Open Access, Peer Reviewed, Referred Research Journal

Print & Online available on https://jbsd.in
ISSN: 2229-3469 (Print); ISSN: 2231-024X (Online)
Research Article

Connecting The Drops: Estimating The Embedded Water Footprint of Kalyan Dombivli Municipal Corporation's Inhabitants

Astha Smarth Kapur* **and Sardar Ananda Patil****

*Research Scholar, Department of Geography, University of Mumbai, Kalina Campus, Mumbai- 400098, Maharashtra, India. E-mail: asthasmarthkapur@gmail.com
**Associate Professor, Department of Geography, ASP College (affiliated to University of Mumbai), Devrukh, Ratnagiri 415804, Maharashtra, India. E-mail: sardarpatilasp@gmail.com

Article Info

Received: 30-06-2023,
Revised: 22-07-2023,
Accepted: 02-08-2023

Keywords: Embedded/ Indirect water-footprint, Kalyan Dombivli Municipal Corporation (KDMC), paper/plastic use, questionnaire, respondents, wards, water consumption.

Abstract

The resource termed 'Freshwater', exerts a direct impact on a country's social and economic sectors encompassing- livability, health and financial progress. Water is utilized in two forms. Firstly, as direct consumption, which is used for bathing, cleaning, irrigating, washing, drinking, cooling and processing, and secondly as, indirect consumption in the form of farm produce, processed agro-products, textiles, paper (books, notebooks, newspapers, magazines), plastic substances and all commodities purchased/used (including both basic and luxury items) in our daily lives. This research investigation emphasises the 'indirect water footprint' wherein the fresh water required to produce several commodities is embedded in the product but remains concealed from direct perception. The study area of Kalyan Dombivli Municipal Corporation (KDMC) has been selected to carry out this examination. The Ulhas and Kalu Rivers demarcate the northern border of the study region. The territorial limits of the study region are earmarked by 19°11'50" N to 19°18'35" N Latitude and 73º 4'0" E to 73°13'50" E Longitude. A household questionnaire survey and interview sessions were conducted in A, B, C, D, F, G, and H Wards with the view to calculate the 'Indirect Water Footprint'. The water consumption data collected from 1896 respondents has been processed by categorizing it under two heads namely; Paper Use Footprint and Plastic Use Footprint. Finally, the data has been organized, computed, tabulated (MS Excel) and mapped (Arc-Map) to arrive at meaningful conclusions of determining the embedded water use of the residents of KDMC concerning the two aforesaid parameters. It has been found that Ward D appears to have the largest indirect water footprint and Ward G surfaces as the one with the smallest footprint when the whole ward's population is taken into cognizance.

INTRODUCTION

The precious natural resource commonly referred to as Freshwater, flaunts an undeniable characteristic of being, stunningly irreplaceable. It serves as a lifeline for all biota existing on the surface of the Earth, and no wonder, it is the extensive presence of water, which makes our planet appear *blue* from space, although, all the water that imparts it the blue appearance, is not present in the consumable form, which is why, the pricelessness and worth of freshwater becomes all the more established. It is this water, that is directly consumed for quenching the thirst of humans as well as plant and animal kingdoms alike, whilst, maintaining the agrarian, manufacturing and domestic sectors of any place, district, state or country.

Among the other fronts that are the direct consumers of this fresh water are the myriad varieties of economic fronts which are vital for uplifting and stabilizing the financial status of any given nation. The fact of the matter remains that, the management of this resource, owing to its non-ubiquitous nature and limited occurrence, is of fundamental concern, since, the ever-expanding load of population is consistently exerting a huge pressure on the available quantities of freshwater. A large populace means larger water footprints. In India, a colossal portion of the available fresh water is used by agriculture followed by manufacturing sector and then by the domestic sector, at the residential level. If exhausted, due to non-judicious use, the disastrous consequences would leave the denizens in a state of utter confusion, misery and vice. Hence, its preservation, using appropriate conservation and management mechanisms is the key to sustainability. (Mehla *et al.*, 2023)

There exist two types of water footprints, namely direct and indirect water footprint. As the name suggests, the former type refers to, the usage and consumption of visible and tangible water that flows through household taps whereas, the latter type refers to the usage of products or services that consume water during their production process. Herein, the water required for carrying out the processing and allied procedures is hidden, meaning that, the water is present within the commodity in a latent form. Though indirect water and its usage influence the global economy to a fairly large extent, the knowledge of its consumption is limited only to a few informed citizens. Both direct and indirect water consumption patterns have socio-economic and environmental impacts. A combination of these two types of water consumptions can be collectively called as 'water footprint' albeit, even direct and indirect water consumption patterns can individually be addressed as a water footprint. (A.Y. Hoekstra *et al.*, 2011)

Kalyan Dombivli Municipal Corporation is located in an urban setup. It is well understood that the water requirements of an urban scape are always more than that of a rural scape. Thus, the twin cities of Kalyan and Dombivli have higher water consumption rates and consequent demand. But as one moves farther from the cities, the water demand lessens perceptibly. In this study, footprint estimation has been made at the domestic level (household) in KDMC. The study covers three wards of Kalyan (B, C, D), three wards of Dombivli (F, G, H), and one ward of Titwala (A). Within these wards, an attempt has been made to calculate of the '*concealed water footprint'* of the residents, based on a questionnaire survey, conducted during the field study.

Literature review:

In the 21st century, scholars throughout the world have attempted to determine the water footprint of various components. These scholars are worthy of mention, i.e., Becker and Gondhalekar, 2022; Cai *et al.*, 2019; Chalisgaonkar *et al.*, 2018; Chen *et al.*, 2021; Chini *et al.*, 2017; Chuang *et al.*, 2023; Ding *et al.*, 2022; Ercin and Hoekstra, 2014; Fan *et al.*, 2019; Fang *et al.*, 2018; Feng *et al.*, 2012; Fiałkiewicz *et al.*, 2013; Fialkiewicz *et al.*, 2018; Forin *et al.*, 2020; Gong *et al.*, 2023; Bos *et al.*, 2005; Matta, 2010; Musingafi and Tom Tom, 2014; Ramesh and Ramachandran, 2005 Hoekstra, 2017a, 2017b; Islam *et al.*, 2021; Jackson *et al.*, 2015; Kang *et al.*, 2017; Konar and Marston, 2020; Koteswararao and Chandrasekharam, 2019; G. Li *et al.*, 2021; H. Li *et al.*, 2016; Mahjabin *et al.*, 2018; Manzardo *et al.*, 2016; Mehla *et al.*, 2023; Mekonnen and Hoekstra, 2011; Meng *et al.*, 2022; Neeta Lal, 2014; Nouri *et al.*, 2019; Parra-Orobio *et al.*, 2023; Paterson *et al.*, 2015; Penru *et al.*, 2016; Ruiz-Pérez *et al.*, 2022; Rushforth and Ruddell, 2016; Souza *et al.*, 2021; Tian *et al.*, 2019; Varriale, 2018; D. Wang *et al.*, 2021; Y. Wang *et al.*, 2021; Xian *et al.*, 2019; Yerli and Sahin, 2022; F. Zhang *et al.*, 2018; Y. Zhang *et al.*, 2019; D. Zhao *et al.*, 2017; R. Zhao *et al.*, 2015; and X. Zhao *et al.*, 2017. Interesting to know is the fact that, the studies conducted by Chalisgaonkar *et al.*, 2018; Koteswararao *et al.*, 2021; Mehla *et al.*, 2023; and Neeta Lal, 2014, focus on the Water Footprint of India and Indian cities like Delhi, National Capital Region (NCR) and Hyderabad.

Research Gaps and Selection of Topic:

After conducting the literature review, a significant research gap in the area of the water footprint of India and its cities was noticed. It is noteworthy that, only a limited number of studies have focused on this topic, and none have addressed the water footprint of any of the Maharashtrian cities. Therefore, the Kalyan-Dombivali Municipal Corporation has been selected as the study area due to its proximity to Mumbai, the economic capital of India, to investigate this topic further.

Objective

The present research aims to focus on a micro-level assessment of the hidden use of the available water resources. The main objective of the present research work is to find out the indirect water

footprint of the residents of Kalyan-Dombivali Municipal Corporation at the household level.

Study Area

Kalyan-Dombivli is a twin city administered by a municipal corporation with its headquarters located in Kalyan, in Thane district in the Indian state of Maharashtra. It was formed in 1983. The Kalyan Dombivli Municipal Corporation is a robust and swiftly growing municipal corporation. (Kalyan Dombivli Municipal Corporation 2012). It encompasses an area of 75.46 km^2. The Ulhas and Kalu Rivers demarcate the northern border of the study region. The territorial limits of the study region are earmarked by 19°11'50" N to 19°18'35" N Latitude and 73º 4'0" E to 73°13'50" E Longitude. (Water Division-KDMC 2021). Ulhasnagar Corporation borders it on the east, Ulhas Creek in the north, Ulhas and Bhatsa River flank it in the west, Thane Corporation in the southwest, and Navi Mumbai Corporation surrounds it in the east (Kalyan Dombivli Municipal Corporation 2012). Kalyan and its neighbouring township of Dombivli jointly form the Kalyan Dombivli Municipal Corporation, abbreviated as KDMC. (Kalyan Dombivli Municipal Corporation 2012) Figure 1 shows the location of the study area in Thane District, located within the state of Maharashtra in India.

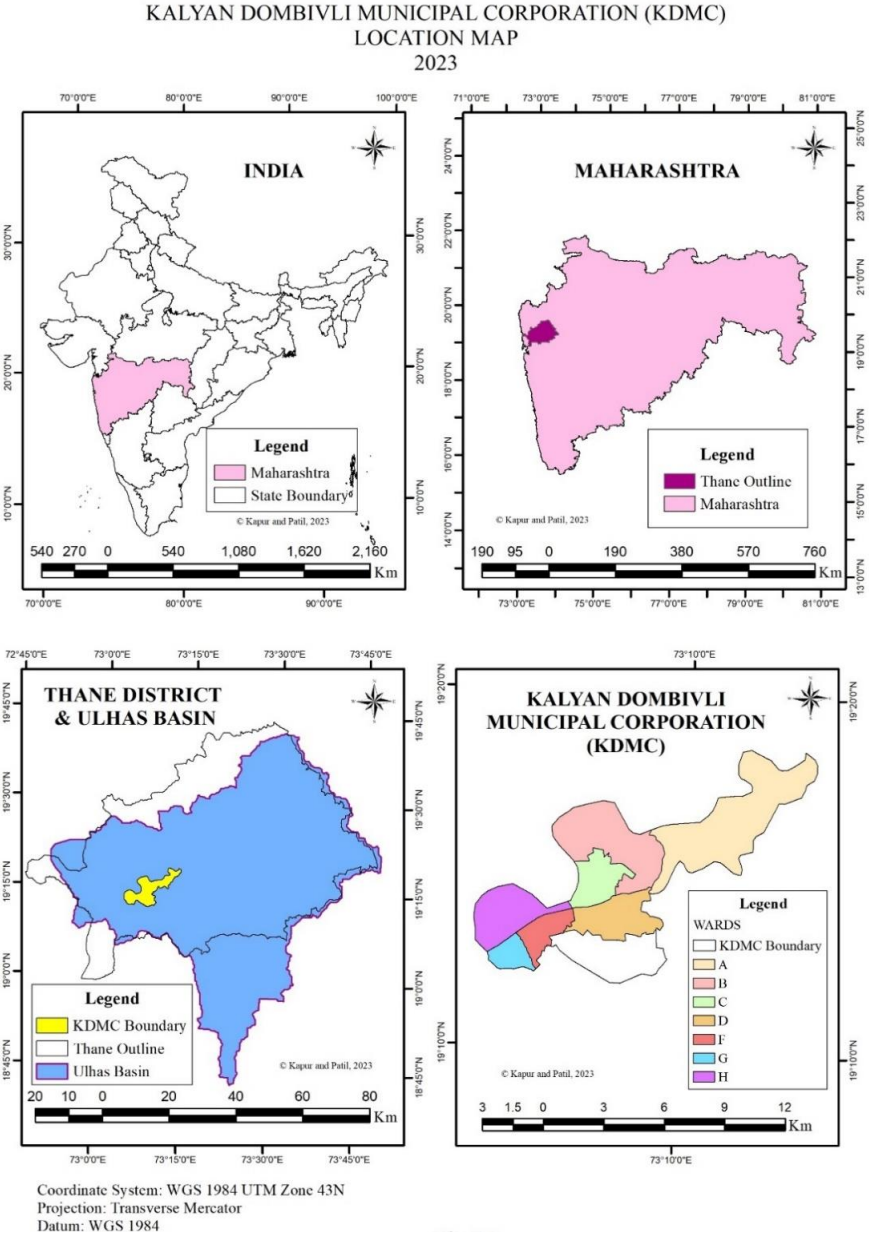

Fig. 1: Location of KDMC Within India

Source: (Survey of India, 2021), (Water Division-KDMC 2021)

MATERIALS AND METHODS

This study is predominantly based on primary sources of data, personally collected during a field survey through the tool of a specially designed well-structured questionnaire, which was prepared bilingually (questions in both English and Marathi) for the convenience of the respondents. Though secondary datasets were also procured from KDMC's office and used here, in terms of the ward-wise population data. A total of 1896 respondents had been interviewed for this purpose. Their responses, recorded in hard and soft copy formats depending upon their preference. These responses, under the headings of- Paper Use and Plastic Use Footprints, were processed and tabulated, using data analysis software like MS Excel and SPSS[1].

To achieve the desired goal, the researchers employed statistical, geostatistical, and spatial analysis techniques. The research methodology used for the study is outlined in the flow chart (Fig. 2). The succeeding paras shall demonstrate the calculations involved.

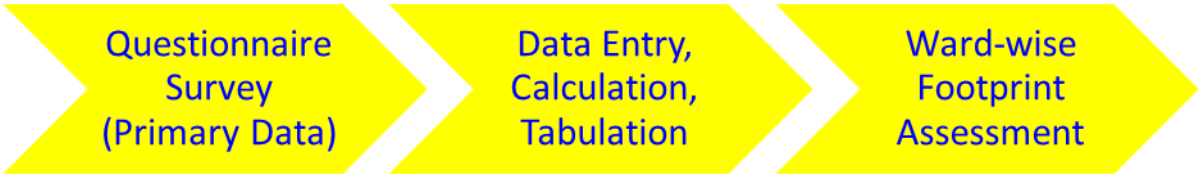

Fig. 2: Methodology
Source: Prepared by the Researcher

Results and Discussion

In an attempt to perform a valid scrutiny of the indirect water footprint of the natives of the study area, several computations with respect to ward-wise population data (2011), number of houses, respondents, their family members and daily discarding of plastic and paper waste were carefully made. This information further enabled the researchers to calculate and estimate the total indirect water footprint of all the residents living in (A, B, C, D, F, G, H) seven wards♦.

Table 1 Kalyan Dombivli Municipal Corporation
Ward-Wise Population, Interviewed Families and Total Members in Interviewed Families, 2023

Wards	Area (in Sq.km.) *	Total Population**	Interviewed Families***	Total Members (all families) ***
A	22.73	122638	428	2152
B	14.31	180251	362	1834
C	5.52	169172	228	1076
D	7.72	145058	256	1256
F	3.86	130474	204	896
G	2.76	114724	206	990
H	8.39	224569	212	1008

*Source: *Calculated by the Researchers in ArcMap Software, **Acquired from*(Directorate of Census Operations 2014), ****Calculated from data obtained during questionnaire survey*

♦ *Note: For total population figures of the seven wards, the 2011 census data has been referred, this ward-wise population data was obtained from the KDMC head office, located in Ward C, Kalyan. Also, the number of respondents who supplied data (by filing the questionnaire), vary from one ward to another. i.e., there is variation in the number of respondents depending on the area (size), which is also variable for the seven selected wards. Only these 7 wards have been selected since they sport an urban outlook.*

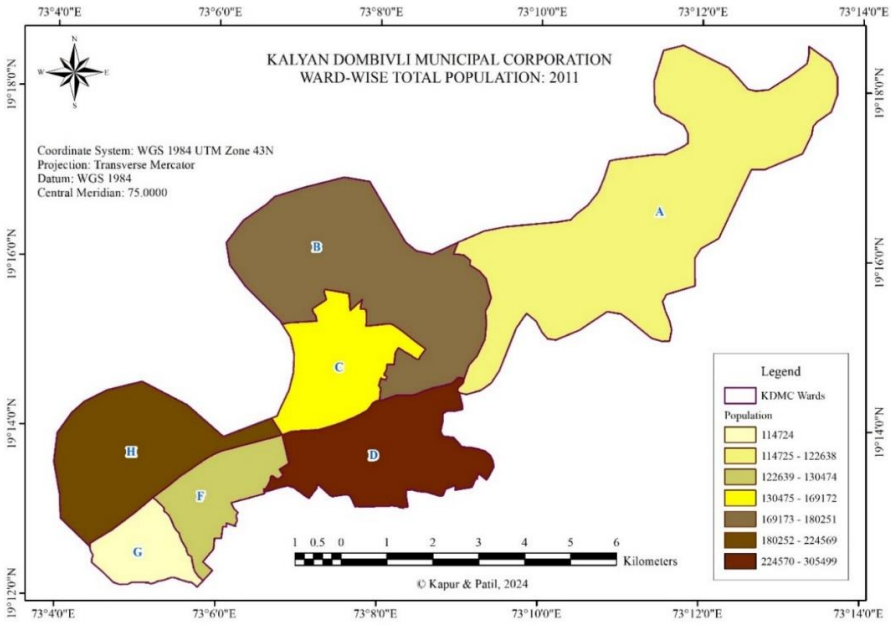

Fig. 3: Ward-wise Total Population of KDMC (2011)
Source: (Directorate of Census Operations 2014)

The two parameters inclusive of amount of 'paper' and 'plastic items' disposed away, helped in calculating the indirect water footprint of the respondents, generated due to their paper and plastic usage. These assisted in acquisition of requisite information pertaining to their everyday concealed consumption of water. The population figures and family member details are repetitive throughout the study and ensuing calculations; thus, they are mentioned in Table 1. Figure 3 presents the ward-wise total population of KDMC. From the map (Figure 3) it is clear that, Ward D followed by Ward H, has the highest total population and Ward G followed by Ward A has the lowest total population. The volume of water (in Liters), required to produce the finished products of paper and plastic used at home by the dwellers was calculated to deduce their concealed footprint•. (Water Department and WWF, 2019)

Paper Use Footprint

Paper is a finished product made out of wood pulp, obtained from specific trees as raw material. It has the characteristics of renewability and biodegradability. Several sheets of paper when joined together, form a book or a notebook, which holds prime importance in gaining education, for students of any age bracket and in manufacturing toilet rolls, tissues, toilet wipes, for printing news, brochures, pamphlets, tickets, stick-bills and so on. These paper sheets even serve the purpose of making paper bags, stickers, cardboard boxes, packaging materials, car filters etc. Therefore, paper, per se, is of dynamic utility, and since its importance cannot be undermined, its usage and disposal are a part and parcel of human existence. (American Forest and Paper Association 2024) There have been instances where reuse and recycling of paper is performed but ultimately it is imperative to understand that the process of paper production involves the consumption of water. This raises the indirect water footprint of the person who finally uses it. Table 2 and Figure 4 present a vivid picture of the 'paper use water footprint' calculations. The mean, median and mode values are similar, thereby depicting consistency and balance within the dataset. Furthermore, there is considerable dispersion from the mean, in all the wards, as represented by the standard deviation values. Though the difference between the maximum and minimum mean and per capita paper use water footprint figures is fairly minuscule, yet there happens to be a huge difference in the total footprint of the wards, wherein, Ward G shows the lowest and Ward D shows the largest footprint values.

• *The standard that acted as the base in the all the subsequent calculations e.g., water usage during machine wash, bucket quantity, flush tank quantity, and tap & shower flow quantity in Liters, were adopted from the standards prescribed by Water Department of World-Wide Fund for Nature (WWF).*

Table 2
Kalyan Dombivli Municipal Corporation
Ward-wise Paper Use Footprint (in liters) of the Residents, 2023

Ward	Respondent's Total FP	Mean FP	Median FP	Mode FP	Standard Deviation	Per-Capita FP	Whole Ward's Foot Print
A	34360	**80.28**	80	80	10.33	15.97	1958104.87
B	28640	79.12	80	80	8.89	**15.62**	2814824.78
C	17960	78.77	80	80	10.38	16.69	2823725.95
D	20040	78.28	80	80	9.04	15.96	**4874363.03**
F	16000	78.43	80	80	8.27	**17.86**	2329892.86
G	16080	**78.06**	80	80	10.27	16.24	**1863395.88**
H	16720	78.87	80	80	10.24	16.59	3724993.73

Source: Calculated by researcher using questionnaire survey data

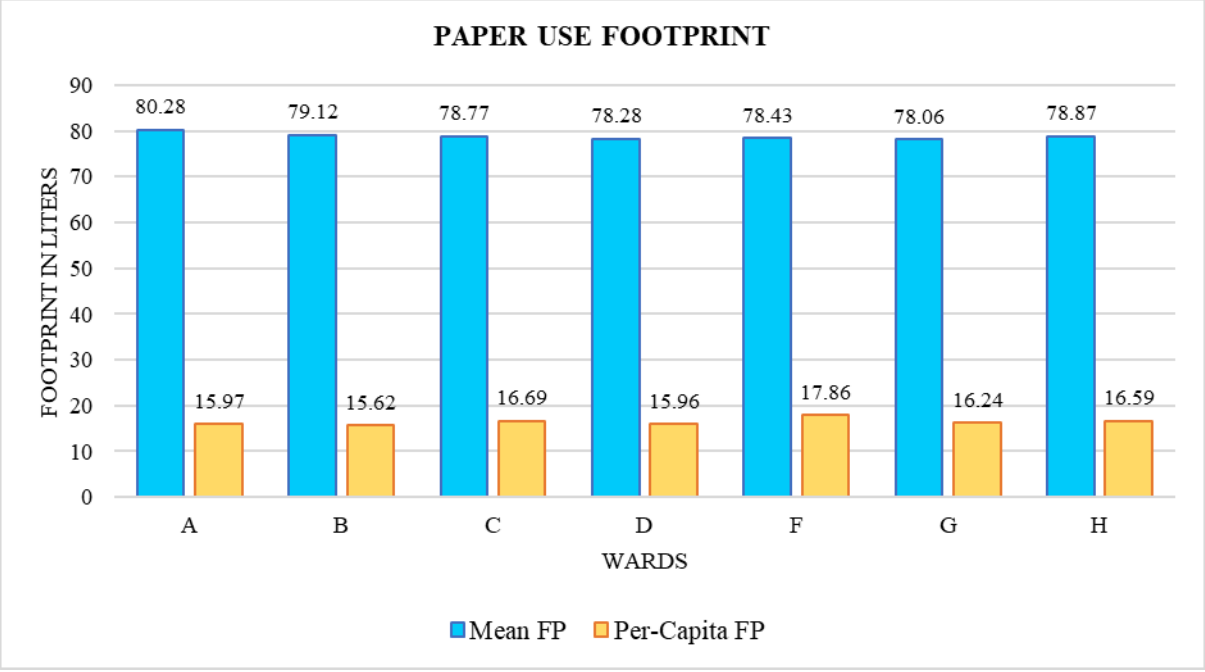

Fig. 4: KDMC Ward-wise Mean and Per Capita Paper Use Footprint, 2023
Source: Made by the Researcher questionnaire survey data

Plastic Use Foot Print

The use of plastic is a necessary evil. Albeit, its harmful/disastrous impacts on the surroundings and environment as a whole, cannot be undermined. Its relevance, not only on the domestic front but also on the agricultural and industrial fronts keeps its cycle of sale-purchase and manufacture, continuous and ongoing. And its advantages continue to override its ills. While conducting the questionnaire survey, several arenas of plastic usage came to light. The residents use it in several forms but its routine use as; milk packets, polythene, plastic bags, straws, packets of savories, packaged water and beverage bottles has been chiefly observed. Therefore, on this basis, the water footprint of the residents has been calculated. The indirect water footprint generated due to the use of plastic is explicit in Table 3. The median and mode values are the same for all the wards, except for Ward A, whose mode footprint (most repetitive value) comes out to be 76.8. It can be observed that the mean figures for almost all wards are pretty close to the median and mode, with just minor differences between them. Ward A depicts the highest and Ward F, the lowest average footprint in litres (Figure 5). The standard deviation values showcase a gap and dispersal from the mean, in the case of all 7 wards, thus, highlighting the presence of variation in the distribution.

As far as the per capita footprints are concerned, negligible differences can be seen among the figures, with 5 out of 7 wards displaying similar footprints and Ward A denoting the largest value. Additionally, from the last column, i.e., total footprints of indirect water consumption, Wards G and D present minimal and maximal water consumption figures respectively.

Table 3
Kalyan Dombivli Municipal Corporation
Ward-wise Plastic Use Footprint (in litres) of the Residents, 2023

Ward	Respondent's Total FP	Mean FP	Median FP	Mode FP	Standard Deviation	Per-Capita FP	Whole Ward's Foot Print
A	22771.2	**53.20**	48	**76.8**	20.41	**10.58**	1297683.28
B	17875.2	49.38	48	48	18.42	9.75	1756828.07
C	11193.6	49.09	48	48	18.19	10.40	1759891.91
D	12192	47.62	48	48	16.68	**9.71**	**2965480.74**
F	9196.8	**45.08**	48	48	14.99	10.26	1339222.41
G	10041.6	48.75	48	48	16.79	10.14	**1163649.01**
H	10425.6	49.18	48	48	16.65	10.34	2322685.09

Source: Calculated by the Researcher questionnaire survey data

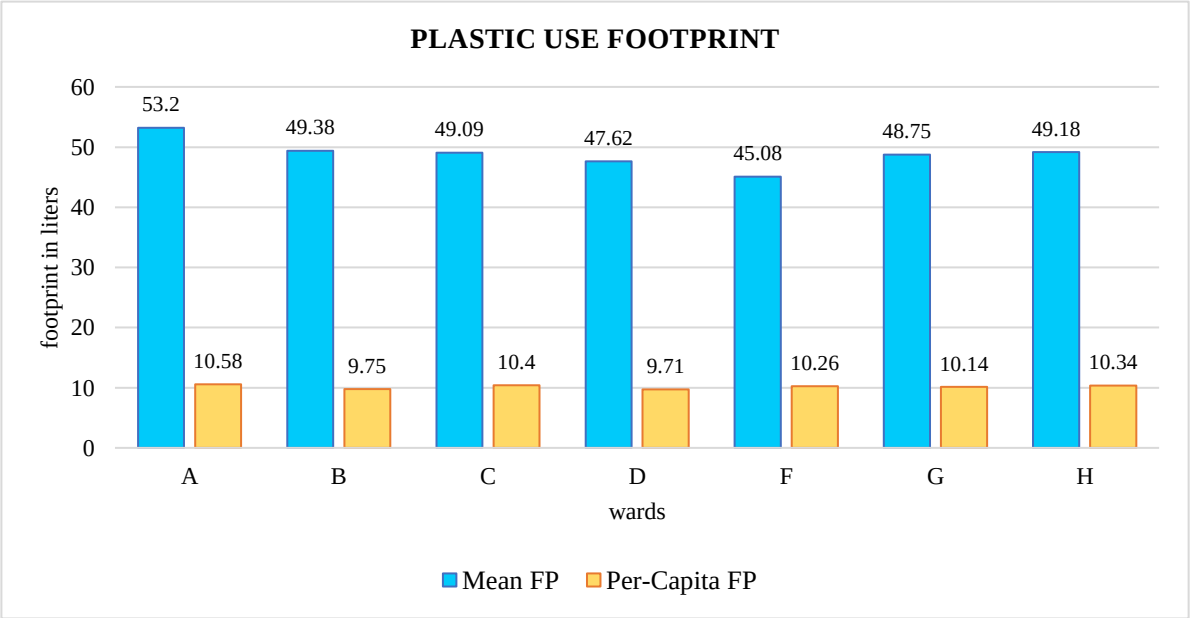

Fig. 5: KDMC Ward-wise Mean and Per Capita Plastic Use Footprint, 2023
Source: Made by the Researcher Using questionnaire survey data

Total Indirect Water Foot Print

While speaking of the indirect water footprint, it is essential to keep in view the two parameters that have been considered, for this area of interest. The total of both these parameters provides an evaluation of the average amount of freshwater that has gone into the manufacturing of the two commodities (paper and plastic). Thus, this hidden water is indirectly consumed by the residents, whenever they purchase any product made of either paper or plastic, they enlarge their indirect water footprint. The indirect water footprint of the interviewed residents of KDMC can be better understood with the help of a map as shown in Figure 6.

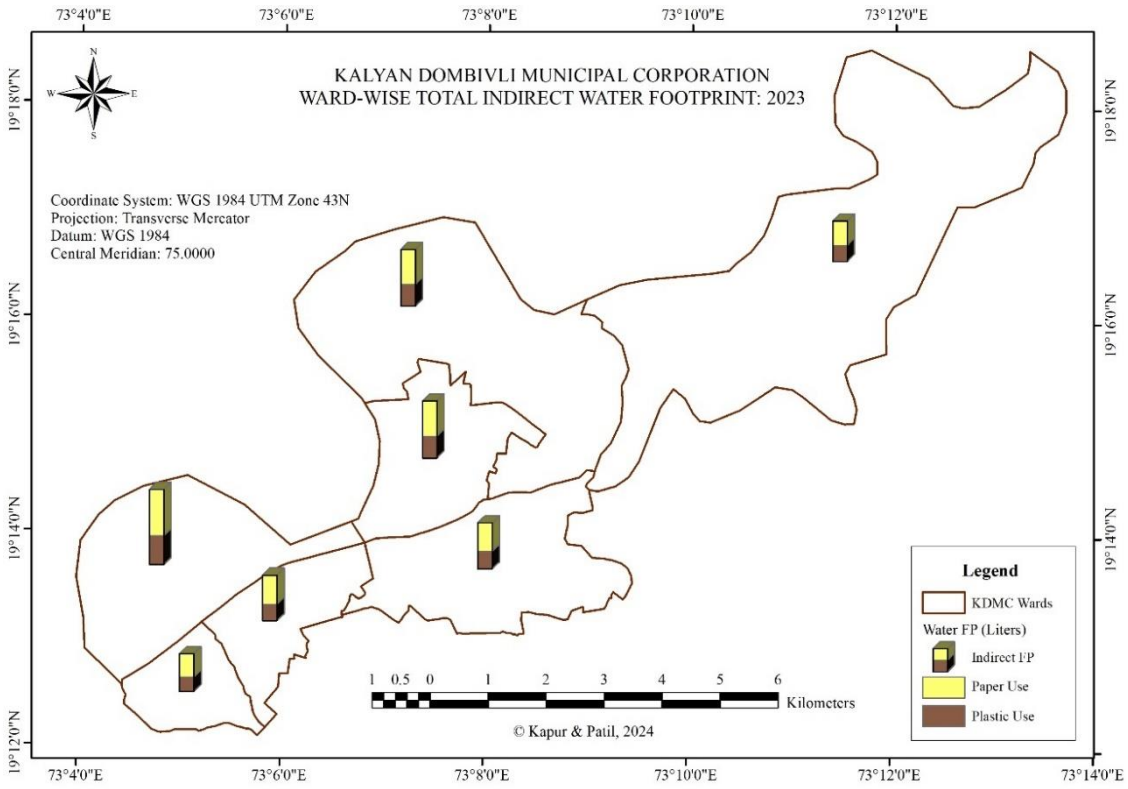

Fig. 6: Ward-Wise Total Indirect Water Footprint, KDMC, 2023
Source: Prepared by the Researcher using questionnaire survey data

Findings

Observation tells that, as far as KDMC's indirect water footprint (for both paper and plastic) vis-à-vis the total population of the whole ward is concerned, Ward D has the highest paper consumption and disposal rate while, Ward G has the lowest rate when the figures for the whole population are considered. On the other hand, when it comes to per capita usage and disposal of paper, Wards B and F emerge as the least and largest consumers respectively. Whereas, for plastic consumption/disposal, Wards A and D surface as the ones with the lowest and largest footprints respectively.

On attempting a comparison of the paper and plastic usage, ward-wise, it becomes clear that, the use of paper greatly surpasses the use of plastic in all the wards. One reason that can be safely attributed to this large difference between paper vs plastic disposal is that a large section of the population of the area in question falls in the student age group and this is the age when paper is a mandatory requirement in order to successfully carry out studies. While conducting the primary survey in order to gather the responses of the people regarding their water needs, it was understood that, in general, the residents of KDMC make a conscious decision to sparingly make use of plastic products given their non-biodegradable nature and harmful impacts on the natural resources, suggesting their concern for the environment. Additionally, it is vital to ascertain the fact that, Ward D displays the highest indirect water footprint in terms of 'total population' of the ward, because, it houses the maximum number of people (Fig. 3) and supports a heavy population density.

A crucial and mention-worthy detail is; since, a large chunk of the inhabitants, comprises of students and also office goers who are open to the option of eating out. This accelerates their consumption of junk/fast food plus hot/cold beverages, which come in paper and plastic packaging. Hence, the enhanced use and disposal of paper and plastic by these people, in a variety of forms is pretty obvious and justified. Besides, the processing and manufacture of fast foods and beverages too require freshwater in copious quantities, thus, further accelerating the inhabitants' indirect water footprints.

CONCLUSION

There are myriad and manifold commodities of human use, whose production and manufacture require several gallons of fresh water, but for the sake of convenience, only two commodities of regular purchase, have been considered here (paper and plastic). Without a doubt, both these items have paved their way into the houses of the residents of KDMC, in the form of newspapers, writing sheets, note-books, covering papers, paper bags etc. as well as milk packets, polythene bags, plastic water/cold drink bottles and so on. There is a pressing need of the hour that, the young adults i.e., students as well as the mature and elderly must attempt to reduce their paper use and plastic burden on the environment. The scope of this burden needs to encompass other consumer goods like; textiles, processed foods, handbags, shoes, clothes etc. Even the paper wastage needs to come down drastically. For this purpose, collective efforts, in the form of awareness campaigns, on the part of the citizens and the ULB need to be channelized and put into effect at the earliest. These undertakings, commencing at the micro or household level will go a long way in not only reducing the stress on the precious freshwater resources but also on the environment as a whole. Herein, the youth can play a pivotal role in terms of footprint reduction and 'green' production, especially in colleges through awareness programs. This will further help them to understand the evils of their indiscriminate dependence on the practice of consumerism and those goods and services that are highly water intensive like; leather products, animal meat etc. Therefore, they shall attempt to curb their overall water consumption by minimising embedded water footprint.

REFERENCES

American Forest and Paper Association, 2024. Pulp http:// https://www.afandpa.org/paper-wood-products/pulp#:~:text=Pulp%20is%20used%20in%20a,cardboard

Becker L, Gondhalekar D, 2022. Estimating the Water and Carbon Footprints of Growing Avocados in the Munich Metropolitan Region Using Waste Heat as a Water-Energy-Food Nexus Potential. *Front Sustain Food Syst*, **6**. doi:10.3389/fsufs.2022.857650.

Cai B, Liu B, Zhang B, 2019. Evolution of Chinese urban household's water footprint. *J Clean Prod*, **208**. doi:10.1016/j.jclepro.2018.10.074.

Chalisgaonkar D, Jain SK, Nema MK, Mishra PK, 2018. *Quantification of Water Footprint of National Capital Territory (Nct) of Delhi, India*. In: Singh V, Yadav S, Yadava R, editors. Water Resources Management. Select Proceedings of ICWEES-2016, **78**. Singapore: Springer Nature Singapore Pte Ltd, Pp 151–165.

Chen Z, Gong B, Jiang J, Liu Z, Chen K, 2021. Dynamics of the Urban Water Footprint on the Tibetan Plateau: A case study of Xining, China. *Int J Environ Res Public Health*, **18**(9). doi:10.3390/ijerph18094566.

Chini CM, Konar M, Stillwell AS, 2017. Direct and indirect urban water footprints of the United States. *Water Resources Res*, **53**(1). doi:10.1002/2016WR019473.

Chuang WK, Lin ZE, Lin TC, Lo SL, Chang CL, Chiueh P Te, 2023. Spatial allocation of LID practices with a water footprint approach. *Science of the Total Environment*, **859**. doi:10.1016/j.scitotenv.2022.160201.

Ding Y, Li Yongping, Zheng H, Ma Y, Huang G, Li Yanfeng, Shen Z, 2022. Mapping Water, Energy and Carbon Footprints Along Urban Agglomeration Supply Chains. *Earths Future*, **10**(4). doi:10.1029/2021EF002225.

Directorate of Census Operations M, 2014. Census District Handbook, Village and Town Directory, 2011. 28th-Part XII A ed. *Thane: Directorate of Census Operations, Maharashtra*.

Ercin AE, Hoekstra AY, 2014. Water footprint scenarios for 2050: A global analysis. *Environ Int*, **64**. doi:10.1016/j.envint.2013.11.019.

Fan JL, Wang J Da, Zhang X, Kong LS, Song QY, 2019. Exploring the changes and driving forces of water footprints in China from 2002 to 2012: A perspective of final demand. *Science of the Total Environment*, **650**. doi:10.1016/j.scitotenv.2018.08.426.

Fang K, Zhang Q, Yu H, Wang Y, Dong L, Shi L, 2018. Sustainability of the use of natural capital in a city: Measuring the size and depth of urban ecological and water footprints. *Science of the Total Environment*. doi:10.1016/j.scitotenv.2018.02.299.

Feng K, Siu YL, Guan D, Hubacek K, 2012. Assessing regional virtual water flows and water footprints in the Yellow River Basin, China: A consumption based approach. *Applied Geography*, **32**(2). doi:10.1016/j.apgeog.2011.08.004.

Fialkiewicz W, Bursztа-Adamiak E, Kolonko-Wiercik A, Manzardo A, Loss A, Mikovits C, Scipioni A, 2018. Simplified direct water footprint model to support urban water management. *Water (Switzerland)*, **10**(5). doi:10.3390/w10050630.

Fiałkiewicz W, Burszta-Adamiak E, Malinowski P, Kolonko A, 2013. Urban Water Footprint City Water Management Monitoring and Evaluation System. *Ochrona Srodowiska*, **35**(3).

Forin S, Mikosch N, Berger M, Finkbeiner M, 2020. Organizational water footprint: A methodological guidance. *International Journal of Life Cycle Assessment*, **25**(2). doi:10.1007/s11367-019-01670-2.

Gong B, Liu Z, Liu Y, Zhou S, 2023. Understanding advances and challenges of urban water security and sustainability in China based on water footprint dynamics. *Ecol Indic*, **150**. doi:10.1016/j.ecolind.2023.110233.

Hoekstra AY, 2017a. Water Footprint Assessment: Evolvement of a New Research Field. *Water Resources Management*, **31**(10):3061–3081. doi:10.1007/S11269-017-1618-5/FIGURES/3. [accessed 2023 Aug 13]. https://link.springer.com/article/10.1007/s11269-017-1618-5.

Hoekstra AY, 2017b. Water Footprint Assessment: Evolvement of a New Research Field. *Water Resources Management*, **31**(10). doi:10.1007/s11269-017-1618-5.

Hoekstra A. Y., Chapagain AK, Aldaya MM, Mekonnen MM, 2011. The Water Footprint Assessment Manual: Setting the Global Standard. London.

Islam KMN, Kenway SJ, Renouf MA, Wiedmann T, Lam KL, 2021. A multi-regional input-output analysis of direct and virtual urban water flows to reduce city water footprints in Australia. *Sustain Cities Soc*, **75**. doi:10.1016/j.scs.2021.103236.

Jackson N, Konar M, Hoekstra AY, 2015. The water footprint of food aid. *Sustainability (Switzerland)*, **7**(6). doi:10.3390/su7066435.

Kalyan Dombivli Municipal Corporation,2012. Revised City Development Plan, Published by *KDMC*, Kalyan.

Kang J, Lin J, Zhao X, Zhao S, Kou L, 2017. Decomposition of the urban water footprint of food consumption: A case study of Xiamen City. *Sustainability (Switzerland)*, **9**(1). doi:10.3390/su9010135.

Konar M, Marston L, 2020. The water footprint of the United States. *Water (Switzerland)*, **12**(11). doi:10.3390/w12113286.

Koteswara Rao D, Chandrasekharam D, 2019. Quantifying the water footprint of an urban agglomeration in developing economy. *Sustain Cities Soc*, **50**. doi:10.1016/j.scs.2019.101686.

Koteswara Rao D, Regonda SK, Dornadula C, 2021. Water and food nexus: Role of socio-economic status on water-food nexus in an urban agglomeration Hyderabad, India using consumption water footprint. *Water (Switzerland)*, **13**(5). doi:10.3390/w13050637.

Li G, Han X, Luo Q, Zhu W, Zhao J, 2021. A study on the relationship between income change and the water footprint of food consumption in urban China. *Sustainability (Switzerland)*, **13**(13). doi:10.3390/su13137076.

Li H, Liu G, Yang Z, Hao Y, 2016. Urban Gray Water Footprint Analysis Based on Input-Output Approach. *Energy Procedia*, **104**.

Mahjabin T, Garcia S, Grady C, Mejia A, 2018. Large cities get more for less: Water footprint efficiency across the US. *PLoS One*, **13**(8). doi:10.1371/journal.pone.0202301.

Manzardo A, Loss A, Fialkiewicz W, Rauch W, Scipioni A, 2016. Methodological proposal to assess the water footprint accounting of direct water use at an urban level: A case study of the Municipality of Vicenza. *Ecol Indic*, **69**. doi:10.1016/j.ecolind.2016.04.016.

Mehla MK, Kothari M, Singh PK, Bhakar SR, Yadav KK, 2023. Water footprint assessment and its importance in Indian context: A meta-review. *Water Supply*, **23**(8).

Mekonnen MM, Hoekstra AY. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. *Value of Water Research Report Series, UNESCO-IHE, Delft, The Netherlands*, **1**(50).

Meng X, Lu J, Wu J, Zhang Z, Chen L, 2022. Quantification and Evaluation of Grey Water Footprint in Yantai. *Water (Switzerland)*, **14**(12). doi:10.3390/w14121893.

Neeta Lal, 2014. India's growing water footprint not sustainable, say experts. *The Third Pole*.

Nouri H, Chavoshi Borujeni S, Hoekstra AY, 2019. The blue water footprint of urban green spaces: An example for Adelaide, Australia. *Land Urban Plan*, **190**. doi:10.1016/j.landurbplan.2019.103613.

Parra-Orobio BA, Soto-Paz J, Ramos-Santos A, Sanjuan-Quintero KF, Saldaña-Escorcia R, Dominguez-Rivera IC, Sánchez A, 2023. Assessment of the Water Footprint in Low-Income Urban

Neighborhoods from Developing Countries: Case Study Fátima (Gamarra, Colombia). *Sustainability (Switzerland)*, **15**(9). doi:10.3390/su15097115.

Paterson W, Rushforth R, Ruddell BL, Konar M, Ahams IC, Gironás J, Mijic A, Mejia A, 2015. Water footprint of cities: A review and suggestions for future research. *Sustainability (Switzerland)*, **7**(7). doi:10.3390/su7078461.

Penru Y, Antoniucci D, Barrero MJA, Chevauché C, 2016. Water footprint calculation: application to urban water cycle. *International Journal on Interactive Design and Manufacturing*, **10**(3). doi:10.1007/s12008-016-0327-2.

Ruiz-Pérez MR, Alba-Rodríguez MD, Marrero M, 2022. Evaluation of water footprint of urban renewal projects. Case study in Seville, Andalusia. *Water Res*, **221**. doi:10.1016/j.watres.2022.118715.

Rushforth RR, Ruddell BL, 2016. The vulnerability and resilience of a city's water footprint: The case of Flagstaff, Arizona, USA. *Water Resour Res*, **52**(4). doi:10.1002/2015WR018006.

Souza FAA, Bhattacharya-Mis N, Restrepo-Estrada C, Gober P, Taffarello D, Tundisi JG, Mendiondo EM, 2021. Blue and grey urban water footprints through citizens' perception and time series analysis of Brazilian dynamics. *Hydrological Sciences Journal*, **66**(3). doi:10.1080/02626667.2021.1879388.

Survey of India, 2021. Onlinemaps Portal. Online Services to Citizens, Business and More, Survey of India, Ministry of Science and Technology, Government of India https://onlinemaps.surveyofindia.gov.in/

Tian Z, Wang S, Chen B, 2019. A three-scale input-output analysis of blue and grey water footprint for Beijing-Tianjin-Hebei Urban Agglomeration. *Energy Procedia*, **158**.

Varriale R, 2018. New water footprint indicators for urban water cycle. *TeMA - Journal of Land Use, Mobility and Environment*, **11**(3).

Varriale R, 2019. Water Footprint Indicators for Urban Planning. *TeMA - Journal of Land Use, Mobility and Environment*. **3** (20).

Wang D, Hubacek K, Shan Y, Gerbens-Leenes W, Liu J, 2021. A review of water stress and water footprint accounting. *Water (Switzerland)*, **13**(2). doi:10.3390/w13020201.

Wang Y, Xian C, Ouyang Z, 2021. Integrated assessment of sustainability in urban water resources utilization in China based on grey water footprint. *Shengtai Xuebao*, **41**(8). doi:10.5846/stxb201911302593.

Water Department, WWF, 2019. *Water Footprint of the Residents of Delhi*. World Wide Fund for Nature, New Delhi.

Water Division-KDMC, 2021. *Maps & Shapefile*. Kalyan Dombivli Municipal Corporation.

Xian C, Pan X, Zhen Q, Han B, Jiang Y, Zhou W, Ouyang Z, 2019. Integrated assessments of nitrogen pollution footprints and grey water footprints in the urban ecosystem. *Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae*, **39**(3). doi:10.13671/j.hjkxxb.2018.0451.

Yerli C, Sahin U, 2022. An assessment of the urban water footprint and blue water scarcity: A case study for van (Turkey). *Brazilian Journal of Biology*, **82**. doi:10.1590/1519-6984.249745.

Zhang F, Zhan J, Li Z, Jia S, Chen S, 2018. Impacts of urban transformation on water footprint and sustainable energy in Shanghai, China. *J Clean Prod*, **190**. doi:10.1016/j.jclepro.2017.08.157.

Zhang Y, Tian Q, Hu H, Yu M, 2019. Water footprint of food consumption by Chinese residents. *Int J Environ Res Public Health*, **16**(20). doi:10.3390/ijerph16203979.

Zhao D, Tang Y, Liu J, Tillotson MR, 2017. Water footprint of Jing-Jin-Ji urban agglomeration in China. *J Clean Prod*, **167**. doi:10.1016/j.jclepro.2017.07.012.

Zhao R, He H, Zhang N, 2015. Regional water footprint assessment: A case study of Leshan City. *Sustainability (Switzerland)*, **7**(12). doi:10.3390/su71215829.

Zhao X, Tillotson MR, Liu YW, Guo W, Yang AH, Li YF, 2017. Index decomposition analysis of urban crop water footprint. *Ecol Modell*, **348**. doi:10.1016/j.ecolmodel.2017.01.006.