

Evaluating Urban Hydrological Performance: Insights from a Metabolic Flow Analysis of Panchkula City

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Abstract

This study employs an urban metabolism approach to evaluate the hydrological sustainability of Panchkula, India. By framing the city as a living system, the research moves beyond conventional sectoral analysis to map the full cycle of water flows: from direct consumption and decentralised extraction to virtual water embedded in trade. A mixed-method design was used, combining municipal, environmental secondary data with primary surveys covering 500 households across diverse socioeconomic groups/activity uses, for the year 2024–25. A custom Excel-based toolkit enabled metabolic flow analysis and calculation of sustainability indicators. The metabolic diagnosis reveals that urban system is under acute stress. Total annual water demand is 66.47 million cubic meters (MCM), with agriculture accounting for 63% and domestic use 32%. Striking inequities exist: “real” domestic demand is 130 litres per capita per day (lpcd) in formal housing versus 46.5 lpcd in slums. Groundwater meets 74.3% of total demand, but extraction exceeds natural recharge by 205%, creating annual deficit of 46.09 MCM. Centralised supply covers only 40.3% of demand and suffers 39% distribution losses. Despite 40.8 MCM of annual rainfall, storage deficiencies render most of it as unutilized runoff. The city imports 70% of its centralised supply, and its total water footprint (636.7 MCM) is dominated by green virtual water from food imports (69%), underscoring deep external dependency. These quantitative flows—inputs, stocks, losses, and outflows—highlight systemic inefficiencies. Transitioning to a circular metabolism is essential. Key interventions include rainwater harvesting, reduction of distribution losses, wastewater reuse, groundwater regulation, and crop adjustments.

Keywords

Groundwater, hydrological performance indicators, mass balance, urban metabolism, urban sustainability.