www.water-alternatives.org Volume 14 | Issue 3

Tiwale, S. 2021. Number narratives of water shortages: Delinking
water resources development from water distribution in Mumbai, India.
Water Alternatives 14(3): 841-865

Number Narratives of Water Shortages: Delinking Water Resources Development from Water Distribution in Mumbai, India

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ABSTRACT: This paper examines the numbers associated with the water demand estimation process followed for the city of Mumbai, particularly focusing on the per capita water supply standard. The per capita standard is a critical figure for the planning, design, and operation of the entire urban water supply system from dam to household level tap. Historically, high per capita standards were consistently prescribed for Mumbai to overestimate water demand and construct number narratives of water shortages. These narratives were successfully used to appropriate a larger share of water by justifying a series of dams and keeping other urban centres and villages within the region water deprived. In colonial and post-colonial times Mumbai always received enough water, brought using higher per capita standards. However, these supply standards were never measured and monitored during actual service delivery within the city. The water demand of poor slum residents was overcounted by following universal per capita standards when bringing water to the city. However, the same slum residents were subtracted or underserved during actual service delivery. Analysing colonial and post-colonial practices of water resources development, this paper illustrates the limitations of the existing approach of water demand estimation using the prescribed per capita standard, which delinks the process of water resources development from water distribution within the city. The prescribed per capita standard does not reflect the conditions of access and status of supply provisioning and underplays the issues pertaining to the poor performance of the distribution network, which further marginalises the urban poor.

KEYWORDS: water demand estimation, water supply, standard, narratives, Mumbai, India

INTRODUCTION

> *We have calculated the domestic demand considering the norm of 240 litres per capita per day as suggested by Chitale Sahib.*
>
> Deputy Hydraulic Engineer, Municipal Corporation of Greater Mumbai (MCGM)[1]

This was the response of the Deputy Hydraulic Engineer of the Water Supply Department of the Municipal Corporation of Greater Mumbai (MCGM) when asked about the per capita water supply standard followed by Mumbai.

[1] Statement made by the Deputy Hydraulic Engineer at the Water for Slum Dialogue Forum organised as part of the Mumbai Water Distribution Improvement Programme (M-WDIP) by the MCGM on 1 March 2016.

In a benchmark report produced in 1994 titled 'Report of the Expert Committee (Water Planning) on Bombay's[2] Future Water Resources and Improvement in Present Water Supply Scheme' the Expert Committee under the leadership of Dr Madhav Chitale recommended the provision of 240 litres per capita per day (lpcd)[3] to citizens of Mumbai for domestic use alone (Expert Committee, 1994). Dr Chitale, winner of the prestigious Stockholm Water Prize, former Secretary of the Ministry of Water Resources (the highest post an engineer can hold in the Central Government of India), a highly influential figure in the Indian water sector and known for his technical and administrative knowledge, was asked to chair the Expert Committee to prepare a long-term plan for the development of water resources for Mumbai. Indeed, such is the respect for Dr Chitale among the engineering fraternity that even in his absence the Deputy Hydraulic Engineer referred to him as *sahib* – a term used since the colonial period to show respect to the master.

The Expert Committee forecast that Mumbai would face a water shortage of 2507 million litres per day (MLD) in the year 2021. To mitigate this it recommended the construction of four large dams for the city: Middle Vaitarna, Kalu, Gargai and Shai. Subsequently, the Expert Committee's report was accepted by the Government of Maharashtra (GoM) and the prescribed per capita supply standard of 240 lpcd was used further, while projecting a demand of 5940 MLD for 2041. This demand figure was used to justify three large-scale water resources development projects, including the Gargai and Pinjal dams and the Damanganga-Pinjal river-linking project. The projected water demand figures played a crucial role in securing more water for Mumbai in the region and justifying these multiple dam projects.

It has been long standing global practice that dams and other large water infrastructure projects are assessed for their environmental impact and socio-economic consequences in addition to exploration of their material, ideological, technical, political and cultural dimensions (McCully, 2001; Nüsser, 2003; D'Souza, 2014; Tilt et al., 2009; Kaika, 2006). Studies have shown how hydraulic missions and associated hydrocracies perceive dams as symbols of national pride, the developmental state, modernisation and the conquest of nature, paving the way for regional and economic development (Molle et al., 2009; Baghel, 2014; Baghel and Nüsser, 2010; Nüsser, 2003).

Notwithstanding the debate on the environmental and social implications of dams, cities around the world are increasingly dependent on them for water supply. As cities grow due to urbanisation they depend more and more on large, distant reservoirs. Significantly, it is evident that the increased use of reservoirs assures a higher level of per capita supply to cities (Mukherjee et al., 2010). A global survey of large cities indicates that around 75.5% of urban water comes from surface water sources and around 78% of the urban population primarily depends on surface water to meet their daily demand. Around 12% of the world's large cities use inter-basin transfers to quench their thirst (McDonald et al., 2014). As per the World Commission on Dams report, 12% of large dams are for water supply (WCD, 2000). Moreover, as illustrated in this paper, large cities like Mumbai have continuously engaged in planning, designing, and constructing dams throughout their history to meet demand.

Despite such heavy dependence on water-supply dams and their catalytic impact on the process of urbanisation, dams have received little attention from urban geographers and urban political ecologists (Kaika, 2006; Mukherjee et al., 2010). Water-supply dams have been studied in relation to the distribution of water within cities and their connection with end users (Tiwale et al., 2018) in addition to their social and environmental impacts, including that of rural-urban water transfer (Punjabi and Johnson, 2018). These analyses and discussions are based on a premise of acceptance of the proposed dam project as one of the options in meeting cities' current and future water demand as calculated by experts, yet rarely do they question how the dams are planned, designed, prioritised, justified, financed or commissioned to appropriate water from the hinterland.

[2] The city of Bombay was renamed Mumbai in 1995. For the purposes of consistency I refer to it as Mumbai throughout this paper, wherever possible.

[3] The other water uses, including industrial and commercial uses and leakages and losses, were calculated separately.

Drawing on the concept of technopolitics, defined as 'the strategic practice of designing or using technology to constitute, embody, or enact political goals' (Hecht, 2001: 256), this paper looks at how numbers have been used consistently throughout history to justify dam projects that appropriate a larger share of water from the neighbouring region. It shows how the process of estimating water demand, which is generally seen as complex, yet natural and apolitical, is in fact modified by prescribing higher values of per capita standard. Scrutinising the process of calculating the thirst of the city is essential as it determines the number of dams and their size, the number of villages to be displaced and households to be rehabilitated, hectares of forest and sensitive ecosystems to be drowned in the hinterland, and the long-term impact of such large water transfers to the city on the socio-economic development of catchment inhabitants.

Water in the urban agglomeration

Urban scholars have critically examined differentiated conditions of water access and the inequitable distribution of water practised spatially and temporally within cities in the global south (Björkman and Harris, 2018; Truelove, 2018; Gandy, 2008; McFarlane and Rutherford, 2008; Boakye-Ansah et al., 2016; Ahlers et al., 2014). These studies have identified the role of multiple factors, including power relations, class, ethnicity, land tenure, political patronage, global and regional processes of economic and political reconfiguration and the materiality of networked infrastructure, in shaping inequitable flows in the city (Tiwale et al., 2018; Murthy, 2012; Swyngedouw, 1997; Anand, 2011; Graham and Marvin, 2001; Alda-Vidal et al., 2018; Tiwale, 2019). However, little attention has been paid to the processes of water distribution occurring among multiple municipal corporations, councils, industrial townships and villages within a large urban agglomeration, especially where the water supply is governed and managed in a fragmented manner.

Studying processes of water distribution within urban agglomeration involves asking many questions. For example, do urban centres within large agglomeration manage their water demands independently or in collaboration with each other? Do they compete or cooperate when it comes to accessing scarce water resources? What is the nature of their relationship with each other in the context of water? What does the process of allocating water resources involve and how equitably is water apportioned among different urban centres? What is the historical trajectory of water sharing among urban centres within urban agglomeration? As noted by Sivaramakrishnan (2014), these aspects are largely related to metropolitan governance, which itself is a very complex issue for urban agglomerations in India.

This paper initiates the process of exploring some of these aspects of water in the urban agglomeration of the Mumbai Metropolitan Region (MMR). Mumbai's water supply has been studied at greater depth, exploring its multiple aspects, including access, equity and quality within the municipal boundary (Contractor, 2012; Subbaraman et al., 2013; Anand, 2011; Gandy, 2008; Wissink, 2013) and the relation with its distant hinterland (Anand, 2017). This paper focuses on the development of water resources for Mumbai in the context of a larger metropolitan area with specific emphasis on investigating how numbers are used to capture and secure a larger share of the resources for the city, resulting in the inequitable distribution of water in the MMR.

The per capita water supply standard in urban water supply

Urban water demand is determined by several factors, including population growth, the extent of industrialisation and commercialisation, technological advancement and changing behavioural patterns. All these factors have their own unpredictable trends (Trifunovic, 2006; Mays, 2000). Often, the demand-supply gap is measured by comparing the water supply capacity with the estimated water demand, the latter being calculated by multiplying the population by a per capita water supply standard. This approach frames water supply as a 'quantity' issue (Maria, 2008) and demands the development of newer water resources as a logical solution supporting a 'supply-side hydrology' (D'Souza, 2003) or a 'state-hydraulic' paradigm (Bakker, 2005).

Therefore, both the per capita supply standard used by experts and the water demand estimation process require critical attention. Based on the numbers, a time-bound strategy for the development of water resources, along with the conveyance system to carry water from the source to the city, is planned and subsequently executed. The per capita supply standard is also used within the city to determine the size of water treatment plants, multiple storage reservoirs, service reservoirs, transport mains, pumping stations, secondary and tertiary distribution systems and in-house plumbing. Aside from the network infrastructure and associated capital investment, the per capita supply standard followed by a utility determines the operational cost of the water supply system.

Additionally, from a consumption point of view, underlining the linkage of household-level water consumption with critical health, economic and social outcomes, various studies have recommended a minimum level of per capita consumption, ranging between 20-50 lpcd (Stelmach and Clasen, 2015). According to the WHO and other authorities, a basic minimum of 50 lpcd is required to meet the needs of hydration, food preparation and basic hygiene (Howard and Bartram, 2003; Gleick, 1996). Therefore, it is essential to scrutinise the per capita supply standard followed in planning versus the volume actually supplied.

NUMBERS: OBJECTIVITY, SCIENTIFICITY, LEGITIMISATION AND NARRATIVES

In the contemporary profoundly numerical culture, numbers play a critical role in defining as well as resolving problems. The nature and severity of problems are often measured, expressed and conveyed in numbers so as to provide a 'gloss of scientificity' (Molle and Mollinga, 2003: 537) and glare of objectivity. Quantitative analysis including mathematical modelling, forecasting and scenario building are preferred and often demanded by decision-makers while approaching the problem over a mere qualitative description. Decision-makers are always interested in knowing 'how much', 'at what rate' and 'by when' beforehand. Therefore, King and Kraemer (1993) argue, "in the heat of the political battles, some numbers beat no numbers every time".

Researchers have critically examined how numbers are chosen, assembled, processed, interpreted and circulated to communicate the message (Fischer, 2003; Porter, 1995; Stone, 1997). According to Porter (1995), numbers are presented and interpreted as a standalone entity, hiding the process of their genesis and the identity of their creators. The anonymous nature of numbers, which dissolves idiosyncrasies and follows scientific procedures, is expressed in the absence of passion, opinion, ethics and politics, and it grants numerals legitimacy by default in the eyes of the majority world. In fact, such objectivity over space and time and their neutrality and apolitical nature are the strengths of numbers. Porter (1992: 644) argues, "numbers and calculation span continents, leap oceans, link laboratories, factories and governments", partly because numbers and associated mathematics are a "highly structured language" that gives a sense of a universalised knowledge and build the confidence of its users by detaching the "individuality of its makers". On the other hand, Molle and Mollinga (2003) argue that numbers lack credibility in themselves. This must be built through processes of institutional and scientific legitimisation; otherwise the numbers are the mere opinions of private entities or groups of academics.

Thus, scrutiny of the numbers and the process of quantification that is followed reveals their political nature. The numbers produced through the quantification process are no longer innocent as the process itself determines what is to be counted and what is to be excluded. Stone (1997: 197) argues, "by the time we are adults, the categorization part of counting is so much second nature that we tend to forget we do it", which involves judgement, prioritisation, selection and discretion and these processes are inherently political. Quantification represents a slice of a physical reality convenient to an observer to make a point. One must remember that in the complex real world absolute quantification is near impossible. Hence, in scientific forestry the forest is traditionally counted as a simple volume of timber, neglecting the complex ecosystem of diverse flora and fauna (Scott, 1998), and in river basin modelling a river is mathematically abstracted as a conduit for water, ignoring the concept of river continuum and its relation to land and basin inhabitants.

The scrutiny of numbers is a powerful tool to reveal the associated technopolitics where the numbers themselves are primarily mobilised to depoliticise the process of problem framing and objective setting. Despite such importance, the numbers and their strength in shaping the urban waterscape are inadequately appreciated and investigated by urban geographers, political ecologists, STS scholars and critical sociologists, as very few studies examine the use of numbers in the context of urban water supply (Tiwale et al., 2018; Tiwale, 2019).

Number narratives

Numbers rarely appear in politics as naked figures but are clothed in symbols, metaphors and narratives to outline problems or potential solutions, especially in policy debates. The numbers express whether a problem is big, growing, small, or declining, including its future trends. Narratives convey the intensity of the problem through a combination of numbers and words. As Stone (1997: 204) explains, it is rarely just reported that a number has changed from this to that. Such reporting is often articulated as numbers having "r[isen] rapidly, skyrocketed, escalated, plummeted, plunged, moved sluggishly, crept, edged, hovered, or otherwise behaved dramatically".

Not only do the numbers indicate objectivity and accuracy, but they also express the relationship between people, places, practices and things through literary and social technologies (Shapin and Schaffer, 1985). For example, citing the case of Smoketree, California, Brooks (2017) showed how a number narrative of '500 years of water' promised abundance, while '50 years of water' warned of scarcity, and both were intended to influence water management practices and the overall development of the region. Thus it is important to investigate "how stories with numbers come about and circulate" (Brooks, 2017: 35).

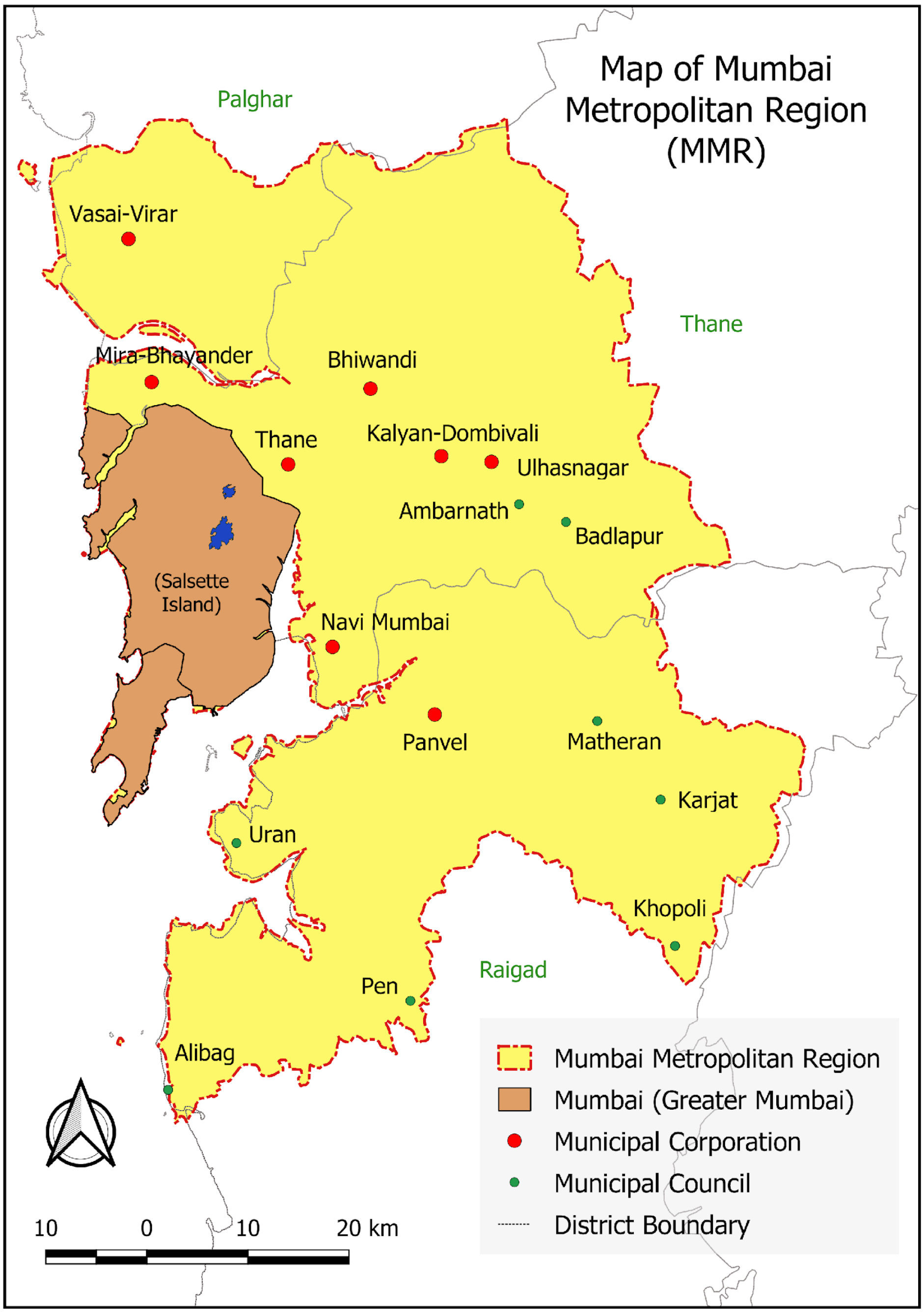
Number narratives are linked to social discipline, practices and values and political action. The numbers do not exist 'out there' but are an outcome of a specific knowledge-making process (Brooks, 2017). The narratives build and are built by authority and associated numerical practices. They not only convey a message but often force a reader or listener to imagine or think about further actions and considerations (Fischer, 2003). For example, as described below, numbers describing water shortages call for the development of new water resources. Such narratives are often self-validating, drawing logic from common sense, making them rational, convincing, uncontroversial, persistent and resilient (Molle and Mollinga, 2003; Molle, 2008). Numbers intended to establish authority and rally support from diverse actors can be reductionist, limiting heterogeneity, curbing alternative worldviews and defining problems and potential solutions according to mainstream thinking by depoliticising the discourse (Molle and Mollinga, 2003). Therefore, when investigating the origin of numbers it is relevant to examine the narratives built using these numbers and how they are stabilised and circulated to achieve political goals.

This paper proposes an examination of the numbers involved in the water demand estimation process. It shows how the number used as the per capita supply standard builds the narratives of water shortages to legitimise large water resources development projects and to delink the process of water resources development from the issue of water distribution.

INEQUITABLE WATER ALLOCATION IN THE MUMBAI METROPOLITAN REGION (MMR)

Mumbai is the world's seventh-largest urban agglomeration (Brinkhoff, 2020). Over the last few decades it has outgrown its municipal limit, leading to the growth of new urban centres in its vicinity. The island city has spatially expanded from 603 km^2 to 4419 km^2, covering nine municipal corporations, eight municipal councils and 994 villages, together forming the Mumbai Metropolitan Region (MMR)[4] with a population of 22.8 million (Figure 1). The Mumbai Metropolitan Region Development Authority (MMRDA)[5] has been established for the coordinated planning and development of the region (MMRDA, 2021).

Figure 1. Map showing the Mumbai Metropolitan Region along with the municipal corporations and councils.

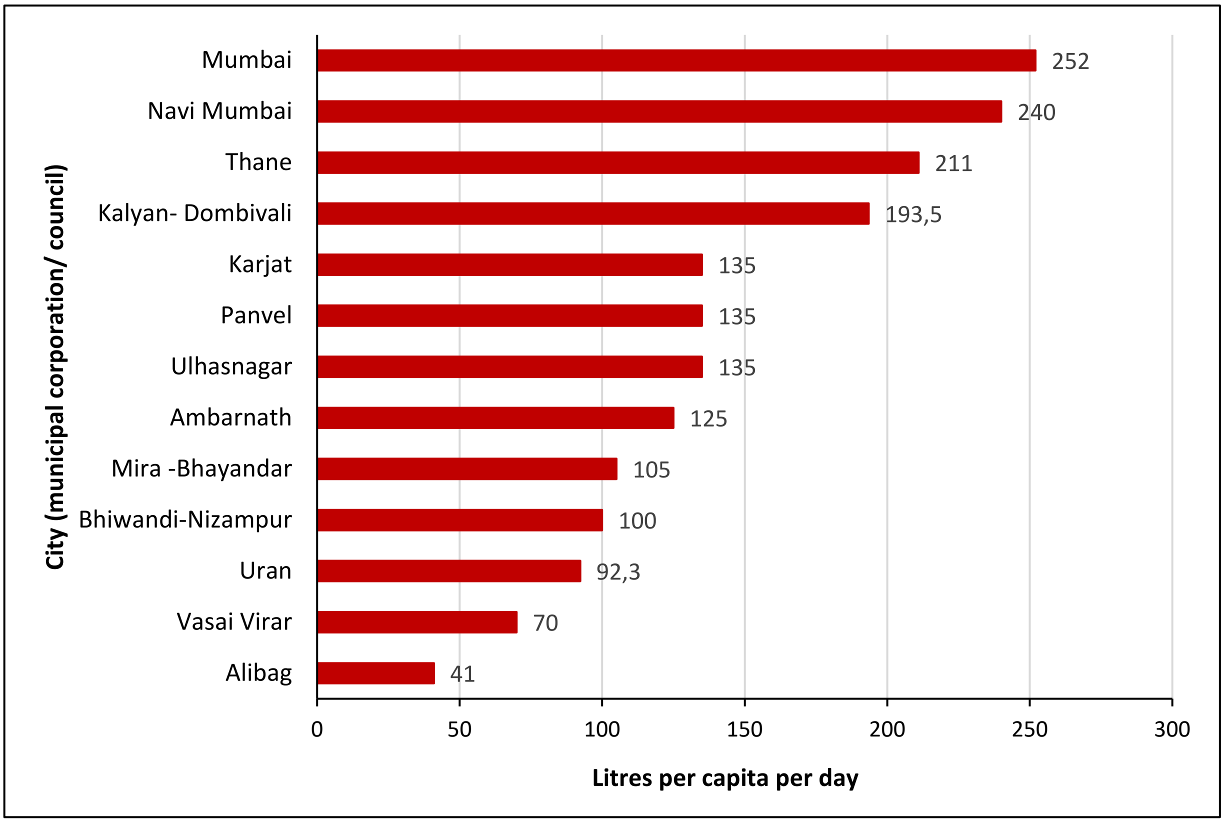


[4] Prior to the renaming of Bombay as Mumbai in 1995 the MMR was known as the Bombay Metropolitan Region (BMR). For the purposes of consistency, throughout this paper it is referred to as the MMR wherever possible.

[5] Prior to the renaming of Bombay as Mumbai in 1995 the MMRDA was known as the Bombay Metropolitan Region Development Authority (BMRDA). For the purposes of consistency, throughout this paper it is referred to as the MMRDA wherever possible.

Continuous growth in urbanisation and industrial activities in the metropolitan region has put tremendous pressure on its water resources. The MMR consumes 5427 MLD of water for domestic purposes (MMRDA, 2021), but it is highly inequitably shared among urban centres, as shown in Figure 2. A comparison of the per capita consumption across urban centres in the MMR reveals a disparity among various cities at the source level. The cities of the MMR are clearly divided into water-surplus cities and water-scarce cities. Mumbai, Navi Mumbai, Thane and Kalyan-Dombivali are water-surplus municipal corporations consuming 252[6], 240, 211 and 194 lpcd respectively (MMRDA, 2021). These levels are much higher than the per capita standards prescribed by the Central Public Health and Environmental Engineering Organisation (CPHEEO),[7] fixing a maximum of 150 lpcd for a metro city (like Mumbai) and a maximum of 135 lpcd for other urban centres (CPHEEO, 1999). The prescribed standards also include the water requirements of various institutions, commercial establishments and minor industries, excluding bulk water users. Meanwhile, the Vasai-Virar, Mira-Bhayander and Bhiwandi-Nizampur municipal corporations and the Alibag municipal council are water-scarce urban centres. The Vasai-Virar municipal corporation, the fastest growing urban local body in the MMR, consumes only 70 lpcd, almost 50% less than the set standard of 135 lpcd; and Alibag is managing with only 41 lpcd, which is even less than the rural water supply norm of 55 lpcd (GoI, 2013; MMRDA, 2021).

Figure 2. Water resource availability in litres per capita per day for major cities in the MMR.



Data source: MMRDA, 2021

[6] 252 lpcd is excluding industrial supply provided to bulk consumers.

[7] The Central Public Health and Environmental Engineering Organisation (CPHEEO) is the technical wing of the Ministry of Housing and Urban Affairs, Government of India, that sets norms, standards and technical guidelines and prepares manuals for urban water supply and sanitation in India.

Mumbai alone consumes around 67% of the MMR's water supply at a rate of 252 lpcd, causing a disparity in water resource availability in the metropolitan region. This level of consumption is only feasible because, historically, Mumbai could appropriate a larger share of water by constructing a series of dams in the region. At present, Mumbai sources water from seven dams, of which six were built, and are owned and operated by, the MCGM.

To analyse water appropriation in the urban agglomeration of Mumbai, this paper investigates the historical process of water resources development led by Mumbai with a specific focus on the numbers involved. This involves analysing the prescribed per capita water supply standards and the process of estimating water demand to illustrate how numbers are mobilised to construct narratives of water shortages in order to justify large dams. This paper does not focus on a sociological understanding of engineers, their tendency to overestimate and manipulate numbers or their motives and goals. Separate studies are required to reveal these crucial aspects of engineers and engineering, which are beyond the scope of this paper.

The data pertaining to the historical trajectory of the expansion of Mumbai's water supply was collected following an archival study approach during 2016-2020. Various reports were studied, including the master and regional plans, appraisal reports, feasibility reports, water resource assessment reports, detailed project reports, the impact assessment report and project archive reports prepared by the MMRDA, MCGM, consultants and other authorities. The numbers, computational methods, associated assumptions and respective rationales provided in these reports were carefully verified and analysed. In addition, 11 semi-structured interviews were conducted with five senior water supply engineers at the MCGM, including a Deputy Chief Engineer, a Deputy Hydraulic Engineer and Executive Engineers, water supply engineers associated with the state water supply and sewerage board, consultants and experts on the water supply situation in Mumbai and the MMR. Due to field constraints, approaching MCGM officials was difficult. Since, in some cases, government authorities were reluctant to share information and reports, the Right to Information Act, 2005[8] was used to access data.

Apart from numbers, the appropriation of water by Mumbai is also linked with other important factors that are beyond the scope of this paper. These include Mumbai's image as the country's financial capital, its capacity to mobilise financial resources (sometimes independently) to build water resources infrastructure, its position as the capital of Maharashtra state, knowledge, legacy and the institutional capabilities of its water supply department compared with neighbouring municipal corporations, and the political influence of its leaders given their historical dominance in the region.

DOUBLE STANDARDS IN THE COLONIAL ERA: MOCKERY OF THE BRITISH MODEL OF WATER SUPPLY

During colonial times, under the influence of the British sanitary movement, water resources were continuously planned and developed, assuming universal coverage and per capita supply standards followed in British cities. Historical data indicate that there was even a period when Mumbai's per capita water availability surpassed that of London (Bolton, 1884; Hardy, 1991; Stonebridge, 1927).

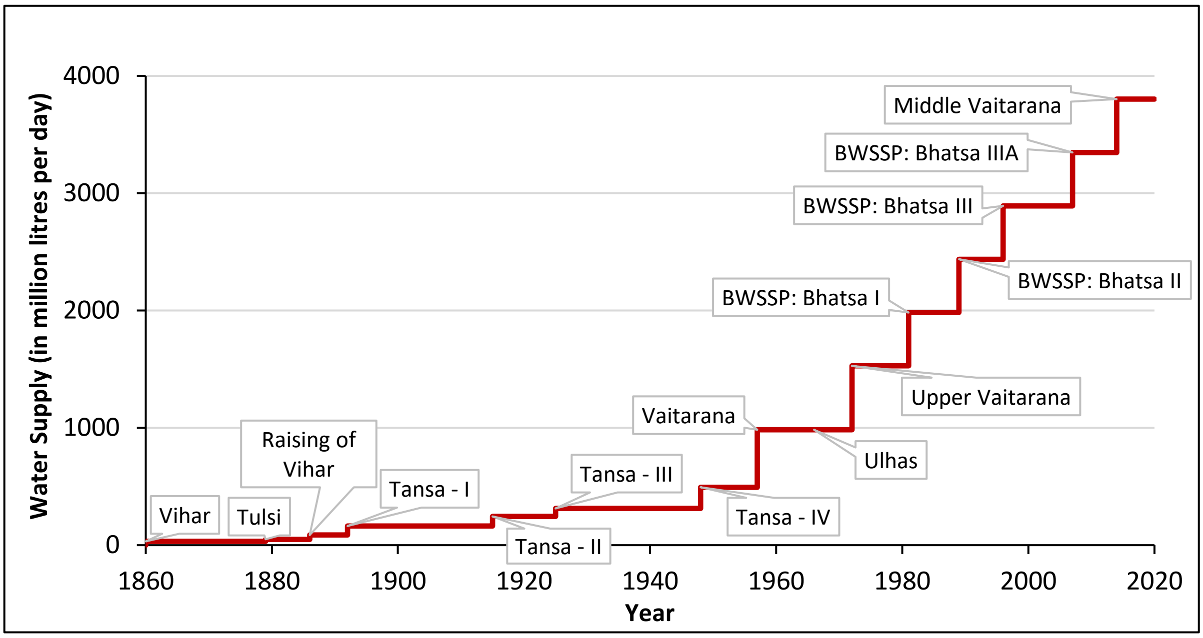
In the mid nineteenth century Mumbai faced severe water shortages, the severity of which was so critical that water was imported from nearby islands by steamer, boat and railway (Conybeare and Locke, 1858). The crisis led to the construction of Mumbai's first piped water supply system under the leadership of British engineer Henry Conybeare, bringing 32 MLD of water from Vihar[9] reservoir in 1860 (Tulloch, 1872; Dossal, 1988). Later, with the increase in population, British engineers further augmented the water supply by constructing another reservoir – Tulsi, upstream of Vihar – in 1879 and raising the height of the Vihar dam in 1886 (see Figure 3). Successively, engineers moved beyond Salsette Island and

[8] The Right to Information Act, 2005 mandates the timely response to citizen requests for government information. https://rti.gov.in/aboutrti.asp

[9] In earlier documents this scheme is spelled 'Vehar'.

initiated the exploration of water resources on the mainland. In 1892 the Tansa scheme to harness the water resources from Vaitarna Basin was commissioned and subsequently expanded in phases in 1915, 1925 and 1948 to harness its entire potential of 410 MLD to ensure adequate supply for the growing city (Figure 3).

Figure 3. Incremental augmentation of water resource infrastructure of Mumbai city.



The objective of the process was to ensure an adequate quantity of water for the city, which was measured in 'per capita per day' provisioning. As an influence of the British sanitary movement,[10] colonial engineers brought the British model of water supply to the city of Mumbai. It aimed to compel the working class to use more water by providing readily accessible, universal and affordable water services to improve public health. In support of the first water supply scheme, Vihar, engineer Henry Conybeare argued for the public health, economic productivity and public mortality benefits the scheme could bring to the city of Mumbai (Broich, 2007). While designing Vihar, Conybeare studied the water supply schemes of Liverpool, Manchester, Leicester, Bristol and Glasgow (Broich, 2007; Doshi, 2014). More importantly, the sizing of the Vihar scheme was based on a supply standard of gross 20 gallons (or 91 litres) per capita per day (gpcd), covering the entire population of the city (Conybeare and Locke, 1858; Dossal, 1988; Tulloch, 1872) and following the standard of European cities. In 1850 Londoners were also receiving 20 gpcd (Hardy, 1991). For Mumbai, the standard of 91 lpcd followed by Conybeare was on the higher side, considering the absence of a sewerage system[11] and minimal industrial water use during that period.[12]

[10] Colonial engineer Henry Conybeare designed Mumbai's first water supply scheme following a gravitational scheme proposed by English civil engineer John Frederick Bateman who had done pioneering work in shaping the modern British water supply system. Moreover, the sanitarian Edwin Chadwick had written to Bateman in 1844 imploring him to become a specialist in the water supply work (Broich, 2007).

[11] Drainage works were initiated in Mumbai in 1879 (GoI, 1924).

[12] In the plan prepared by Conybeare there was no mention of industrial water use. At the inception of the Vihar scheme, industrial water use was minimal. This demand increased later with an increasing number of cotton mills. In 1856 the first cotton mill started production in Mumbai (Morris, 1965).

Adequacy in terms of per capita supply was maintained during the colonial era. Once the Tansa scheme was completed in 1892 Mumbai was receiving gross 38 gpcd (173 lpcd) covering the entire population as per the 1891 census (Stonebridge, 1927). This was much higher than London, which was delivering only 28.6 and 27.8 gpcd in 1882 (Bolton, 1884) and 1900 (Hardy, 1991) respectively. By 1926 Mumbai was receiving a total of 286 MLD, adequate to provide a gross 225 lpcd covering Mumbai's then 1.27 million population (Stonebridge, 1927). Later, in 1941, the water supply system was providing an average gross 273 lpcd to Mumbai, meeting the prevailing standard of 227 lpcd[13] (World Bank, 1973). Therefore, in terms of per capita water supply, Mumbai had sufficient water to serve its entire population during colonial times.

However, though the Vihar scheme was designed with 91 lpcd covering entire population, following its commissioning the native poor were denied the benefits of the scheme and their share of water. The first commissioner of Bombay, Arthur Crawford, was against providing in-house connections to the native poor, insisting only on public sources in the form of standpipes (Kelkar, 2015). The native poor were blamed for excessive use of water and wastage, yet at the same period in England increased water use was encouraged as it was linked with improved sanitation, and waste was considered a structural part of the system (Kelkar, 2015). Hardy (1991: 79) has noted that the London water supply system was facing similar issues related to wastage because of the leaky system and "neither scrupulous nor thoughtful" consumers. For example, in London the amount of wastage in the water supply was around 60%. Out of 45 million gallons of daily supply around 27 million were lost and unaccounted for (Pedder, 1873). Additionally, there were several issues of water losses due to poor plumbing, according to reports: "in no town in the world do plumbers' work and the plumbing trade stand lower than in London" (Stern, 1954: 1001). However, the colonial rulers preferred to construct a narrative of 'wastage of water by native poor' and provided a limited number of standpipes to deny the poor their water share and hide technological inefficiencies, i.e. water losses caused by a faulty distribution system and poorly cast pipes (Tulloch, 1872), as well as leaky plumbing and defective standpipes imported from England (Kelkar, 2015). At the same time the colonial administration continued its practice of washing the streets with water procured from the Vihar scheme as a sanitary practice. Indeed, streets were often overwatered, making them slippery and dangerous for pedestrians (Kelkar, 2015).

This indicates that during the planning phase the water demand of poor natives was assessed by applying a universal per capita supply standard. However, during actual delivery the water was used by the ruling elite class to meet their own demands. On the one hand, the colonial rulers denied water to the native poor and on the other, given the sparse spread of the distribution network, the poor were not in a position to afford the cost of an extension of the network to their localities for private connection[14] (Dossal, 1988). As a result the native poor were never able to consume their share of the 91 lpcd of water based on which the Vihar scheme was initially conceived and justified.

This raises questions over the utility of the per capita supply standard used in the design of the scheme, since it never materialised when it came to the actual distribution of water. Moreover, it illustrates the disconnect between 'water resources development' and 'water distribution' that has been inscribed in the water supply system of Mumbai since the beginning. The water resources were developed following British norms and values and water was distributed following discriminatory colonial practices within the city.

CONSTRUCTING NARRATIVES OF WATER SHORTAGES AND SECURING WATER RESOURCES

The post-colonial history of water supply in Mumbai is full of narratives of an increasing population, severe water shortages and the continuous development of new water resources. After independence,

[13] 50 gallons per capita per day.

[14] Consumers had to pay for the network to be extended towards their premises.

following a colonial trend, four new large dams, namely, Vaitarna, Upper Vaitarna, Bhatsa (Phases I, II and III) and Middle Vaitarna, were commissioned to meet the city's thirst. As shown in Figure 3, throughout history engineers were continuously busy either planning or executing large dam projects for the city. These were justified, as shown below, by constructing narratives of shortages using higher per capita standards than the prevailing standards prescribed by national-level agencies for large cities.

Per capita supply standards: consistency, objectivity and convenience

Large dam projects were planned and justified based on studies commissioned by the MCGM, the MMRDA and the Government of Maharashtra (GoM) to estimate the current and future water demands of Mumbai and the metropolitan region. An examination of these studies indicates that while estimating demand the experts have consistently used higher per capita standards than the prevailing standards prescribed by national agencies for large cities. In all, 12 reports were prepared by nine different agencies, prescribing different values of per capita standards to be used to estimate water demand and develop water resources for Mumbai, as listed in Table 1.

The data indicate that there was no consistency while using the per capita standard to estimate water demand and shortages. In many reports no appropriate reasons were cited for discarding the earlier standard or introducing a new per capita standard for the same planning horizon year. Other than appraisal reports prepared by the World Bank and the master plan of Mumbai, none of the reports provided an appropriate rationale for choosing a particular number as a per capita standard. The absence of scientific evidence, theoretical explanation or empirical data raises questions about the objectivity of these prescribed standards.

In the late 1960s three reports calculated the water demand for the city of Mumbai. In 1968 British consultant Binnie and Partners, appointed by the Government of Maharashtra, proposed the standard of 255 lpcd (BMRPB, 1969) for domestic use and 350 lpcd covering domestic and non-domestic use (Binnie and Partners, 1968 cited in World Bank, 1972). These standards were considerably higher than the gross 227 lpcd suggested a year earlier (Table 1). The figures proposed by Binnie and Partners were vital as they played a key role in conceiving the Bombay Water Supply and Sewerage Project (BWSSP), partly supported by the World Bank.

In 1969 a study group[15] set up by the Bombay Metropolitan Regional Planning Board (BMRPB) examined the earlier reports and concluded that the standard of 255 lpcd used for domestic use was too high for Mumbai and alternatively proposed a figure of 182 lpcd. However, while calling this "a fair allowance for the domestic use", the group provided no rationale other than it was "the opinion of the group" (BMRPB, 1969: 3). This lower standard was still considerably higher than the prevailing per capita standards proposed by the national-level agency, the Zakaria Committee,[16] which had prescribed 132 lpcd for domestic use for large cities (Zakaria Committee, 1963).

In the 1970s three agencies – the World Bank (1973), BMRPB (1974) and a consultant appointed by the BMRDA (1978) – followed different standards while forecasting water demand for Mumbai. Of these agencies only the World Bank provided a rationale for the per capita standard used in their appraisal report. It was based on a weighted average of housing category and empirical data of household-level water consumption,[17] which was further extrapolated according to municipal ward-wise probable

[15] This study group included experts such as N. V. Modak, former Special Engineer of the Bombay Municipal Corporation, who played a key role in the planning and execution of the Vaitarna (or Vaitarna-cum-Tansa) scheme, and as an honour the Vaitarna Reservoir was named after him as 'Modak Sagar'.

[16] In 1963 the Zakaria Committee was appointed by the Central Council of Local Self Government to address the question of augmentation of the financial resources of urban local bodies under the leadership of Dr Rafiq Zakaria, the then Minister of Urban Development, Government of Maharashtra.

[17] However, the empirical value of per capita consumption was multiplied by a factor and increased further to compute the per capita standard under 24-hour supply conditions (which was not there).

development trends (World Bank, 1973). Following this method the experts prescribed a standard of 158 lpcd to calculate the then existing domestic demand for 1971 and forecast 186 lpcd for 1981. These values of per capita standards were important as, based on this report, Phase I of the BWSSP was planned and executed.

Table 1. Per capita water supply standards used by various agencies to estimate domestic and non-domestic water demand for Mumbai.

S. No.	Year	Details of report	Per capita standard used (in lpcd)[a]	
			For domestic use only	For domestic + non-domestic use
1	1967	An econometric analysis of water requirements of Bombay region, Dr R. Bhardwaj, Bombay University	-	227 (1981)
2	1968	Interim Report on Water Supply for Bombay Metropolitan Region, M/s Binnie and Partners	255 (1991)	350 (1991)
3	1969	Report of the study group on water supply, water pollution, drainage and sanitation, Bombay Metropolitan Regional Planning Board	182 (1991)	317 (1991)
4	1973	Appraisal of Bombay Water Supply and Sewerage Project, India, World Bank	158 (1971); 186 (1981)	-
5	1974	Regional Plan for Bombay Metropolitan Region 1970-91, Bombay Metropolitan Regional Planning Board	-	341 (1991)
6	1978	Feasibility Report Part – I on Water Resources Study of Bombay Hydrometric Area for Water Resources Management Board of Bombay Metropolitan Region Development Authority, Kirloskar Consultants Limited	200 (1991) 225 (2001)	-
7	1981	Revision of Water Resources Study of Bombay Metropolitan Region and Bombay Hydrometric Area for Water Resources Management Board of Bombay Metropolitan Region Development Authority, B. S. Kapre (Consultant)	234 (2001)	-
8	1983	Water Resource Development Plan, BMRDA (now MMRDA)	234 (2001)	-
9	1986	Staff Appraisal Report India: Third Bombay Water Supply and Sewerage Project, World Bank	180 (1991); 190 (2001)	-
10	1994	Report of the Expert Committee (Water Planning) on Bombay's Future Water Resources and Improvement in Present Water Supply Scheme, led by Dr Chitale, GoM	240 (2001 onwards)	-
11	1999	MMRDA Regional Plan (1996-2011), MMRDA	225 (2001) 250 (2011)	-
12	1999	Master plan for water supply of Mumbai (for its growth by the year 2021), MCGM	205 (2001, 2011, 2021)	-

Data sources: Binnie and Partners, 1968; BMRPB, 1969; World Bank, 1972; World Bank, 1973; Bombay Metropolitan Region Planning Board, 1974; Kirloskar Consultants Limited, 1978; Kapre, 1981; World Bank, 1986; Expert Committee, 1994; MCGM, 1999; MMRDA, 1999

[a] The figure in brackets indicates the year of water demand forecast for which the given per capita standard was used.

While estimating domestic water demand for the year 1991 five different values of per capita standards were prescribed by different agencies with considerable variation: 180, 182, 200, 255 and 341 lpcd, where the last figure included non-domestic water use (see Table 1). These standards were higher than the prevailing standard of 125-200 lpcd (covering domestic and non-domestic water use) prescribed for all large cities in India by the Expert Committee appointed by the Ministry of Works and Housing, Government of India, in 1976 (GoI, 1976).

In the 1980s, while calculating water demand for 2001, two agencies used different per capita standards for two different purposes. In 1983, while allocating available water resources within the metropolitan region, the MMRDA forecast Mumbai's water demand using the standard of 234 lpcd for domestic use (MMRDA, 1999). Three years later, in 1986, World Bank experts computed the city's domestic water demand using the standard of 190 lpcd for 2001. Accordingly, the World Bank planned and executed Phase III of the BWSSP project, bringing 455 MLD water from the Bhatsa Dam. This clearly indicates that while working on the regional plan and allocating water resources a higher standard (234 lpcd) was used to calculate water demand. However, for the same planning horizon year, 2001, a much lower standard of 190 lpcd was used in planning and executing the water resources development project (BWSSP Phase III). So, for the same city and the same planning year different standards were used while allocating water resources and executing water resources development project.

In 1994 the Expert Committee led by Dr Madhav Chitale estimated domestic water demand using the standard of 240 lpcd without providing an appropriate rationale (Expert Committee, 1994). From 1994 onwards the same value was adopted by MCGM engineers to develop all subsequent water resources. Moreover, this value was higher than all the earlier standards used for planning purposes.

To estimate domestic water demand for 2001 five different per capita standards were employed, ranging from 190 to 240 lpcd. Furthermore, all the standards determining domestic water use were far higher than that prescribed by the CPHEEO (1999) – a maximum of 150 lpcd to cover the domestic and non-domestic demand of large cities.

Additionally, various authorities used the per capita standard that best served their objective, and that the standards have not reflected or correlated to the citizens' actual water requirements. As explained above, while justifying the development of new water resources, the Expert Committee (1994) prescribed the per capita standard of 240 lpcd for domestic use and cited the examples of cities with higher per capita supply such as Delhi (275 lpcd), Taipei (282 lpcd) and Bangkok (217 lpcd) in support of the prescribed standard. However, in 2012, while addressing the question of 'Does Mumbai have enough water?' to switch over to a 24-hour supply, the Deputy Municipal Commissioner, Special Engineering, MCGM, argued that the domestic supply of 180 lpcd was sufficient for Mumbai to switch from intermittent to continuous supply (Bambale, 2012). To support this argument he cited the examples of London (150 lpcd), Singapore (160 lpcd), Kuala Lumpur (120 lpcd) and Paris (150 lpcd) and concluded, "Mumbai has enough water to switch over from the present intermittent to continuous pattern of water supply", as Mumbai's water availability was more than some of the cities with 24-hour supply (Bambale, 2012).

The Expert Committee was appointed to plan future water resources for Mumbai and secure more water for the city. It is therefore perhaps unsurprising that it used a relatively high per capita supply standard of 240 lpcd. Accordingly, it cited the examples of cities with higher per capita water consumption. To justify the 24-hour supply scheme for the city the municipal engineer argued that even 180 lpcd was enough for the city. To support the argument he cited the examples of cities with lower per capita water consumption. Since water demand depends on a range of factors, merely selectively citing the cities with their per capita consumption values without providing any additional detail does not amount to substantial evidence or justification for choosing a particular number as the per capita standard for Mumbai. This suggests that the experts selectively proposed standards depending on their goals and selected supporting evidence at their convenience.

Number narratives of water shortages and resource appropriation

By taking relatively high values of per capita standards experts overestimated the water demand of Mumbai. This section discusses how, based on these exaggerated figures for existing and future water demand, narratives of water shortages were constructed and circulated to secure more water resources for the city and to justify the time-bound development of water resource infrastructure, citing urgency. These narratives appear in textual form throughout the reports assessing the available water resources and estimating existing and future demand for Mumbai and are dominated by numbers expressing absolute water shortages in MLD or percentages. For experts and engineers, these numbers are the appropriate means to communicate the magnitude or intensity of water shortages.

In the 1960s the British consultancy Binnie and Partners studied the availability of water resources and forecast that the water demand in the MMR in 1991 would exceed the available water resources of the region. Preparing an appraisal report to build on this study World Bank experts calculated an existing water supply shortage of 29% in 1971 and demanded immediate action to improve the city's supply situation (World Bank, 1973). This number narrating a shortage justified the World Bank's support for the Bombay Water Supply and Sewerage Project (BWSSP) initiated in 1973 to bring water from Bhatsa Dam in three phases, each bringing 455 MLD to the city (World Bank, 1973).

Later, the consultants appointed by the MMRDA forecast water demand to be 3050 MLD and 3066 MLD by 1991 and narrated water shortages for Mumbai (Kirloskar Consultants Limited, 1978; Kapre, 1981). Further, consultants recommended the development of Middle Vaitarna and Kalu as new resources for Mumbai (Kapre, 1981). This illustrates that the narrative of shortage was so strong, even during Phase II of the BWSSP project, that the planners were already discussing and exploring future water resources for the city.

In 1983, while preparing the Perspective Plan for 2001, the MMRDA estimated Mumbai's water demand at 4384 MLD for the year 2001, using a per capita standard of 234 lpcd (BMRDA, 1985). As a response, Mumbai was officially allowed to develop an additional three sources, including Middle Vaitarna, Kalu and Gargai dams. A total of 1710 MLD was allotted to Mumbai alone to meet its future water demand (MMRDA, 1999). The estimated demand of 4384 MLD was extremely high. Twenty years later, in 2021, the consumption level of Mumbai is only 3750 MLD. In subsequent years the narratives were consistently strengthened by repetition in ever renewed forms for the time-bound development of the allotted water resources.

For example, while justifying Phase III of the BWSSP project in 1986, the World Bank's appraisal report pushed for the construction of the Middle Vaitarna and Kalu dams by 2000 to avoid an "unacceptable deterioration" in service provision.

> In 1994 the water demand of BMC[18] is estimated around 3700 mld (see Annex 2); the Middle Vaitarna scheme would increase water availability to about 3320 mld thus further reducing the shortfall at that time to about 10%. In the event that population and water demand continue to increase as predicted then the development of the Kalu scheme (with an estimated yield to BMC of around 500 mld) would be needed before year 2000 in order to meet the suppressed water demand and prevent any unacceptable deterioration in water service levels (World Bank, 1986: 11).

Though the statement above does not appear evocative or persuasive as such, in engineer-speak this is a strong statement. In technical reports prepared by engineers and internally used by decision-making authorities (who are again engineers or experts) convincing happens by presenting numbers in a firm and authoritative manner.

[18] Bombay Municipal Corporation, now Municipal Corporation of Greater Mumbai (MCGM).

Later, in 1994, the Expert Committee, led by Dr Chitale, estimated the water demand of Mumbai at 5400 MLD for 2021 and narrated shortages of 1727 MLD for 2001 and 2507 MLD for 2021. The Committee noted (Expert Committee [1994: 4-1]):

> The projected requirement of water for MCGB[19] for the year 2021 is estimated to be 5400 mld. (…) After the completion of the MCGB's ongoing Bombay-III project (drawing water from Bhatsa), 2893 mld water will be available to Bombay from Bhatsa and Vaitrana together with Vehar and Tulsi. Thus there will be gap of 2507 mld in the demand and supply which will have to be met by the year 2021 by developing additional sources.

Further, as a logical remedy, the Expert Committee recommended the time-bound development of four large dams, Middle Vaitarna (477 MLD), Kalu (590 MLD), Gargai (455 MLD) and Shai (1067 MLD), to be completed within two decades, by 2013. Additionally, the Committee recommended Pinjal as an additional water resource with a capacity of 865 MLD to meet subsequent demand. Since the Expert Committee report was officially accepted by the Government of Maharashtra these recommendations significantly influenced the water resources development of the city of Mumbai (MCGM, 2005). At a later stage, while preparing the master plan for Mumbai in 1999, the planners replaced Kalu and Shai sources with the Damanganga-Pinjal link project, involving inter-basin transfer (MCGM, 1999). The sources of Kalu and Shai were allotted to other urban centres of the metropolitan region for the cited reasons of higher operational costs (for Mumbai) and the possibility of future water pollution in the catchment areas.[20]

The water-shortage narrative was continued in subsequent reports. The National Water Development Agency (NWDA)[21] reproduced it to justify the Damanganga-Pinjal link project with an estimated budget of Rs. 28 billion. While anticipating an "acute shortage of domestic water", the Detailed Project Report (DPR) of this river-linking project stated (NWDA, 2014: 50):

> With the present pace of development of Greater Mumbai, it is anticipated that there would be acute shortage of domestic water in the year – 2050. As per the assessment of Municipal Corporation of Greater Mumbai (MCGM) the present domestic water demand for Mumbai City (year 2012) is 4529 MLD (1653 Mm^3) and the cumulative water supply from all the sources is 3675 MLD (1341 Mm^3). The projected domestic water demand for Greater Mumbai by the year – 2041 is 6680 MLD (2438 Mm^3) and the projected supply as 4980 MLD (1818 Mm^3) (on completion of Gargai and Pinjal projects) leaving a shortage in supply of 1700 MLD (620 Mm^3). The shortage in water supply will further increase as the demand will reach to 7000 MLD (2555 Mm^3) by the year – 2060 and the cumulative water supply from various sources including from middle Vaitarna, Bhatsa and Gargai projects will remain 4980 MLD (1818 Mm^3) only.

According to a Superintending Engineer at the NWDA, the above-mentioned water demand estimates were submitted by the Chief Engineer (Water Supply project), MCGM, without disclosing the details of the assumptions made or methodology followed in arriving at these figures (MCGM, 2011). It was further stated that the numbers submitted were not independently cross-checked or verified by NWDA engineers while conceiving the project[22] (NWDA, 2019). This means that the basic figures justifying a project costing Rs. 28 billion were not adequately scrutinised. Moreover, the Deputy Hydraulic Engineer of Mumbai's water supply department confirmed that these estimated figures were not scrutinised by

[19] Municipal Corporation of Greater Bombay now MCGM.

[20] Given the difference in elevation, water would need to be pumped from the sources at Kalu and Shai. This was expected to increase the operational costs significantly – to around Rs. 500 million/year (MCGM, 1999). The Damanganga-Pinjal link project was therefore preferable. It would allow raw water transmission to Mumbai by gravity, from a catchment with relatively low population density and less prone to water quality issues.

[21] The National Water Development Agency (NWDA) was established by the Government of India to assess the feasibility of river-linking projects and prepare detailed project reports.

[22] Information obtained under the Right to Information Act, 2005.

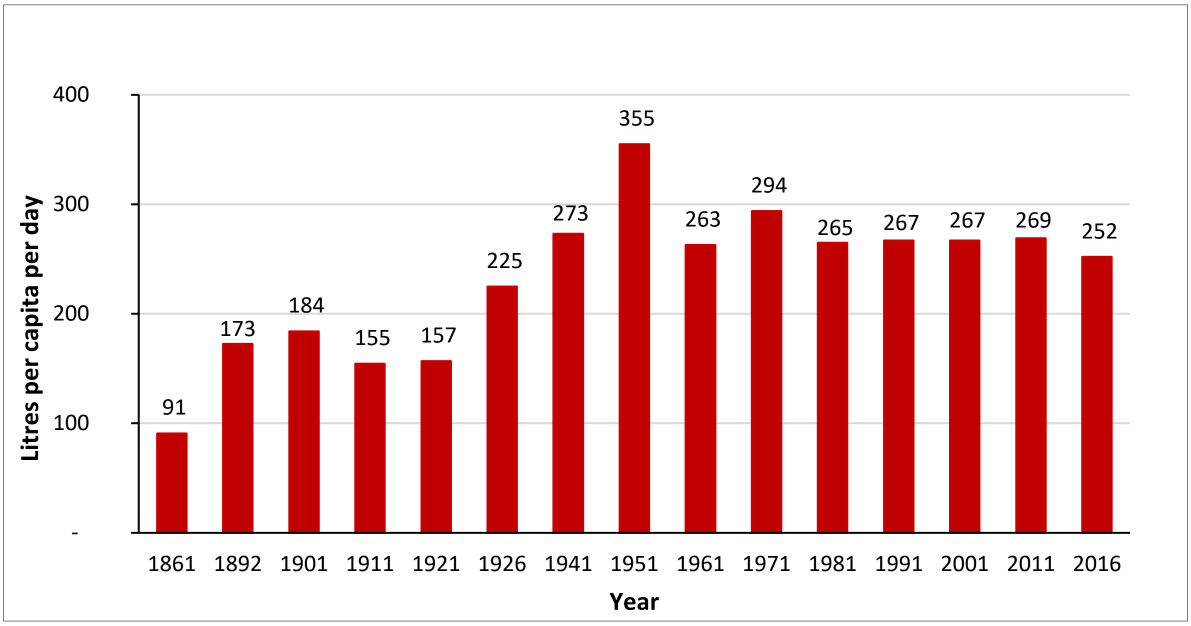
any other authorities providing environmental and forest clearances and other approvals, including permission for land acquisition for the project.[23]

Using the narratives mentioned above, Mumbai executed three phases of the BWSSP project, adding a total water volume of 1365 MLD by 1996; it completed the Mumbai-IIIA project, bringing an additional 455 MLD from the Bhatsa Dam in 2007; and it commissioned the Middle Vaitarna Dam with a capacity of 455 MLD in 2014, as described in Figure 3. At present, the Pinjal and Gargai dams and the Damanganga-Pinjal link project, which will bring a total of 2891 MLD, are at various stages of construction.

WAS THERE A SHORTAGE AT THE CITY LEVEL?

Historical data indicate that Mumbai was always supplied with adequate quantities of water. As illustrated in Figure 4, at the city level the water supplied per capita was much more than the existing per capita standard of 150 lpcd prescribed by the CPHEEO for metro cities (CPHEEO, 1999).

Figure 4. Historically available water supply for the city of Mumbai in gross litres per capita per day[24].



Data Sources: Stonebridge, 1927; MCGM, 2009; Kadam and Uchgaonkar, 2017; MMRDA, 2021.

It is commonly believed that, being the country's financial and commercial hub, a significant proportion of the water supplied to Mumbai would be used for non-domestic purposes,[25] increasing the city's gross per capita water needs. However, the figures for the last three decades indicate that no more than 10% of the total water supply is directed to non-domestic use. During the 1980s non-domestic water demand in Mumbai began to decrease significantly due to sickness and closure of a number of industrial units (Bhide, 2015) and water conservation measures adopted by industries due to a steep hike in the tariff for non-domestic use (MMRDA, 1999). As per the Water Utilities Data Book prepared by the Asian Development Bank in collaboration with the city water utilities in 1992, industrial and commercial water

[23] Personal interview with a Deputy Hydraulic Engineer, Municipal Corporation of Greater Mumbai and information obtained under the Right to Information Act, 2005.

[24] It is the ratio of the total quantity of water supplied to the city in litres per day to the population of the city.

[25] Based on comments received for an earlier version of this paper.

demand in Mumbai was only 10% of the total demand (ADB, 1993; MMRDA, 1999). Similarly, in 2005 non-domestic water use was at a maximum of 335 MLD (GoM, 2005), accounting for around 10% of the total supply. According to the Deputy Municipal Commissioner, MCGM, this non-domestic water use further dropped to 8% in 2016 (Bambale and Wadhavane, 2016). So, for the last three decades, based on the MCGM's own figures, the share of non-domestic water use has stagnated at between 8-10% of the total supply.

Table 2 illustrates the extent of overestimation by comparing the demand forecast by various experts and the quantities of water actually supplied for the years 1991, 2001, 2011 and 2021. The table shows that historically water demand was consistently overestimated using higher per capita standards.

Table 2. Estimated water demand and actual water supply for the years 1991, 2001, 2011 and 2021.

Year	Estimated demand (in MLD)	Name of agency and year of estimation	Actual supply (in MLD)	Actual gross per capita per day supply (in lpcd)
1991	3150	Bennie and Partners (1968)	2638[a]	267 (MCGM, 2009)
	3050	Kirloskar Consultants (1978)		
	3066	B. S. Kapre Consultant (1981)		
	3568	World Bank (1986)		
	3026	Mumbai Metropolitan Region Development Authority (MMRDA) – (1999) *(estimation of existing demand)*		
2001	3646	Kirloskar Consultants (1978)	3200[b]	267 (MCGM, 2009)
	3425	B. S. Kapre Consultant (1981)		
	4384	MMRDA (1983)		
	4358	World Bank (1986)		
	4620	Expert Committee (1994)		
	3848	MMRDA (1999)		
	3856	Municipal Corporation of Greater Mumbai (1999)		
2011	3589	B. S. Kapre Consultant (1981)	3350[c]	269 (Kadam and Uchgaonkar, 2017)
	5043	Expert Committee (1994)		
	4471	MMRDA (1999)		
	4408	MCGM (1999)		
	4957	Water Supply and Sanitation Department, GoM (2005)		
	4529[d]	National Water Development Agency (2014)		
2021	5400	Expert Committee (1994)	3750[e]	252[f] (MMRDA, 2021)
	4949	MCGM (1999)		
	5521	Water Supply and Sanitation Department, GoM (2005)		
	5135	MCGM (2011)		

[a] After completion of Phases I and II of the BWSSP

[b] After completion of Phase III of the BWSSP

[c] After completion of the Mumbai-IIIA project

[d] This figure was the existing water demand for 2012 as estimated by the NWDA while preparing the DPR for the Damanganga-Pinjal link project.

[e] After completion of the Middle Vaitarna project in 2014

[f] For 2016 and excluding industrial water use. The data for the year 2021 is not yet available.

For example, for 1991 experts estimated water demand ranging from 3050 to 3568 MLD and narrated water shortages. However, in 1991, as per the white paper released by the MCGM (2009), Mumbai was supplied with only 2638 MLD – far less than the demand forecast and yet the gross per capita supply was 267 lpcd, covering both domestic and non-domestic water use. Even after deducting around 10% for non-domestic use from 267 lpcd (i.e. 26.7 lpcd), a sufficient quantity was available to serve domestic water demand covering the entire population. The projected figures were no closer to the actual demand. Even a short-term forecast of 3568 MLD made by the World Bank in 1986 was higher than the actual supply by 35% (930 MLD), where the actual per capita water supply was itself 1.8 times higher than the prescribed CPHEEO standard of 150 lpcd.

The water demand for 2001 was forecast as high as 4620 MLD by the Expert Committee and 4384 MLD by the MMRDA, and accordingly a narrative of shortage was produced. However, the actual supply was only 3200 MLD, and the MCGM was providing an average of 267 lpcd for all without developing the Middle Vaitarna, Kalu or Gargai dams as per the recommendations.

The Expert Committee forecast the water demand for 2021 at 5400 MLD and predicted an enormous shortage of 2507 MLD. However, the actual water supply to Mumbai in 2021 is around 3750 MLD, and in 2016 Mumbai was supplied with 252 lpcd excluding industrial water use (MMRDA, 2021). Thus, considering the figure from 2016 (in the absence of the latest data for 2021), one can reasonably argue that there is no shortage as predicted by the Expert Committee. Moreover, the forecast water demand was 44% higher than the actual supply, where the gross per capita supply itself is much higher than the CPHEEO standard.

Therefore, Mumbai always had enough water at the city level. Nonetheless, the urban poor and slum residents continued to suffer due to issues of distribution network, including huge leakages and losses, and the inequitable distribution of water. These issues were consistently underplayed, as explained in the next section.

DELINKING WATER RESOURCES DEVELOPMENT FROM WATER DISTRIBUTION

The approach of estimating water demand using the prescribed value of the per capita supply standard (which is not computed via consumer survey and analysis of the distribution network) delinks the process of demand estimation from conditions of access and status of water supply provisioning (i.e. coverage, pressure and supply hours) within the city, as described below. As a result, this approach suppresses the issues of access and inequitable distribution and makes them invisible.

Ignoring conditions of access and status of supply provisioning

While computing water demand for Mumbai using higher per capita standards, critical realities existing within the distribution network were ignored, thereby limiting the water consumption of the majority of the population. There were several such instances in the reports listed in Table 1.

For example, while estimating the then-existing domestic water demand for 1971, the World Bank experts used 158 lpcd as a standard (World Bank, 1973). However, considering the reality of water service provisioning within the city, this standard was on the high side. In 1972 the service coverage was only 80%, as 20% of the city's population was not connected to the network; yet the demand of this 20% was included in the city's overall demand. Moreover, the majority of the connected population was accessing water through standpipes (World Bank, 1996), making it impossible to consume water at a rate of 158 lpcd. Even the residents of multistorey buildings faced access issues due to inadequate terminal pressure (World Bank, 1972). With inadequate and intermittent water supply covering only a part of the population, the majority was not in a position to consume the average of 158 lpcd as assumed by the experts. Furthermore, this standard was estimated from an assumption that the distribution network operated under 24-hour supply condition with adequate pressure, which was not the reality.[26] Therefore, the figures for the water demand at the time, and the corresponding shortage, as computed using the standard of 158 lpcd did not represent the water requirements of the city's residents, since the standard used did not reflect the conditions of access and supply provisioning within the distribution network.

In 1994 the Expert Committee prescribed a standard of 240 lpcd for the entire population when computing demand for 2001 and 2011. As per the censuses of 1991, 2001 and 2011, the slum population of Mumbai was 55.3%, 54.1% and 41.8%, respectively (GoI, 2011; Mahadevia, 1998; Press Information Bureau, 2010). The 240 lpcd supply standard meant the average household in Mumbai with approximately five persons (O'Hare et al., 1998) consumed 1200 litres per day. Considering the conditions of slum residents and the status of supply provisioning – low pressure and intermittent with restricted and inconvenient supply hours – it was nearly impossible to consume so much water. Moreover, the average slum residents in Mumbai did not have the space to store 1200 litres of water.[27] Thus, almost half the city's population was not capable of consuming 240 lpcd. It was unrealistic to assume that the population of slum residents would reduce significantly in one or two decades. However, the Expert Committee preferred to use the high standard and hence forecast very high demand figures.

Double standards while serving slum residents

Although consistently high per capita standards covering the entire population were used while developing water resources for Mumbai, the city administrators officially restricted access to water in slum areas, affecting almost half the population. Several studies have documented the everyday struggle of Mumbai's slum residents in accessing adequate and safe water (Björkman and Harris, 2018; Bapat and Agarwal, 2003; Zérah, 2008; Anand, 2011; Contractor, 2012; Graham et al., 2013). Access to water in slums was restricted in two ways: first, by officially limiting the water supply standard for the slums and second, by denying formal water supply to the non-notified (unauthorised) slums following a cut-off date.

For example, when engineers were computing domestic demand using supply standards ranging from 186 to 240 lpcd in the 1980s and 1990s the city administrators were officially following the standard of only 45 lpcd while serving the notified slum residents (MCGM, 1999). The Expert Committee had used the standard of 240 lpcd to calculate the demand for 2001 and 2011, but even in 2016 the slum water supply was officially restricted to 100 lpcd (Bambale and Wadhavane, 2016). Studies have shown that in some of the slums water consumption was as low as 20-30 lpcd (Karn and Harada, 2002; Subbaraman et al., 2015).

Mumbai never provided water to all slums. Even in 2021 many pockets are still not officially connected to the city's supply network. Until 2014[28] the city denied water to non-notified slums that had come into existence after a specific cut-off date[29] (Husain, 2018). (The politics of the cut-off date have been discussed in detail in the literature and repetition is avoided here [see Murthy, 2012; Subbaraman et al., 2012; Subbaraman et al., 2013]). The numbers of slum residents officially disconnected from Mumbai's formal water supply was and remains significant.

Nonetheless, all of Mumbai's slum residents were counted when estimating demand, and water was brought from distant valleys in their names, despite the fact that at the point of delivery the same residents were either formally denied access to water following the policy of a cut-off date till 2014 or only partially served by officially following much lower supply standard.

[26] The World Bank was insisting on 24-hour supply and therefore computed demand and shortage accordingly, though in reality the supply was intermittent.

[27] It means space required to store six steel or plastic barrels of 200 litres each, which are commonly used by slum residents in Mumbai.

[28] In 2014 the High Court of Mumbai officially ordered the MCGM to supply water to all non-notified slums.

[29] The first cut-off date was set at 1 January 1995 but was subsequently revised to 1 January 2000 and then 1 January 2011.

Practising per capita supply standards and issues of water distribution

Since the per capita standards prescribed by experts failed to reflect the realities of the distribution network, the estimated demands and computed shortages were not realistic. This approach of demand estimation disconnected the narratives of shortages and the subsequent process of water resources development from the existing conditions of access and status of supply provisioning. As discussed in this section, along with inequities in distribution, this approach concealed inefficiencies of the water distribution network.

Discussions with water supply engineers and experts revealed that Mumbai's distribution network is quite 'messy' with significant leakages and losses, making it impossible to ensure service delivery as per the prescribed per capita standards at the household or even pressure zone level.[30] The pressure zones are very large with several criss-cross connections and are not appropriately demarcated. The hydraulic modelling and necessary maps of the distribution network are not available. Additionally, bulk meters are not present in the system, not all domestic consumers are metered and where they are, the reliability of readings is questionable for several reasons. As a result, the monitoring of water flows within the city and measuring of per capita supply, even at the pressure zone level, is not feasible, and tracing and measuring huge leakages in the system is not possible. The estimated (or guesstimated) leakages and losses are around 40%.

In the existing approach of demand estimation and water resources development, inefficiencies of the distribution network, including massive leakages and losses and inequalities existing in water supply provisioning, are not measured, problematised and prioritised. The discourse is biased towards the development of large water infrastructure, ignoring the distribution network. For example, while conceiving the BWSSP project, on the insistence of the World Bank and against the will of municipal engineers, components of distribution network rehabilitation and leak detection were included (World Bank, 1972). However, during the BWSSP Phase I itself, these components were dropped when the project went for mid-course redefinition due to cost escalation (World Bank, 1996). At the same time the components of water resources development were untouched and executed as per the original plan.

Therefore, the use of prescribed per capita standards delinks the process of water resources development from water distribution. This delinking suppresses the alternative narratives of a lack of access and inequitable distribution within the city and further marginalises poorly served households by not problematising and prioritising distribution network issues.

CONCLUSION

This paper reveals the technopolitics associated with the inequitable distribution of water in the Mumbai Metropolitan Region with a specific focus on the prescribed per capita water supply standard. It illustrates how, historically, relatively high per capita standards have been consistently employed to overestimate water demand and construct narratives of water shortages. This in turn is used to secure a larger share of water in the region and justify the development of water resources for Mumbai, depriving other urban centres and villages for decades.

Since these numbers represent forecasts, one can always argue about the uncertainty associated with the forecasting in support of their inflated nature. However, if such forecasts are to determine the number of villages to be submerged or households to be displaced and severely affecting the long-term development of rural populations from whom the water is being diverted, then it is essential that the process of such forecasting needs to be more realistic, rigorous and cautious, reflecting the learnings from past processes. Yet, the history of estimated water demand figures for Mumbai displays consistent

[30] A pressure zone is a distinct area supplied by a service reservoir within a distribution network.

overestimation. This cannot be ignored by simply labelling a couple of isolated incidents of forecasting errors, as suggested by some commentators on a draft version of this paper.

In colonial times a differential approach was followed while development and management of water supply services for Mumbai. British standards and values (universal public health and access) were followed for 'water resources development', and discriminatory colonial practices were adopted for 'water distribution' within the city. Thus, a differential approach was profoundly inscribed into the city's water supply provisioning from the outset and persists one and a half centuries later.

The approach that estimates water demand and shortages using prescribed per capita standards further delinks the process of water resources development from water distribution. It conceals inequities existing within the city, hides inefficiencies of the distribution network and further marginalises the poor by not problematising their plight of access to water on an everyday basis. Improved access for the poor needs a set of different interventions in the distribution network to increase coverage and enhance the quality of supply provisioning (i.e. pressure and duration, timing and reliability of supply). By suppressing leakages and issues related to the distribution network, this approach creates and perpetuates inequalities for two populations: rural villages outside Mumbai, from whom water is being procured for the city, and slum residents within the city, who are suffering a chronically inadequate and inequitable provision of water.

This paper shows that in the entire history of 160 years of piped water supply Mumbai always had an adequate quantity of water to serve its entire population. However, slum residents were either officially not served or underserved by the city administrators. For decades the water demand of all these slum residents was overcounted by applying higher and uniform per capita standards while computing water demand and justifying dams. Yet the slum residents' share of water stored in the dams in their names was formally denied to them at the point of delivery. This paper illustrates the 'utility' of slum residents, given their number, in the eyes of planners and engineers while justifying the development of water resources for the city. It also questions the utility of a per capita supply standard aside from appropriating water resources from the hinterlands and hiding inefficiencies of the water supply network, as this standard is never practised during water distribution.

For 160 years experts posited a 'future' water crisis, demanding new resources by prescribing a particular number as per capita water supply standard and accordingly forecasting demand. At the same time, however, the suffering of around half the city's population, who were consistently underserved or un-served for decades, were not problematised as a crisis. Failing to adhere to the universal per capita supply standard during water supply distribution (or inequitable distribution in other words) within the city was not flagged as a problem by the experts, so no one aggressively pushed for a solution. Inequitable distribution comes to be seen as a 'natural' phenomenon existing within the distribution network. It is thus crucial that additional studies reveal the understanding, motives and perceptions of those planners and engineers who create and use numbers and problematise only particular situations.

ACKNOWLEDGEMENTS

This paper benefitted from discussions I had with Subodh Wagle. The fieldwork of this study was partly supported by the Ford Foundation as part of the Right to City project.

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