1	.041		
Fisher's Exact Test				.103	.078
N of Valid Cases	13				

Inferences:

- Since the Pearson Chi-Square value for Test 1 (=0.048) is less than 0.05, hence null hypothesis is rejected and the alternate hypothesis is accepted as given in TABLE 4.28
- Therefore, it is proved that their a relation between rain water harvesting facility available or installed and time required for the water logging to subside.

5 CONCLUSIONS

The monsoon in India is the reason for India to be such a prosperous country. It is the source of huge amount of fresh water which enables farming in the country and supplies the population with fresh water to cater to all its needs. However, if this is not properly managed or the natural process is disturbed due to human activities, it can disturb the environmental balance and cause lots of problem to the human population.

Pune is a rapidly developing city with the population growing exponentially in the last decade. Owing to its location and weather, it has great potential to be a one of the major cities of the country.

This has led to rapid urbanization and immense construction activities. This has led to increase in concrete cover and reduction in percolation area. As a result, less water is able to penetrate the ground and reach the underground aquifers. This has also increased the amount of runoff generated. With runoff increasing but the storm water handling capacity being limited and constant, it has led to increased water logging in the city. Due to lower water percolation, the city is now facing water crisis every summer.

A solution to these problems is installing Rain Water Harvesting (RWH) systems. This enables rain water to be stored and either used directly or used to recharge the underground water tables. This ensures better utilization of the rain water. This also generates lesser runoffs and thus reduces the pressure on the drainage systems.

From the results obtained from tests conducted based on data collected from the people living across various locations in Pune using survey, we have been able to establish the fact that availability of rain water harvesting systems has direct impact on water logging problems and also ensures quick removal of accumulated water.

We have also observed that most of the housing societies do not have rain water harvesting systems installed. Even though the local laws mention such facilities to be installed, no proper monitoring system is in place. This has resulted in many societies to have been developed without any RWH facility installed. Even if installed, they are not properly maintained which causes their efficiency to reduce and eventually become non-functional. Strict laws with proper monitoring system and periodic audit is necessary for proper implementation of this strategy. Fines or penalties should be levied for non-compliance with such laws. Stringent measures will ensure efficient functioning of the system and the entire population can reap the benefits.

With the rapidly growing population and increasing pressure on natural resources, rain water harvesting is an efficient solution to all the water problems. Proper maintenance and implementation will ensure reaping of maximum benefits from this facility.

Remedial Measures

Authorities should make some new strategies and follow it such as:

- Clearing and protecting water Bodies from encroachment.
- Levying variable tax based on the usage.
- Cutting of subsidy for misusing and excess utilization of water.
- Strict enforcement of Rain water harvesting.
- Enacting strict law and enforcement for protecting water Bodies.
- Establishing more ETP and STP for treating wastewater and reuse.
- Creating water protection for awareness and acting against water theft.
- Providing subsidy or prize those who are implementing strategies for achieving sustainable water management.

REFERENCES

1. Magnus U. Igboekwe, Adindu Ruth, (2011), ‘Groundwater Recharge through Infiltration Process: A Case Study of Umudike, Southeastern Nigeria’, Journal of Water Resource and Protection, pp. 295-299.
2. S. Beecham & R. Fallahzadeh, (2011), ‘Innovative approaches to urban water management in developing countries’, WIT Transactions on Ecology and the Environment, Volume 150, pp. 239-247.
3. P Sundara Kumar, T Santhi, P Manoj Srivatsav, S V Sreekanth Reddy, M Anjaneya Prasad, and T V Praveen (2015), ‘Storm Water Drainage Design (Case Study Vijayawada)’ , International Journal of Earth Sciences and Engineering, Volume 08, No. 02, pp. 507-511.
4. Singhai, A., Das, S., Kadam, A.K. (2019),’GIS-based multi-criteria approach for identification of rainwater harvesting zones in upper Betwa sub-basin of Madhya Pradesh, India’. Environment Development and Sustainability, pp. 777–797.
5. Satheeshkumar, S., Venkateswaran, S. & Kannan, R. (2017) ‘Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India’, Modeing Earth System and Environment 3, pp. 24.
6. Etishree Agrawal, Rajat Agrawal, R.D. Garg and P.K. Garg, (2013), ‘Delineation of groundwater potential zone: An AHP/ANP approach’, Journal of Earth System Science 122**,** pp. 887–898.
7. Viavattene, Christophe & Scholes, L & Revitt, Michael & Ellis, Bryan. (2008), ‘A GIS based decision support system for the implementation of Stormwater Best Management Practices’.
8. Rejani, R., Rao, K.V., Osman, (2015), ‘Spatial and temporal estimation of runoff in a semi-arid microwatershed of Southern India’ in Environmental Monitoring and Assessment187**,** pp. 540.