International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Urban Metabolism of Water Supply System in Pune, India Using Material Flow Analysis

Ashish Kelkar

The Neo Urbanism Planners and Designers, Wrangler Paranjape Road, Pune 411004, India
Email: *neourbanism7[at]gmail.com*

Abstract: ***Urban metabolism analysis, an essential tool in urban planning, helps in analysing the resource management of cities and the study of urban ecosystems. Large amounts of uncontrolled resource input, such as water, energy, food, and fresh air, within cities, along with their linear urban metabolism, result in unhealthy urban systems. The study analyses the urban metabolism of water resources in Pune, India. The data was gathered from secondary sources, which include existing literature such as reports, research articles, and papers. Then, using STAN 2.7 software, material flow analysis (MFA) was performed to understand the balance between water supply inputs and outputs. Research results show how much water was wasted and how much was recycled in Pune city, giving a clear picture of its urban metabolism. Thus, a conceptual framework was developed and discussed for the water supply system of Pune city. Furthermore, recommendations to improve the sustainability of water resource management in Pune were discussed, which would help in achieving the UN's Sustainable Development Goals. Goal No. 6: Clean water and sanitation for all.***

Keywords: Urban Metabolism, Resource Management, Material Flow Analysis, Pune City

1. Introduction

The population in Indian cities is growing exponentially; therefore, it has become important to understand their urban metabolism to make them sustainable for future generations. In most pragmatic terms, urban metabolism is the quantification of the inputs, outputs, and storage of energy, water, nutrients, materials, and waste for an urban region. It has been extensively used since the last decade for various types of analyses in urban planning [1]. The urban metabolism model also facilitates the description and analysis of the flows of materials and energy within cities, such as in a material flow analysis. For the study purpose, material flow analysis is conducted for the water resources of Pune city. Pune, with a population of more than 3 million according to the 2011 census, is one of the fastest-growing cities in India and the second largest in the Maharashtra state of India, next to Mumbai. It is a centre for education and the cultural capital of the state [2]. Due to booming IT sector companies in the city and increasing demand for water, available resources are falling short. Considering its strategic location close to the commercial capital of India, Mumbai, and its geographical settings, the city is unique for research purposes. Following are the aims and objectives of the research:

Aim

1) To examine the urban metabolism for the water supply system in Pune city using material flow analysis.

Objectives:

1) To understand how much untreated water is sent back to the river, leading to water contamination.
2) To study the institutional framework and policies for water conservation that have been adopted in Pune city and maximise the amount of treated water given back into the system for reuse.
3) To recommend improvements in existing policies that would help in sustainable water management in Pune.

2. Literature Review

Globally, it is recognised that there is a water crisis due to a rise in population, high water demand, and shrinking resources for supply. It is getting worse because of socio-political and institutional factors and is posing a threat to the societies and economies of future generations. Factors contributing to poor water management include bad governance, a lack of political will, and economic incentives for developing the infrastructure needed. Also, water used for construction and agriculture causes water scarcity for the portable water used in households. Climate change is another factor that influences water management, and events such as heat waves and droughts occur in urban and rural areas. Moreover, land-use and land-cover changes in the characteristics and patterns of precipitation and evaporation have a significant impact on the balance of water supply and demand [3].

As discussed above, there are some visible environmental changes that have occurred globally in the last few decades, and due to increasing population density in urban areas, there are challenges in maintaining the balance of basic resources such as food, air, water, and hygiene in these areas. In Pune, which is gifted with an ample amount of natural water resources, they are not yet fully organised and managed, and this is due to lifestyle changes of the users that increase per capita demand for water. Also, due to urban sprawl and industrialization, the water sources are falling short and are affecting the groundwater table adversely. It has been estimated that if such urban growth continues in Pune, then there will be an acute shortage of water in the near future. At present, the city administrators are not very keen on bringing awareness amongst citizens about rainwater harvesting systems and storm water management systems, which is creating problems of flooding in monsoon season and water scarcity in summer [4].

“Pune city is blessed with surface water sources; the city is drained by the Mula and Mutha rivers and their tributaries.

Mulshi dam is the major dam on the Mula river, while Temghar and Khadakwasla dams are built on the Mutha river. Khadakwasla Dam is one of the main sources of water for Pune city and its suburbs, which is fed by two upstream dams, Panshet and Varasgaon. In addition to this, there are many lakes located in Pune city; some of them are Katraj Lake, Pashan Lake, Mastani Talav, etc." [5]. On an optimistic note, under the 2025 master plan of Pune, suitable sites for sewage treatment plants (STPs) are marked alongside rivers that favour decentralisation of the STP system. At present, 65% of the wastewater is treated in Pune, and according to the master plan, this capacity would fulfil all the 100% treatment of wastewater. Thus, due to reduced water pollution, it is expected that flora and fauna will reappear and there will be fish in the riverbed, which will enhance the river water ecosystem [6].

3. Materials and Methods

To improve and promote policies regarding sustainable resource management, high-quality information on material flow is required that provides an understanding of the natural resource basis of the country's economy. In most of the countries, intense monitoring of their labour and capital productivity and their energy efficiency is done. However, this information is not sufficient to give an overview of the material flows such as minerals, metals, energy, timber, and water that have been extracted through processing, consumption, and recycling to final disposal, which helps in providing data regarding economic productivity and the quality of the environment. To overcome this knowledge gap, Material Flow Analysis (MFA) is the most useful tool that guides decision making based on statistical approaches, and its principles date back to the 1970s. Currently, there has been good progress in developing methodologies for MFA, with varying stages of development in different countries to increase its use in practical applications [7].

Therefore, in this study, to understand the urban metabolism of the water supply system of Pune city, MFA was conducted using the freeware STAN 7.2, a balancing and visualisation tool for material flow analysis of goods, substances, and energy, which considered data uncertainties through error propagation, data reconciliation, and gross error detection. STAN 7.2 can be used for both static- and quasi-dynamic analysis and allows studying a system on several levels of detail via the introduction of subsystems [8]. In this study, the data for the research was collected from government reports and published papers online. The MFA was performed for the Pune Municipal Corporation (PMC) limit of the city with 23 merged villages. The data was static and measured in 2012, referring to census data from 2011. This was because after 2011, there was no census being prepared in the country, which can be considered a limitation for the availability of the data. However, based on the Pune Master Plan 2025 prepared by the Pune Municipal Corporation, policy recommendations to reduce environmental degradation and improve water resource management were discussed in conclusion. The following steps were conducted to perform MFA for the water supply system in Pune:

Step 1: The data regarding how much water is made available in Panshet, Varasgaon, Temghar, and Khadakwasla dams and how much water is supplied to Pune city, including water losses in the process, was extracted from the PMC report.
Step 2: Data regarding the number of sewage treatment plants and their capacities was then extracted from the PMC Report.
Step 3: The quantity of water treated from the STP and given back to the water supply system of Pune city for agricultural use, gardening, flushing, and release into the Mula-Mutha riverbed was then extracted from the PMC report.
Step 4: The quantity of water that was left untreated and polluting the Mula-Mutha river was extracted from the PMC report.
Step 5: All the data was validated from other reliable secondary sources.
Step 6: All the data was then converted into $m^{3/}$day for the calculations to be done in STAN 7.2.
Step 7: A graphic data presentation of the water supply system of Pune city, established from STAN 7.2, was presented in the Results section.
Step 8: A detailed water supply system for the Pune city framework was prepared, including all the details of its a) water supply and consumption patterns, b) untreated water and runoffs, and c) treated wastewater.

4. Results

As discussed in the methodology section of the paper, all the steps for extracting the data were followed. MFA for Pune's water supply system was conducted using STAN 7.2, and the data was derived from PMC reports and validated by other secondary sources. There are three ways in which water is recycled in Pune city: discharge of treated water by the Water Resources Department (WRD), reuse of treated STP water for nondomestic use from STPs installed by private entities, and reuse of treated STP water for agriculture use from public STPs. [9],[10],[11]. Following are the values for the water supply, water recycling by different sources, and the untreated water released in the Mula Mutha river:

Table 1: Water supply calculation data in M^3/day for STAN 7.2, material flow analysis [9],[10],[11].

Description	*M^3*	*M^3 / Day*	*Percentage*
Water in the Dam Le	824,568,573	68,714,048	-
Actual Water Supplied for use	**325,643,736**	**27,136,978**	**100%**
Discharge of Treated Water by WRD	184,059,503	15,338,292	57%
Reuse of treated STP water for nondomestic use from STPs installed by private entities	4,020,000	335,000	1%
Reuse of treated STP water for agriculture use from public STPs	22,795,062	1,899,588	7%
Total Water Recycled	**210,874,564**	**17,572,880**	**65%**
Untreated water Released in the river	**141,584,233**	**11,798,686**	**35%**

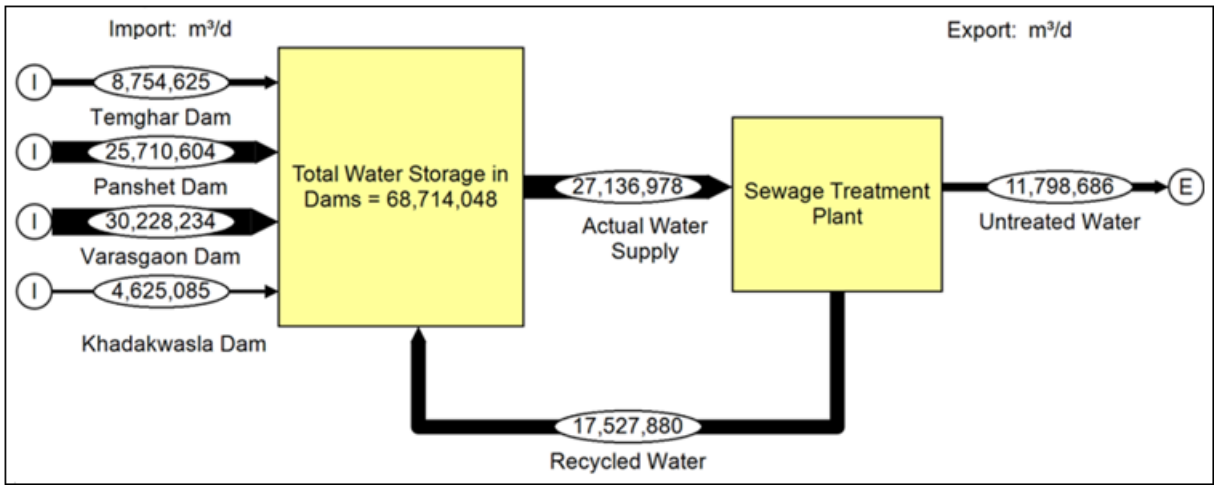

Figure 1: Material flow analysis for water supply system in Pune city derived from STAN 7.2.

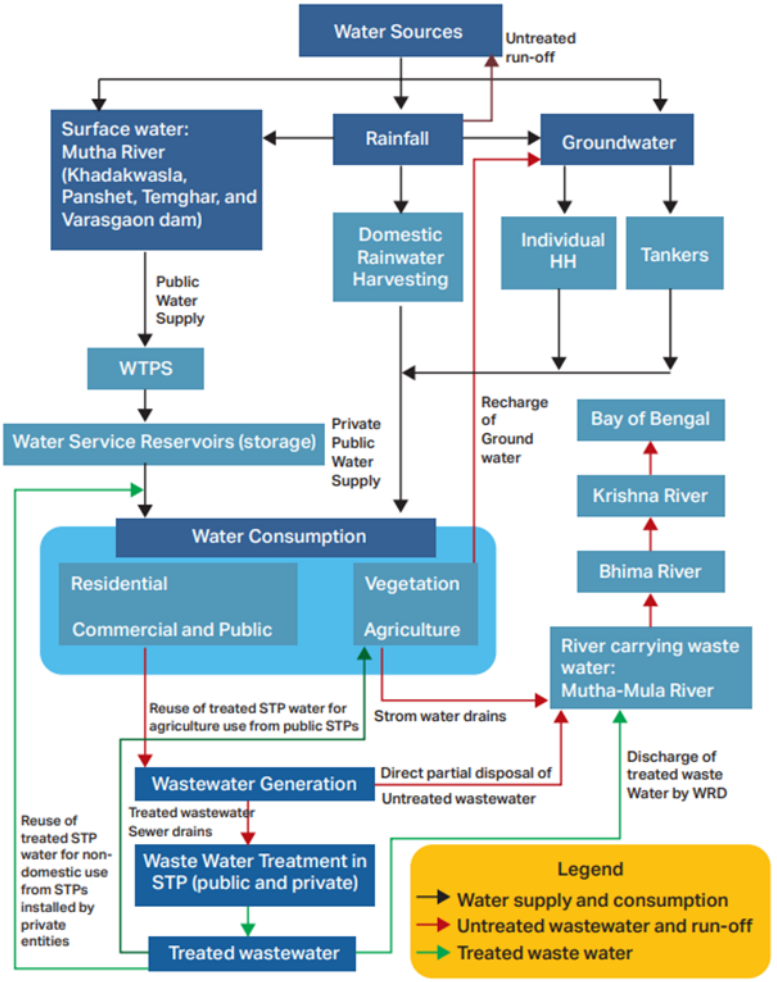

Figure 2: Framework for water supply system in Pune city [11]

In sum, the urban metabolism of the water supply system in Pune city is thus presented here in a schematic diagram that explains how Pune city gets its water supply from different resources. What are the ways that it gets treated using different methods? What are the ways in which the recycled water is used and given back to the system? And finally, how does it get discharged? The MFA gives the percentage value of each, and these findings help to give an overview of the water supply system in Pune city, and based on that policy, recommendations about how water can be used more sustainably are derived and discussed in the discussion and conclusion sections of this paper.

5. Discussion

As per the results of this research, in Pune city, only 65% of the wastewater is treated and given back into the water supply system, and 35% of the water is untreated and is polluting the Mula Mutha rivers. The river gets polluted due to dangerous chemicals, waste, plastic, and other pollutants from human activities. They have an adverse effect on the environment and the health of the citizens. This water pollution should be mitigated with planning, legislation, and policy intervention by the government. There have been some efforts made earlier in this regard, which are discussed below and cover the

aim and objectives mentioned in the introduction section of this paper.

1) Legal Provisions and Acts:

At the national level, there are no legal provisions specifically for urban sanitation. However, there are several legal provisions for sanitation at a broader level. As per the 12th schedule of the 74th Constitutional Amendment Act of 1992, planning and delivery of urban services lie with the local municipalities or urban local bodies. As per this amendment, urban services related to water, environment, and health include water supply for domestic, industrial, and commercial purposes; public health; sanitation; protection of the environment; and promotion of ecological aspects [12].

Some comprehensive regulating agencies, such as the Water (Prevention and Control of Pollution) Act, 1974, are responsible for keeping a check on water pollution and are active in both centre and states. These agencies and control boards check if there is any sewage or pollutants discharged in the water bodies and lakes and are responsible for stopping such activities [12].

At a detailed level, the Environment (Protection) Act, 1986, is responsible for controlling the release of pollutants such as untreated sewage into the environment. Under this act, there are certain norms and standards that every establishment, agency, or individual must fulfil for effluent release from STPs and pay water cess under the Water Cess Act, 1977 [12].

2) Policies and Guidelines

The National Environmental Policy (NEP) of 2006 builds on the various earlier policies that addressed the environment's challenges and need for sustainable development prior to this policy. One of the objectives of this policy is to protect and conserve critical ecological systems and resources [12].

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is aimed at providing basic services (e.g., water supply, sewage, and urban transport) to households and building amenities in cities to improve the quality of life for all, especially the poor and the disadvantaged [12].

National Urban Sanitation Policy (NUSP), 2008: Aim to transform all urban areas into community-driven, totally sanitised, healthy, and liveable cities and towns, ensuring and sustaining good public health and environmental outcomes for all citizens [12].

3) Issues and Challenges

Insufficient services and frail administration organisations and approaches have continued to be the problem areas for water supply and sanitation in India and need an improved organization. However, a few organisations are executing appropriately, even though there is poor support, tainting, or consumption of water resources [14]. "Inadequate institutional performance, a lack of appetite for reforms, and ineffective implementation of existing provisions have affected the performance levels of water supply in both rural and urban contexts. Besides the institutional challenges, other factors affecting water supply in India include political will, environmental sustainability (including climate change), social dynamics, technological appropriateness, and economics. In spite of a sizeable water resource base and vast land resources, India continues to struggle to meet its drinking water requirements" [13].

4) Opportunities

To turn the above-stated challenges into opportunities, system changes are required in the development framework. A decentralised approach with a public participation governance model for better administration would be an appropriate strategy for this. Other water management strategies may include 'Integrated Water Resources Management (IWRM)', which would systematically alter the events of water and land assets to augment financial, social, and government assistance without compromising on indispensable ecological and environmental systems. There is a global change in the approach to water management, and IWRM has become a more recognisable choice than traditional division by region and hierarchical organisational style [14].

6. Recommendations

1) The policies should not only include controlling and putting a check on water pollutants from domestic, industrial, and commercial units but also work at the grass-root level by effectively promoting rainwater harvesting, reduction, reuse, and recycling of water.
2) They should include a mix of incentives, such as rebates on bills and property tax, and penalties for non-compliance.
3) By giving subsidies on rainwater harvesting systems to domestic, industrial, and commercial units, the number of users can be increased. Water bill savings should be rewarded.

7. Conclusion

Water is a key factor in supporting a growing population in cities, and it has to not only cater to the existing population in the city but also the migratory and floating population. In Pune city, people migrate to the city in search of education, jobs, work, and proper earnings, and this growth is uncontrolled. Thus, the urban metabolism of the water supply system in Pune city reveals that the existing infrastructure for the water supply system in Pune city is under great stress, and it becomes difficult to maintain ecological balance, resulting in the failure of the policy structure. This paper discusses the institutional policy framework at the national level and the roles and responsibilities of the local municipality. From this study, it is concluded that the water supply system in Pune city is poorly managed at various levels of state, industry, surface runoff, lack of floodwater management, lakes, and river basins. Also, from the MFA, it is noted that only 65% of the water is treated and given back to the system, and 35% of the water remains untreated and is released into the Mula Mutha River, making it contaminated. Therefore, stricter policies should be framed by the government and followed by industries and other wastewater management agencies. Moreover, a number of STPs should be built and managed to accommodate the large influx of wastewater, and municipal authorities should generate funds for that on a priority basis. If we have to make our future secure, we have to preserve water, as it is an important candidate in domestic, industrial,

and commercial units and respect UN's sustainable development goal number 6: clean water and sanitation for all.

References

[1] Kennedy C, Pincetl S, Bunje P. The study of urban metabolism and its applications to urban planning and design. Environmental pollution. 2011 Aug 1;159(8-9):1965-73.
[2] Mundhe NN, Jaybhaye RG. Chronological development of Pune from 758-2014 AD. International Journal of Environment, Ecology, Family and Urban Studies. 2017;7(5):33-50.
[3] Ricart S, Villar-Navascués RA, Hernández-Hernández M, Rico-Amorós AM, Olcina-Cantos J, Moltó-Mantero E. Extending natural limits to address water scarcity? The role of non-conventional water fluxes in climate change adaptation capacity: A review. Sustainability. 2021 Feb 25;13(5):2473.
[4] Sudarsan JS, Harshavardhan H, Jyothi Priyanka Reddy K, Karun M, Ayushi A, Varma SC, Kumkumwar R. Review on the status of water management practices in Pune city. In AIP Conference Proceedings 2022 Sep 30 (Vol. 2515, No. 1). AIP Publishing.
[5] Urban Waters. Urban Waters Pune [Internet]. 2024 [cited 2024 June 17]. Available from: https://urbanwater.in/cities/pune.
[6] Tirthkar SN. Master plan 2025 of Pune Municipal Corporation for sewage treatment and disposal. J Inst Public Health Eng. 2009;2:13-9.
[7] OECD O. Measuring material flows and resource productivity. The OECD guide. 2008;1.
[8] Tanzer J, Rechberger H. Setting the common ground: a generic framework for material flow analysis of complex systems. Recycling. 2019 Jun 4;4(2):23.
[9] Barringer J. Urban domestic and commercial water reuse in Pune and its influence on the present water crisis. Water Quality, Exposure and Health. 2014 Jun;6:35-8.
[10] Pune Municipal Corporation. Revised city development plan for Pune – 2041 [Internet]. 2024 [cited 2024 July]. Available from: https://pmc.gov.in/informPDF/CDP/2_CPD_Physical_Social_Infra.pdf
[11] The Energy and Resources Institute. Water Sustainability Assessment of Pune [Internet]. 2021 [cited 2024 July]. Available from: https://www.teriin.org/sites/default/files/2021-06/Water_Sustainability_Assesment_%20of_Pune.pdf
[12] Climate centre for cities: National Institute of Urban Affairs. Wastewaters recycle and reuse: Training manual [Internet]. 2022 [cited 2024 July]. Available from: https://niua.in/c-cube/sites/all/themes/zap/pdf/WWRR.pdf
[13] Cronin AA, Prakash A, Sridhar P, Coates S. Drinking water supply in India: context and prospects. Indian water policy at the crossroads: Resources, technology and reforms. 2016:49-71.
[14] Rathee RK, Mishra SK. Water Policies in India: A Critical Review. Indian Journal of Science and Technology. 2021 Dec 26;14(47):3456-66.

Author Profile

Ashish Kelkar received the B-Arch. Degree in Architecture from Pune University and M.A. Degrees in Town and Country Planning from University of West of England in 2001 and 2017. He is the sole proprietor of The Neo Urbanism Planners and Designers with over 22 years of Experience.