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Analysis and Enhancement of Drainage System of Nagpur City

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***Abstract*— The city of Nagpur has been experiencing extreme waterlogging issues even when there is a small amount of rainfall. The reasons for this are the lack of drainage capacity, poor maintenance, clogging of drains with solid waste, and rapid urbanization, which causes the rainwater to accumulate on the roads in a short span of time, thereby causing traffic congestion and inconvenience to the public. The presence of water on the roads for a longer period of time can further deteriorate the condition of the road pavement material, resulting in potholes and a reduced lifespan, and also act as a breeding ground for mosquitoes, thereby increasing the chances of waterborne and vector-borne diseases. In the low-lying residential areas, the floodwater enters the houses, thereby causing damage to property, disrupting the daily life of the citizens, and posing health hazards. The situation becomes more critical during the monsoon season because of the inefficiency of the existing drainage system to handle the runoff water effectively. This paper discusses the primary reasons for the frequent waterlogging situations in the city of Nagpur and the effects it has on the citizens.**

***Index Terms*— Waterlogging, Drainage Capacity, Clogged Drains, Rapid Urbanization Impact, Traffic Congestion, Waterborne and Vector-Borne Diseases, Nagpur City.**

I. INTRODUCTION

Nagpur is one of the most important and growing cities in the state of Maharashtra, India, because of its strategic location in the country. Since the rise in the population due to migration, ["Figure 2"] the development of industries, the establishment of educational institutions, and rapid residential and commercial development over the last few decades; hence, there has been a great deal of pressure on the existing infrastructure, especially the stormwater drainage systems.

The Nagpur stormwater drainage system was developed many years ago when the level of population density, ["Figure 1 and Figure 2"] the amount of developed land, and the rain were very low compared to the present scenario. The rapid development and urbanization in the Nagpur region have also increased the level of natural sites that can be used for the infiltration of the stormwater, which has now been replaced by concrete roads, footpaths, and buildings, which results in the increased level of runoff during the monsoons. Hence, even short and moderate amounts of rain ["Table 1"] can cause an extreme level of waterlogging in the city, which has a significant negative effect on the normal functioning of the city and the provision of infrastructure and services such as housing, traffic, etc. The existing stormwater drainage system is therefore inadequate to support the amount of runoff currently being experienced.

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Some of the centers in the drainage system are capable of draining up to 40-44 mm/hour of rainfall [“Table 1”]; however, owing to the overflowing of the adjacent water bodies like lakes and nullahs, it is reduced significantly. However, the absence of a stormwater drainage system in the city of Nagpur is present in half of the city. Hence, there is a need for the implementation of traditional and technological solutions for the stormwater drainage problems in Nagpur so that the majority of the city has access to the stormwater drainage system. The primary solution would be the addition of the IoT system in the existing stormwater drainage system. The implementation and usage of the IoT technology would be very effective in mitigating the existing problems in the stormwater drainage system in Nagpur by informing the concerned authorities when the level of the water in the drainage system crosses the critical threshold, so that the situation does not become critical because of the flooding in the area because of the waterlogging. The implementation of non-IoT technology would be very effective in the implementation of the stormwater drainage system. Infiltration trenches can be effective in improving the recharge of groundwater and reducing surface runoff through the infiltration of rainwater in the soil when constructed in roadways. Buildings, structure underpasses, and low-lying areas are at a higher risk of waterlogging and hence need to be designed for low drainage efficiency, a large inlet size, and favorable conditions for the eventual removal of the water through pumps and other means (storage tanks, containers, etc.) when they are filled enough during heavy rainfall. Moreover, desilting and cleaning the drains before the monsoon season will be effective in ensuring the smooth drainage of the accumulated water from the underground.

The integration of smart IoT technology and the conventional drainage systems such as infiltration systems and the more efficiently draining underpasses, pumps, and desilting and cleaning the drains before the monsoon season will be effective in providing viable options for addressing the flooding of the underpasses in the Nagpur city. The end result will be the increase in the drainage efficiency of the existing drainage system and the focus on the more efficient and effective drainage management systems.

II. Literature Review

The water logging and drainage failure described above are common problems faced by the cities in countries where there has been rapid urbanization, especially in India, Bangladesh, and other developing nations. “et al.Ashraf”[1] The problems are not only because of inadequate hydraulic capacity but also because of inadequate planning in the urbanization process, the increase in impervious surfaces as a result of urbanization, the blockage of natural drainage channels, inadequate disposal of solid waste materials, and inadequate maintenance carried out on the drainage systems. The result of all the above factors is that the majority of the drainage systems, designed for dry weather flow, are generally flooded as a result of the peak storm flows experienced during the monsoon season. “et al.Ashraf ”[1] Several authors have highlighted the relationship between the changes in the lands and the drainage problems as a result of urbanization. For instance, studies carried out in Bhubaneswar, Srinagar, and Gondia were published and highlighted the results in the following ways: the reduction in the number of minor rivers/streams in the catchment area, the blockage of natural drainage systems, and the increase in impervious surfaces as a result of urbanization leading to the reduction in natural infiltration and drainage capacity. “et al.Shah”[2] The use of GIS and remote sensing tools/methods has helped in the mapping of areas prone to flooding, drainage systems affected by flooding, and areas where the topography causes standing water. The use of GIS and remote sensing tools has helped in the assessment of drainage systems in the city. They are more likely to be used in the analysis rather than the implementation.

A research study conducted by “et al.Atauzzaman”[3] in 2019 aimed at evaluating and characterizing drainage/waterlogging problems in Ward No 5, Pabna Municipality, Bangladesh. The results showed that although the existing sewerage infrastructure has sufficient capacity for accommodating drainage/water flow at present and in the coming years up to 2050, it lacks sufficient capacity for accommodating stormwater runoff during the monsoon season. The causes of waterlogging include vector debris, sediment buildup/seepage from adjacent land, encroachment of growth within drainage systems, and broken sewer lines, which affect around 80% of the total area annually. Although this study identified causes for waterlogging in a region, it did not offer solutions for addressing stormwater management issues in the region.

“et al.Naresh”[4] (2019) conducted a study on evaluating the extent of stormwater drainage systems in Hyderabad using StormCAD software along with rainfall records for the past 20 years. It was also identified that the results showed the drains collectors are of low capacity due to inadequate capacity, blockages, as well as some of the drain outlets and collection manholes not being aligned, thus creating a risk of overflows. Although recommendations were made regarding the redesign of the system as well as maintenance, this study was not fully focused on assessing the economic viability of the recommendations made.

In a study conducted by “et al.Patel”[5] (2017), researchers sought to examine some of the problems associated with drainage on major underpasses in Ahmedabad, India. In this study, it was established that some of these problems resulted from a poor filtration system, poor pumping ability, backflow from geographical conditions and buildings constructed around it. Although potential solutions for these problems exist in the form of a kerb drain or a more efficient pumping system, no study was conducted on whether these solutions would be beneficial in the long run or even feasible for such a drainage system.

“et al.Chintanwar”[6]Some studies conducted on drainage systems on various roads and highways concerning drainage issues have established that a well-functioning surface drainage system is required for the maintenance of a well-surfaced road or highway while at the same time preventing hazardous driving conditions on these roads. According to “et al.Mukherjee”[7], standing water on these surfaces due to a lack of proper longitudinal and transverse cross slopes, blocked side ditches, sedimentation, and lack of maintenance can lead to hydroplaning on these surfaces while at the same time damaging the pavement structure itself. There have been several recent studies “et al.Awwad”[8] primarily focused on observational/conceptual data over a fairly short period of time.

During the discussions regarding long-term mitigation strategies, many of the terms that were used to describe Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), and Water Sensitive Urban Design (WSUD) appeared many times. Many studies evaluating the performance of SUDS, LID and WSUD have been conducted. There are many opportunities for the use of permeable pavements, swales, rain gardens, infiltration trenches, recharge wells, “et al.Arifjanov”[9]and retention ponds in attenuating stormwater runoff, especially in low and moderate rainfall events; however, the studies showed that the effectiveness of this process decreases in extreme rainfall events, and the land constraints in high-density urban areas limit their use. In India, the effectiveness of stormwater drainage systems in terms of urbanization patterns, permeability, and conservation of water bodies has revealed a wide range of differences in different regions, as explained in a review article “et al.Qin, Y”[10] in 2020. Many studies mentioned in the “et al.Vishwakarma”[11] foregoing paragraph indicated that innovative stormwater facilities are an integral part of effective stormwater runoff reduction; however, a study on planning-level analysis for the sustainability assessment of stormwater drainage systems showed very little insight into the site-specific performance of stormwater drainage systems. Sustainability assessment of stormwater drainage systems in many cities in India is based on index-based ranking, and an analytical hierarchy process is also used; however, this is also limited in scope, as it is based on secondary data only.

The literature also reveals that the reason for the systems of urban drainage is failing is no longer just in the capacity of the sewers, but also in the rapid rate of urbanization, the natural drainage systems, and lack of planning and maintenance; as opposed to just the capacity of the sewers. There has been considerable progress in recent times in drainage problems using GIS-based analysis tools, hydrologic modelling tools, and sustainability evaluation tools. Most of the articles on drainage systems are directed at providing planning frameworks or engineering techniques for constructing these systems. However, there has not yet been enough research on methods to integrate different types of drainage methods including hydraulic engineering, structural techniques for controlling drainage, the pumping of drainage systems, and sustainable drainage methods into a single cohesive system. It is evident that there is still a lack of publicly available information regarding the design of integrated stormwater drainage systems that are site specific and have some real potential for operation on a sustainable basis.

III. METHODOLOGY

The methodology adopted for evaluation and enhancement of drainage facilities in the city of Nagpur comprises steps that cover issues of study and design in an IoT framework.

A. An Assessment of the Existing Drainage System

An in-depth assessment of Nagpur city's existing system of rainwater drainage will provide insight into the topography, existing capacity, age, and condition of the existing drainage systems. Waterlogged areas with little or no drainage facilities during rainy periods are also identified.

B. Waterlogging Causes

The definition of causes of waterlogging is determined by key contributing factors, which include insufficient capacity of drain systems, insufficient disposal or lack of disposal systems, siltation of drains, lack of maintenance, and rapid urbanization. The areas with the highest rate of waterlogging are found to be in low lying

areas, such as near roadways and intersections, and in densely populated areas, which will have the highest rate of waterlogging during monsoons.

C. Data Collection and Analysis

Data on rainfall, increase in population, and discharge capacity of existing drainage systems is collected from authentic or available resources for comparison with the increased rate of runoff due to rapid increase in population and decreased infiltration areas.

D. IoT-Enabled Smart Drainage System

The IoT (Internet of Things) enabled drainage system will allow us to improve the current efficiency of our drainage systems. In this system, height sensors will be installed to constantly monitor the amount of water in the drainage system, and flow sensors will be installed to constantly monitor a drop in the flow of water due to clogs in the drainage system. The data collected will be connected to a microcontroller and communication module.

E. Automated Garbage Removal System

There will be an automated garbage removal system installed in the drainage system to prevent clogging of the system with plastic, garbage, and silt. This system will ensure the free flow of storm water collected in the system.

F. Real-Time Monitoring and Alert System

The data collected will be sent to a central monitoring system. Once the height of the water collected in the system crosses a predetermined height, the relevant government authority (municipality) will receive a notification through a mobile app.

G. Evaluating Performance

The performance of the program will be evaluated based on the comparison of the water levels before and after the implementation of the program and the reduction in time as a result of stagnation of the water, discharge volume, and time.

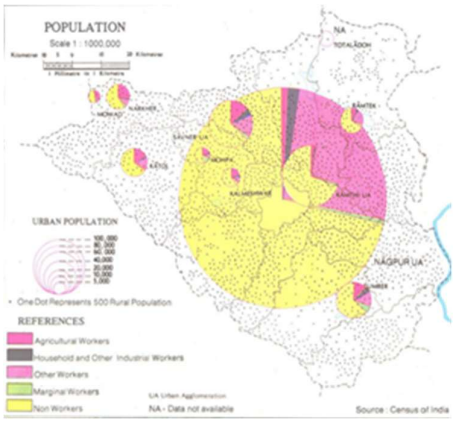

Figure 1. Urban Population of Nagpur City [12]

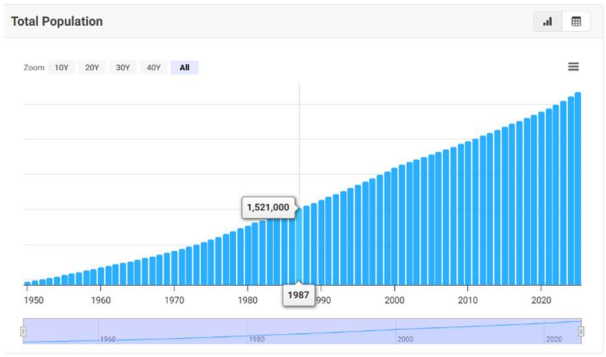

Figure 2. Census of Nagpur City [13]

TABLE I: HEAVY RAINFALL (>65 MM) RECORDED IN NAGPUR DIVISION [14]

Year	Date	Rainfall in mm
2025	08-07-2025	77.8
2025	09-07-2025	95.8
2024	20-7-2024	73.7
2024	21-07-2024	70.6

IV. RESULT

The impact of analyzing the data available on rain fall and observations indicate that the issue of water logging is becoming common in the Nagpur City even during periods when the amount of rain fall occurring is moderate or heavy. The break down of the level of precipitation over the past has shown that the most common rain levels to

be witnessed at Nagpur City are levels of precipitation at least 65 mm per day same as on the past.["Table 1"] An example of this is that two heavy rainfalls duly took place on two days in July 2025 and the amount of rain fall was 77.8 mm and 95.8 mm, respectively. ["Table 1"] In a similar vein, the rainfalls in July 2024 lasted two days in a row, and the amount of rain fall was 73.7 mm and 70.6 mm respectively. ["Table 1"] An increased rainfall by all these amounts would result in congesting the current storm water drain system in Nagpur City. The conclusions of this paper indicated that current stormwater drainage system at Nagpur City is inadequate because of the lack of sufficient size and area. In certain portions of Nagpur City, there is absence of a stormwater drainage outlet and the prevailing storm water drains are clogged by solid waste materials and also by the encroachment of the existing storm water drainage by the private establishments. Nevertheless, intersections, underpasses, and low-lying areas of Nagpur are the most critical areas where water can be trapped during the flood and remain because of its massive size.

The process of urbanization has occurred very rapidly in Nagpur. This has led to the growth of non-permeable areas and consequent decrease in stormwater! The quantity of rainfall of a specific area and the capacity of the drainage systems to take the rainfall has a significant difference and as a result, drainage systems tend to overflow thereby rendering the roadway surfaces impractical because of flood. Moreover, the effectiveness of drainage systems is diminished in terms of bad maintenance during the high monsoon seasons.

Nevertheless, to receive the benefits, the proposed IoT smart drainage system can yield such benefits as timely monitoring of the water level in the drainage systems, timely warning of potential clogging (or ground saturation), an opportunity to take immediate actions by interested authorities, and a shorter period during which the roadway surfaces will be flooded (or waterlogged). Besides the gains accessed by the means of smart monitoring systems, automatic systems of garbage removal at drainage junctions can be of great advantage in reducing clogging in drainage systems, as well as improve the movement of water in drainage systems. Infiltration trenches, drainage system upgrading to support underpasses, pumps are also some of the examples of supporting systems to a smart monitoring system.

V. Conclusions

The authors deduced that the lack of capacity of the drainage system, inappropriate maintenance of the drainage system, obstruction of the drainage system by solid wastes, absence of natural drainage channels and the high rate of urbanization are many of the factors that make the Nagpur City confront the problem of waterlogging. The current drainage system which was to be used during moderate rainfalls has not had the capacity to cope with moderate and even heavy rainfalls because of the elevated rainfalls; there is therefore a necessity of improving the current drainage system. Flooding in the urban area may be disastrous due to the amount of rainfall (more than 65 mm/day). According to the results, the current drainage system should be improved to address the urban flooding issues. The suggested solution, requiring the utilization of real data by means of the IoT devices, garbage collection by means of automated devices, and the improvement of the usual drainage system, is a long-term solution that may be implemented to address the issues with the drainage system in the City of Nagpur. This could be utilized in the effort of minimizing the impacts of flooding by using technology and planning to maintain the systems, and this would be extremely useful by the Nagpur and other urbanizing cities infrastructure in the maintenance of the drainage systems as well as the provision of early warning and intervention to the drainage systems through the use of enhanced monitoring systems in the management of drainage systems.

References

[1] Ashraf, M. A., & Chowdhury, M. S. A. (2009). Drainage planning in the cities of Bangladesh: Case study of drainage and water logging in Chaktai Commercial Area, Chittagong. Journal of Bangladesh Institute of Planners, 2, 49–60.

[2] Shah, B., Bhat, M. S., Alam, A., Sheikh, H. A., & Ali, N. (2023). Impact of urban growth on the natural drainage network of the Srinagar city. Urban Water Journal.

[3] Ataузzaman, M., Uddin, M. R., & Barman, N. R. (2019). Drainage and water logging in Pabna Municipality of Bangladesh: A case study. Journal of Civil, Construction and Environmental Engineering, 4(6), 100–106. https://doi.org/10.11648/j.jccee.20190406.12

[4] Naresh, A., Naik, M. G., & Nagalaxmi, G. (2019). Analysis of existing stormwater drainage system for central zone of Hyderabad city using StormCAD. E-Proceedings of the 38th IAHR World Congress, Panama City, Panama.

[5] Patel, K., Patel, R., Patel, K., Trivedi, K., & Patel, D. M. (2017). Storm water drainage for underpass. International Journal for Innovative Research in Science & Technology (IJIRST), 3(9). https://www.ijirst.org/articles/IJIRSTV3I9005.pdf

[6] Chintanwar, Y., Burde, P., Lanjewar, P., Sukhadeve, S., Akanpalliwar, S., Gadap, S., & Parkhi, A. (2024). Analysis of storm water drainage system for bridge underpass. International Journal of Research Publication and Reviews, 5(4), 508–512.
[7] Mukherjee, D. (2014). Highway Surface Drainage System & Problems of Water Logging in Road Section. International Journal of Engineering and Science (IJES), 3(11), 44–51
[8] Awwad, M. (2021). Studying the effects of roads geometry and design parameters on the pavement drainage system. Civil Engineering Journal, 7(1), 49–58.
[9] Arifjanov, A., Samiev, L. N., Abdulkhaev, Z., Abduraimova, D., Yusupov, S., & Kaletová, T. (2022). Model of urban groundwater level management in drainage systems. Acta Hydrologica Slovaca, 23(2), 172–179.
[10] Qin, Y. (2020). Urban flooding mitigation techniques: A systematic review and future studies.
[11] Vishwakarma, R. K., Joshi, H., & Goonetilleke, A. (2023). Sustainability Evaluation of the Stormwater Drainage System in Six Indian Cities. Sustainability, 15(20), 14906.
[12] "Survey of India," *Government of India*: https://www.surveyofindia.gov.in/
[13] "Population of Nagpur," *Maps of India*: https://www.mapsofindia.com/nagpur/population.html
[14] "Previous Year Rainfall Data," MahaRain: https://maharain.maharashtra.gov.in/test/maharain/previous_year_rain.php