Water Supply Engineering
Prof. Manoj Kumar Tiwari
School of Water Resources
Indian Institute of Technology-Kharagpur

Lecture - 07
Components of Water Demand

Hello friends and welcome back. We have been discussing about the water demand in the earlier lecture and in this particular lecture we will take the discussion further, we will talk about what are the various components of the water demand.

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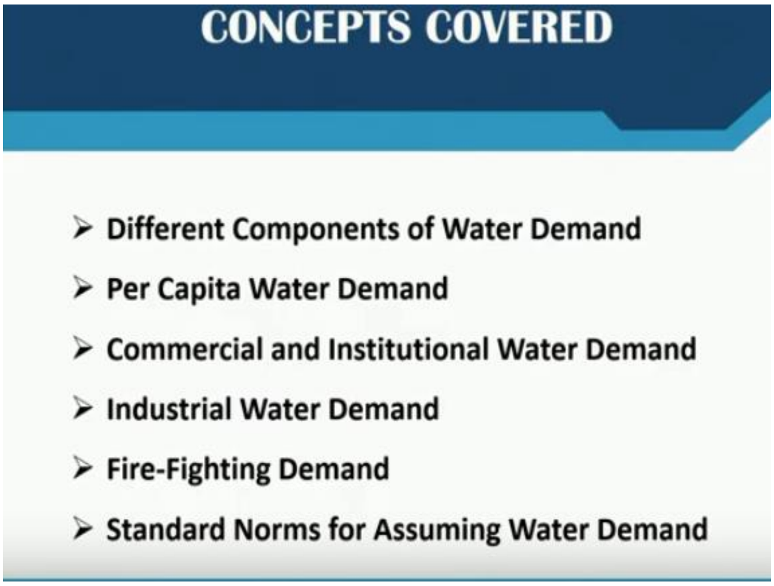

In previous lecture we discussed about the basic aspects of water demand and what are the various types of water demand. In this class, what we are going to cover is what are the various components of the water demand specifically the domestic water demand, which is typically represented in per capita water demand. Then the other types of demand like commercial, institutional water demand or industrial water demand we will touch upon these aspects as well.

We will see how firefighting demand is estimated and what are the various guidelines given for that and some of the empirical formulas that are used for the estimating firefighting demand. And towards the end, we will discuss what are the standard norms for assuming water demand, because we need to consider, we may need to assume certain water demand for design purpose. So what are the norms for that.

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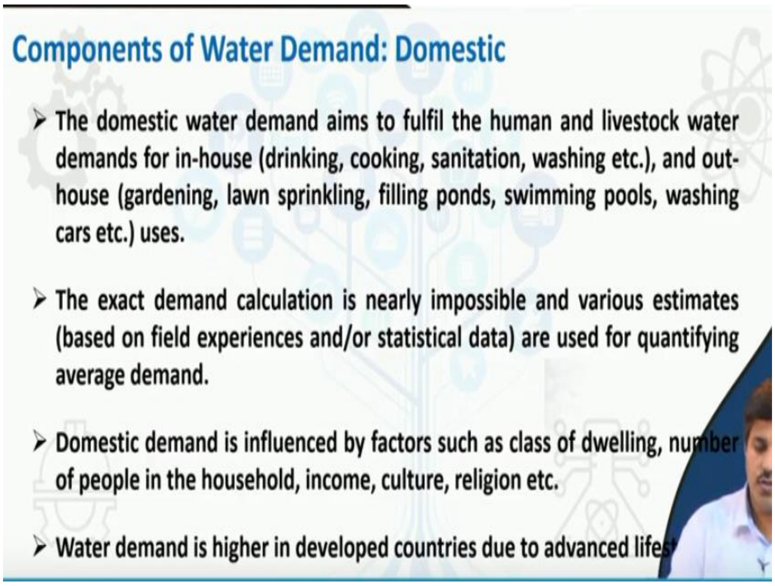

So to begin with the most important use of water is meeting domestic demand okay because this particularly the in-house domestic demand which includes drinking, cooking, basic sanitation. So these are some of the most important uses of water, although the bulk of the water is used in the agricultural sector, but when we prioritize the uses, it is the domestic demand which comes at the first priority.

So that is the first priority and then within the domestic we can have certain out-house uses as well like gardening, lawn sprinkling, then kind of people if they are having swimming pool at the home, so the water for the swimming pool, washing cars, washing lawns, so those kind of demand is also considered under the domestic demand only. The exact demand calculation is practically impossible, okay.

Because there is so much variability in the uses of water. The my capacity of using water or my habit of using water is going to be different than presumably any other person out there. So I might drink say three liters of water per day somebody might be drinking two somebody might be drinking four somebody might be drinking five some people might be drinking three also.

But then for how long I take the bath for how many times I go to the washroom or toilets and then the flush the toilets, okay. What are my food habits, so particularly there is so much variability across the habit of the people and the living standard and the kind of type of dwellings all those things. So based on that, it practically becomes very impossible to precisely calculate the demand or to precisely know how much water a person is going to use.

Further, there is so much of variation in the uses of demand. We will discuss that though in the subsequent lectures. But just to brief on that a person's water demand on a winter day may be different than that on a summer day and then that on a monsoon day. Then if it is a weekend, vacations people are at home, so the amount of water consumed at home is probably going to be higher than the other.

So there are lot many factors lot many stuff which kind of leads to the fluctuation in the demand as well. We will discuss those in the detail in one of the later classes. But the point is that overall this domestic demand is influenced by the kind of factors such as class of dwellings, number of people living in a household, what is the income, what is the culture they are being followed, what is the religion, sanitation practices, food habits, so on variety of aspects okay.

Generally what has been seen that water demand is higher in the developed countries.

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Per Capita Water Consumption: Domestic

S. No.	Use/purpose	Quantity, L/c-d
1.	Drinking	05
2.	Cooking	05
3.	Bathing	55
4.	Laundry	20
5.	Utensils washing	10
6.	House washing	10
7.	Toilet washing, etc.,	30
	Total	135 L/c-d

Source: IS 1172–1983: Code of basic requirements for water supply, drainage and sanitation—Bureu of Indian standards

And that is presumably due to the lifestyle which is fairly advanced in the developed world as opposed to the developing countries or underdeveloped countries. So in India, if we see the guidelines, the IS code that suggest around 135 liters per capita per day of water consumption. So liter per capita per day essentially means liter per person per day. That is divided into various sub uses, okay.

Again, it is number which is kind of put like a guideline, in the form of a guideline. It does not necessarily means that drinking water is only five liters per day per person or cooking water is only five liters per day per person. This varies a lot, this is kind of an average value based on the statistical data available and the experts opinion that has been encountered in putting these guidelines.

So typically, for drinking and cooking purpose, the demand is considered as five liters per person per day or per capita per day. Bathing is the highest water consumption in home around 55 liters per capita per day. Then the laundry for 20 and cleaning utensils, house cleaning is around 10 and the toilet washing which is the second largest is of the order of 30.

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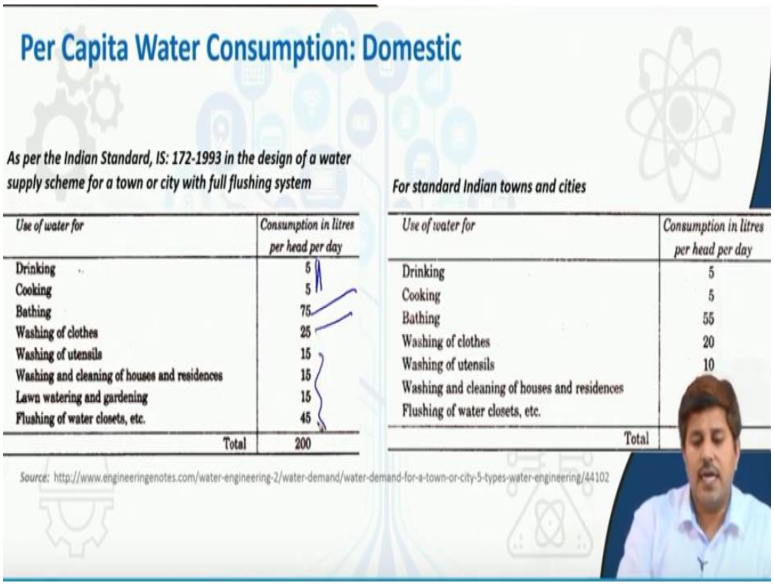

However, these numbers are not uniformly accepted and are not actually fixed, okay. Even the IS code have different standards for different type of city. The one that we were seeing is considered applicable for standard towns and cities of moderate sizes. But if we kind of see the guideline for the for this bigger towns and particularly cities with full flushing system, it used to be 200 lpcd, where the drinking and cooking needs were of similar capacity.

But then bathing was 75, washing clothes 25. So all other uses were practically hiked okay. So that is one another estimate from the IS code.

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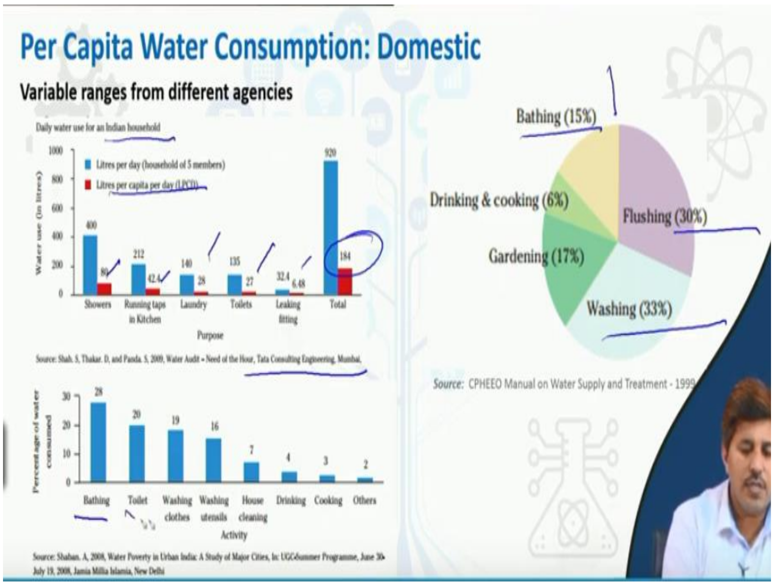

However, there are variable ranges reported from the different agencies as well okay and these variation are in substantial ranges okay. So if we see kind of let us say in a study conducted in Mumbai okay this is from Tata Consulting Engineers, Mumbai. So they figured out that for an Indian household, average Indian household, the per capita demand, red blocks are for per capita demand.

So per capita demand is 80 for showers around 42 for running taps in the kitchen, so for kitchen purpose, 28 goes to laundry, 27 goes to toilets. Then leaking and fittings is around 6.48 and overall consumption is 184 liters per capita per day, average consumption okay. That is one use, one type of kind of study done. There are similar other studies.

But they may come, actually come present a different kind of numbers as well like CPHU manual suggest that bathing requirement is 15% whereas flushing is 30% and washing is 33%. So they consider bathing required smaller whereas, in most of the studies, the showers or the water for bathing purpose is considered as the highest consumption within the household, okay.

That was also found in another study where percentage of water consumed for bathing was actually 28%, for toilet 20% and then rest of the consumptions were relatively smaller.

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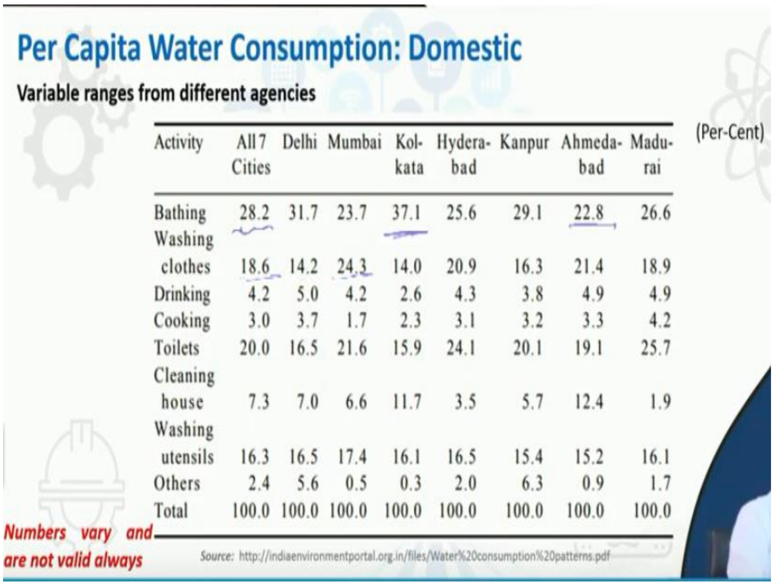

Per Capita Water Consumption: Domestic

Variable ranges from different agencies

(Per-Cent)

Activity	All 7 Cities	Delhi	Mumbai	Kol-kata	Hydera-bad	Kanpur	Ahmeda-bad	Madu-rai
Bathing	28.2	31.7	23.7	37.1	25.6	29.1	22.8	26.6
Washing clothes	18.6	14.2	24.3	14.0	20.9	16.3	21.4	18.9
Drinking	4.2	5.0	4.2	2.6	4.3	3.8	4.9	4.9
Cooking	3.0	3.7	1.7	2.3	3.1	3.2	3.3	4.2
Toilets	20.0	16.5	21.6	15.9	24.1	20.1	19.1	25.7
Cleaning house	7.3	7.0	6.6	11.7	3.5	5.7	12.4	1.9
Washing utensils	16.3	16.5	17.4	16.1	16.5	15.4	15.2	16.1
Others	2.4	5.6	0.5	0.3	2.0	6.3	0.9	1.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Numbers vary and are not valid always

Source: http://indiaenvironmentportal.org.in/files/Water%20consumption%20patterns.pdf

There has been another study, so the point is that these number vary and may not always be valid, okay. This is a report from another study which studies seven cities and they also came up with different percentage numbers for different uses. So for bathing it is around for, if you take the average of all cities it is around 28 but it actually varies from 22.8 in Ahmedabad to around if you see the highest is in around Kolkata 37.1% okay.

Similarly, like for washing clothes, the average was 18.6%. The variation was again the highest requirement was in Mumbai and the lowest requirement was actually in the Delhi. So that way, the different uses could be different, like the percentage of water required for different uses could be different across the different cities or different places as well.

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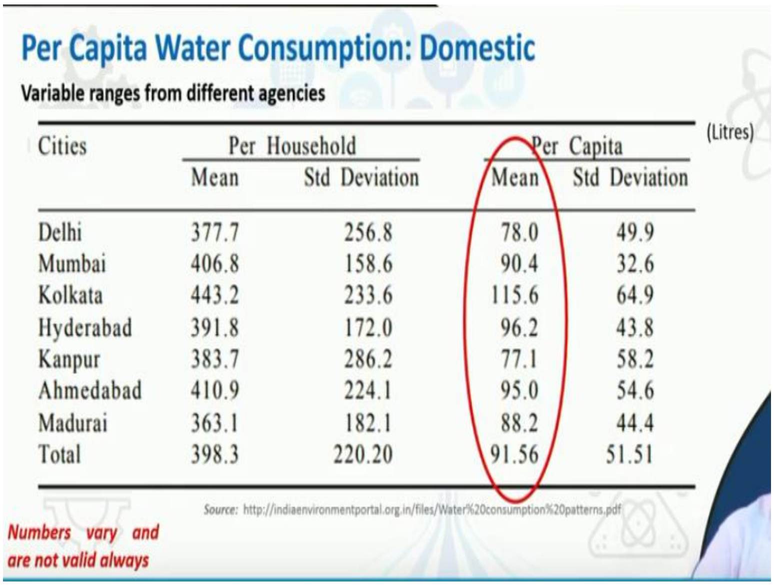

Cities	Per Household		Per Capita	
	Mean	Std Deviation	Mean	Std Deviation
Delhi	377.7	256.8	78.0	49.9
Mumbai	406.8	158.6	90.4	32.6
Kolkata	443.2	233.6	115.6	64.9
Hyderabad	391.8	172.0	96.2	43.8
Kanpur	383.7	286.2	77.1	58.2
Ahmedabad	410.9	224.1	95.0	54.6
Madurai	363.1	182.1	88.2	44.4
Total	398.3	220.20	91.56	51.51

The same study also has estimated overall per capita consumption and the mean values reported for Delhi, Mumbai, Kolkata, Hyderabad, Kanpur, Ahmedabad, Madurai given kind of a total average mean of just above 90 liters per capita per day, which is actually looks smaller and does not look true if we see the guidelines.

And the standard uses reported by the various utilities because the amount of water supplied per capita, if we see the number from the different utilities, it varies widely and particularly in the cities like metros, Delhi, Mumbai, Kolkata, it is substantially high, okay. So it says that around like even Delhi consuming 78 liters per capita per day is a pretty low number, okay.

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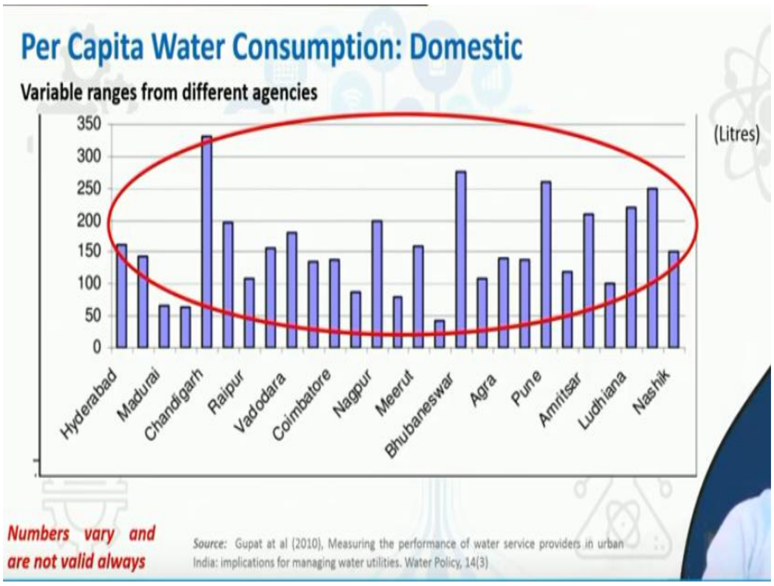

This is another report actually, which is from various cities, more number of cities was considered in here and we can see that the per capita uses was as low as less than 50 in some places okay. And whereas, in Chandigarh it was actually more than 300, okay. In Bhubaneshwar again more than around 275 or so. So there are places where the water consumption is very high.

There is places where the water consumption is very low, per capita water consumption. This essentially may not be the actually demand okay because the demand from people may be higher. Many of these studies does not consider demand, but consider the consumption. So even if my demand is higher, the amount of water being supplied to me is less. So that case the total consumption is going to be less.

So per capita consumption might be less even though the demand is higher. So that aspect also needs to be considered when we are actually discussing the demand.

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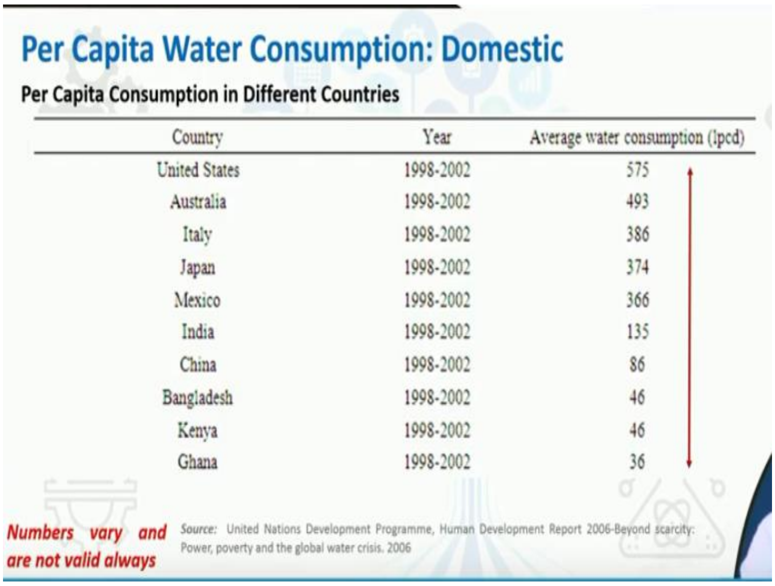

Country	Year	Average water consumption (lpcd)
United States	1998-2002	575
Australia	1998-2002	493
Italy	1998-2002	386
Japan	1998-2002	374
Mexico	1998-2002	366
India	1998-2002	135
China	1998-2002	86
Bangladesh	1998-2002	46
Kenya	1998-2002	46
Ghana	1998-2002	36

Now the per capita consumption in different countries also vary, okay and it is interesting that to see that many of the developed countries like United States has around over 575 liters per capita per day consumption. Australia of the order of around 500. Italy 386. So the developed countries has quite high water demand. India we have 135.

And there are countries like China, Bangladesh, Kenya, so they have much smaller per capita consumption as well. So it depends on the amount of water being supplied and the demand being arised from the people.

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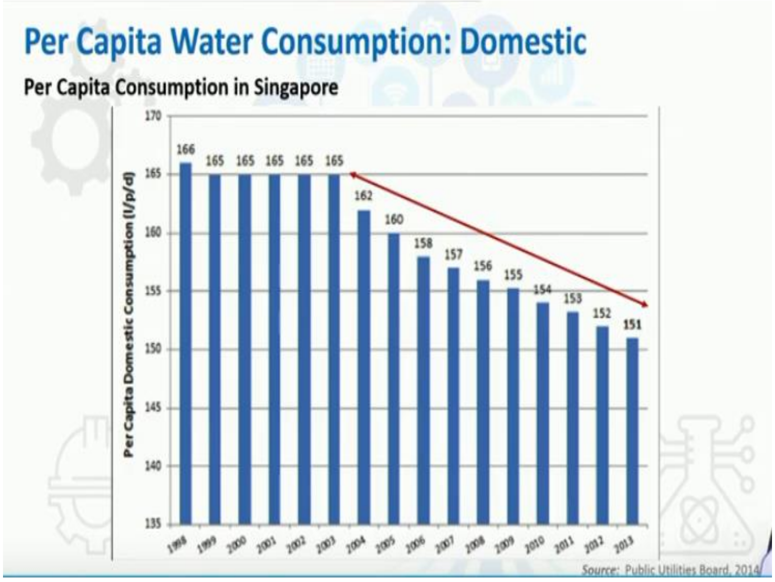

Now this demand, per capita demand may be controlled also. It is not necessarily that per capita demand is fixed or it is always, many places it is found to be increasing because as we are going towards more and more modern lifestyle, okay as you see that in the developed nations the water demand is high.

So as we are also on the like following the same path for the development, we are also tending to use more water, okay. We are shifting from taking bath in the bucket to taking bath in the say shower, moving to the shower then moving to the bathtubs Jacuzzis and swimming pool. So that will of course lead to increase in the per capita consumption.

Washing clothes by hand in a bucket or a couple of buckets water as opposed to using the washing machines is of course going to increase the water consumption. So that way, the water like with the progress of time, water consumption typically increases but it can be controlled also and Singapore has presented a very nice example for that how we can control the per capita consumption.

So in Singapore, like up to around 2003, the water consumption is 165 liters per capita per day, but with the interventions of the Public Utilities Board, they have been able to cut down their water consumption to less than 150 now okay. The data till 2013 suggest that it is 151 but they have cut down it now to less than 150.

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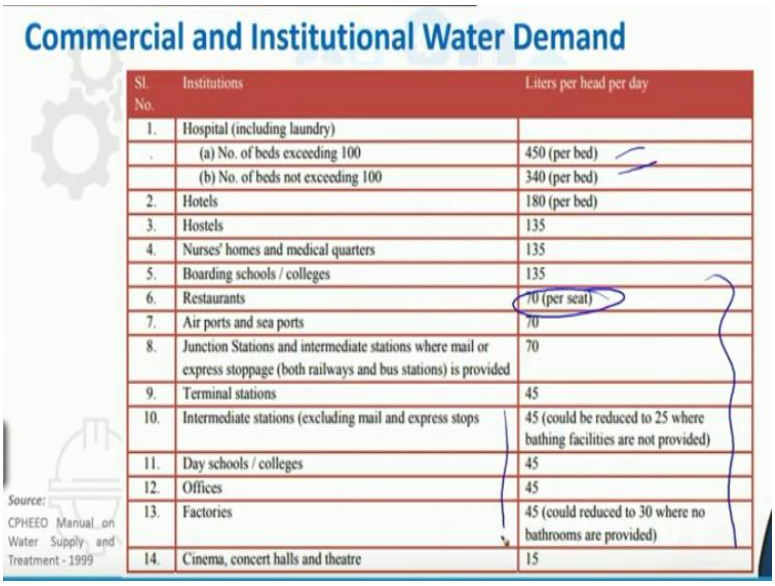

Commercial and Institutional Water Demand

Sl. No.	Institutions	Liters per head per day
1.	Hospital (including laundry)	
.	(a) No. of beds exceeding 100	450 (per bed)
	(b) No. of beds not exceeding 100	340 (per bed)
2.	Hotels	180 (per bed)
3.	Hostels	135
4.	Nurses' homes and medical quarters	135
5.	Boarding schools / colleges	135
6.	Restaurants	70 (per seat)
7.	Air ports and sea ports	70
8.	Junction Stations and intermediate stations where mail or express stoppage (both railways and bus stations) is provided	70
9.	Terminal stations	45
10.	Intermediate stations (excluding mail and express stops	45 (could be reduced to 25 where bathing facilities are not provided)
11.	Day schools / colleges	45
12.	Offices	45
13.	Factories	45 (could reduced to 30 where no bathrooms are provided)
14.	Cinema, concert halls and theatre	15

Source: CPHEEO Manual on Water Supply and Treatment - 1999

That is about the domestic demand. There are other components of the demand as well as we discussed in the last class also that there are various types of water demand. So commercial and institutional water demand is also needs to be considered. And that also although varies, but average numbers are suggested in certain manuals like in CPHEEO Manual.

So these are the average number suggested for hospital. They have two criteria. If number of beds exceeds hundred or if it is less than hundred, so accordingly per bed water demand is suggested. Similarly for hotels, hostels, nursing homes, restaurants, boarding schools, airports. So all that data is available and you can see like this is the per head water demand.

So for mean that if the capacity of a hostel is n number, so average demand is 135. If there are say 40 seats in a restaurant so per seat there has to be 70 liters demand per seat okay. Similarly for of day schools, offices, factories, cinema halls, all those places, so there are some institutional and basic commercial water demand.

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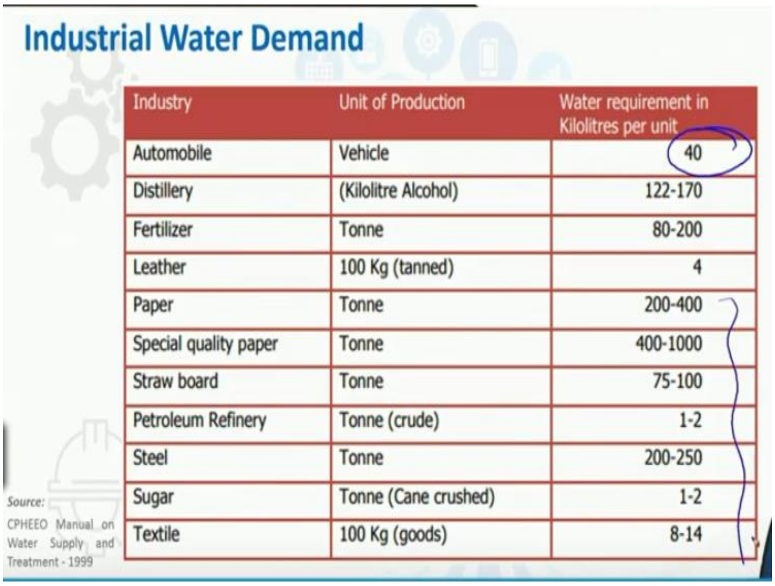

Industry	Unit of Production	Water requirement in Kilolitres per unit
Automobile	Vehicle	40
Distillery	(Kilolitre Alcohol)	122-170
Fertilizer	Tonne	80-200
Leather	100 Kg (tanned)	4
Paper	Tonne	200-400
Special quality paper	Tonne	400-1000
Straw board	Tonne	75-100
Petroleum Refinery	Tonne (crude)	1-2
Steel	Tonne	200-250
Sugar	Tonne (Cane crushed)	1-2
Textile	100 Kg (goods)	8-14

Similarly, for the major industries, the demand is suggested in the CPHEEO Manual and that is based on the per unit production. So for say if it is automobile industry so per unit vehicle production the amount suggested is around 40 kilolitres. So one vehicle, production of one vehicle requires around 40 kilolitres of water okay.

Similarly in distillation per kilolitre of alcohol produced reads around 122 to 170 kilolitres of water, huge water demand okay. For fertilizer 80 to 200 kilolitres per tonne. So that way we can see that the water demand is available for various industries as well.

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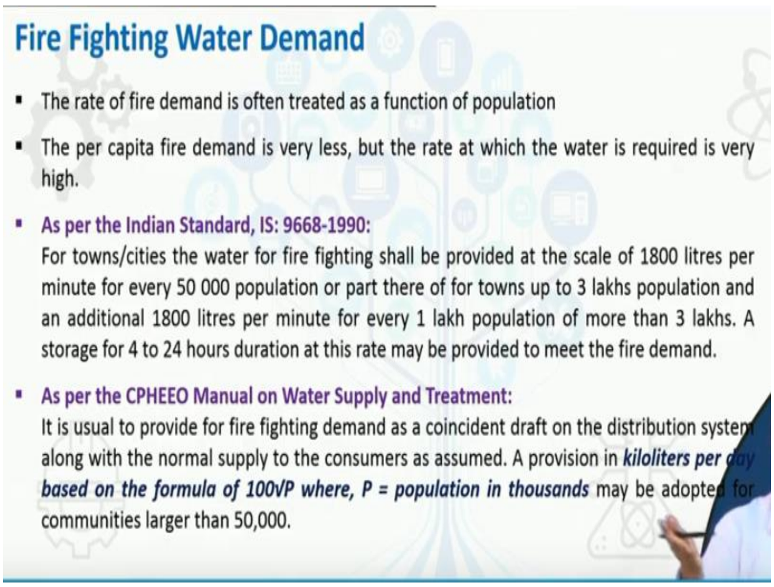

Now the another component of demand is the firefighting demand. Firefighting demand is traditionally an accidental demand. It is not always required. It will require only when there is a fire breaking. Now in the case of a fire breaks, the water needed to control the fire is going to be required at that particular incident but at very high flow okay.

So the fire demand is such that it does not require say lot of water on over a period of a day or month or that way. The amount of water needed is huge, but only for some part of time and as a result, the per capita flow like if we average it over the total population, let us say a city of one lakh one fire incidents breaks maybe in a month or so. So if we say per capita per day fire demand is going to be very low, but the rate at which this water is needed could be substantially high okay.

So that is important that the system should be capable enough to supply water at this particular rate when a fire breaks up. So for Indian conditions the fire demand as per Indian standards, there are guidelines to kind of considered 1800 liters per minute for every 50,000 population, okay, up to three lakh population and then an additional 1800 liters per minute for every one lakh population of more than three lakhs okay.

As per CPHEEO Manual it kind of uses the formula provided by the manual. So it is based on the kilolitre per day fire demand, can be estimated as hundred square root P where P is the population in thousand. So if we are talking about say one lakh a town with say 10 lakhs population or a town with one lakh population, so one lakh population means hundred thousand population.

So P becomes hundred okay and the amount of water required on a kilolitre per day would be hundred square root of hundred. So thousand kilolitres per day water would actually be needed okay. If population is higher say if the population is instead of one lakh it is say 10 lakhs okay, so for 10 lakh population this P becomes 10 lakhs means thousand, thousand. So P becomes 1010, accordingly the estimate can be made.

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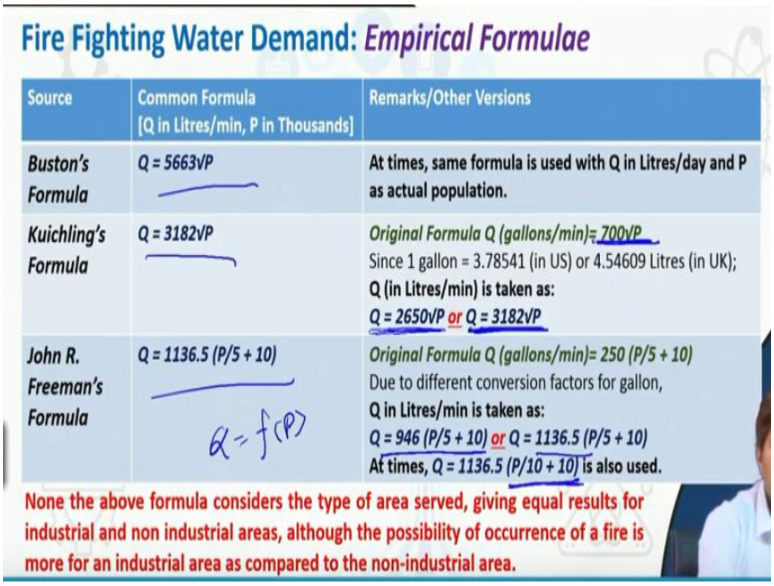

There are various empirical formulae for calculating fire demand and it is generally perceived to be kind of related to the population because fire breaking although is an accidental event, but more number of people living in a area has a higher chance of catching fire at least or more number of fire incident in that area. So based on that majority of the empirical formula are population dependent okay.

And some of the popular formulas for calculating the fire demand are the Buston's formula which uses Q is equal to 5663 square root of P. There is a Kuichling's formula and Freeman's formula. So they have the different nature of equations for calculating fire demand. But interestingly if you see, all are actually the function of population okay.

So fire demand is they all of them has considered a function of population. Now this formula actually there are various versions of the formula. So if you see like the Buston's formula, the Q is in litres per minute and P in thousand but same formula some people use with considering Q in litres per day and P as an actual population instead of population in thousand okay.

Similarly, the various other formulas like Kuichling's formula or Freeman's formula, so there are various versions of these available and that is primarily because of different conversion factors. So the original formula say for Kuichling's is Q is equal to 700 square root of P where population is in thousand and Q is in gallons per minute. So when we convert gallon to the litre in US one gallon is considered as 3.78 litre, but in UK, which is Imperial unit is considered as 4.546 liters.

So that way when we convert gallons to litre or when we try to estimate Q in litres per minute, by multiplying 700 to 378 we get a number of 2650. So some people use this formula as well on the name of formula for the same production Q in litres per minute while some people use this formula. Similarly, for Freeman's case also. So because of the different conversion factors, some people use this like 946 as a multiplier.

Whereas some people use 1136.5 as a multiplier okay to P/10 + 100 where P is in thousand, okay. At times, there are versions means some references or some books refer to be P/10 + 10 instead of P/5 + 10. So there could be, there are some other variations of the formula, and it is important to know this and important to know the reason also that it is basically because of the different conversion factors.

Otherwise, like when you when someone explore the books or literature on that, he may get confused as the for the same formula the different numbers are available or different forms of the formula are available. The point is none of these formula considers the type of area where population is residing in or the type of area being served by the water.

And considers kind of a equal result for industrial town or non-industrial town whereas the possibility of firebreak is relatively higher in the industrial area as compared to the non-industrial area because of the activity because of the densed population and because of kind of the activities that takes place in an industrial area.

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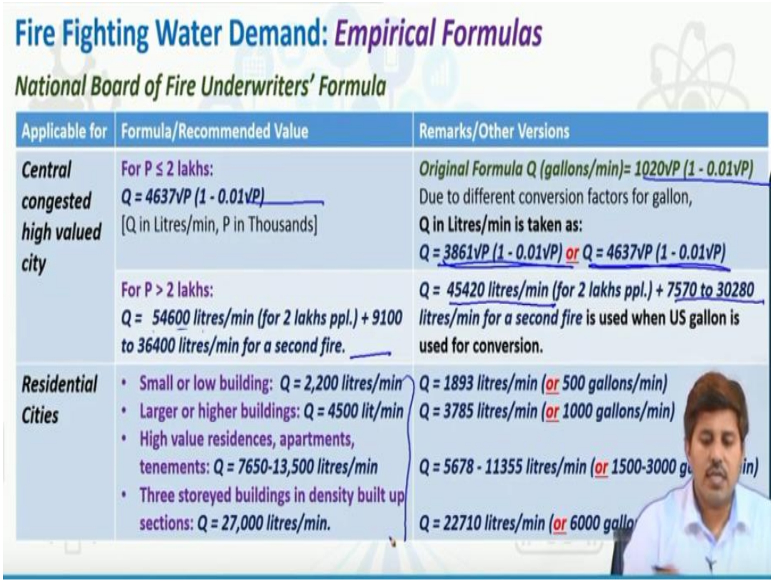

So they have a higher chances of catching fire okay. There is a National Board for fire Underwriters formula. So that is also practically kind of empirical formula and then the given guideline supported numbers. So for congested and high value cities particularly kind of industrial towns, they suggest that the so this basically covers that there could be a different requirement of fire fighting water in the industrial and residential town.

So for industrial or centrally congested high valued cities, it consider for population less than two lakhs this equation whereas for population greater than two lakhs the number becomes this. So for first two lakhs same equation is used which gives a demand of 54,600 liters per minute and then additional 9100 to 36,400 liters per minute for second fire is considered.

Like other formulas also. So original formula here is also 1020 square root of P in the gallons and because of the different conversion rates, we get two versions of this formula. So either this or this can be used for less than two and similarly, correspondingly two different numbers are suggested for the population greater than two lakhs. For residential cities, okay again there are different classes.

So small to low building, the requirement could be 2200 litres per minute, larger or higher value buildings around 4500 litres per minute. High value residents apartments it is then from 7650 to 13,500 litres per minute and three storeyed buildings in densely built up sections is around 27,000 litres per minute demand.

Now same all these factors can actually be revised based on the conversion as we said in the if we go into the gallon, so essential recommendation is 500 gallons, 1000 gallons; 500 gallons for small or low buildings, 1000 gallons for larger and higher value buildings. 1500 to 3000 gallons for the high value residential apartments and for three storeyed building it is 6000 gallons okay. So that based on the gallon conversion, we can get different values here as well.

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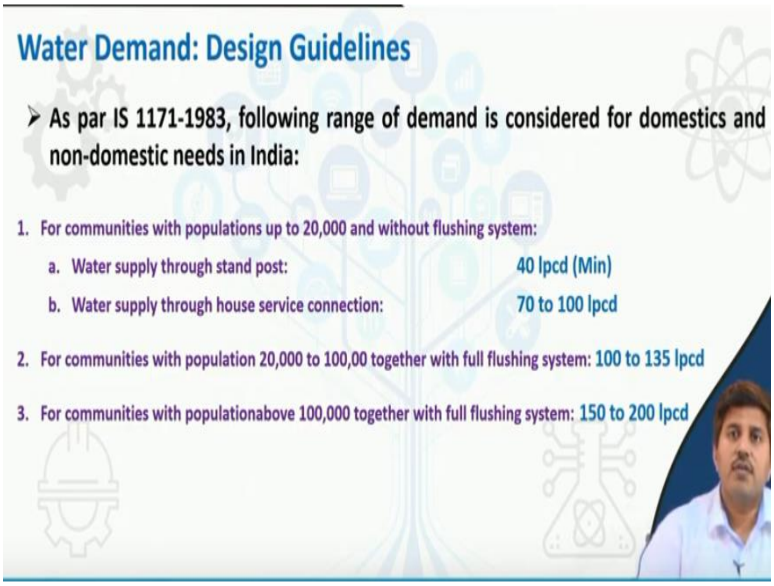

So this is about estimating the firefighting demand. Now for selecting the number or criteria for designing services, we have to kind of assume per capita demand okay, which considers because we cannot specifically see a large industrial demand may be considered separately.

But generally the all other demand including the domestic demand, in-house and out-house domestic demand including the commercial demand including the civic area water supply, like the common places water demands. So all is most like eventually is considered as population dependent and there are guidelines to consider the domestic and non-domestic needs.

So in India, as per IS 1171 – 1983 for communities with population up to 20,000 and without flushing system, if water is being supplied through stand post, so minimum 40 liters per capita per day supply has to be there. If water is being supplied through house service connections so the 70 to 100 lpcd is the recommended range. For communities with population greater than 20,000 to one lakh and with full flushing system, the recommended range is 100 to 135 litres per capita per day.

And for communities with population more than a lakh together with full flushing system, the recommended range for design is 150 to 200 lpcd.

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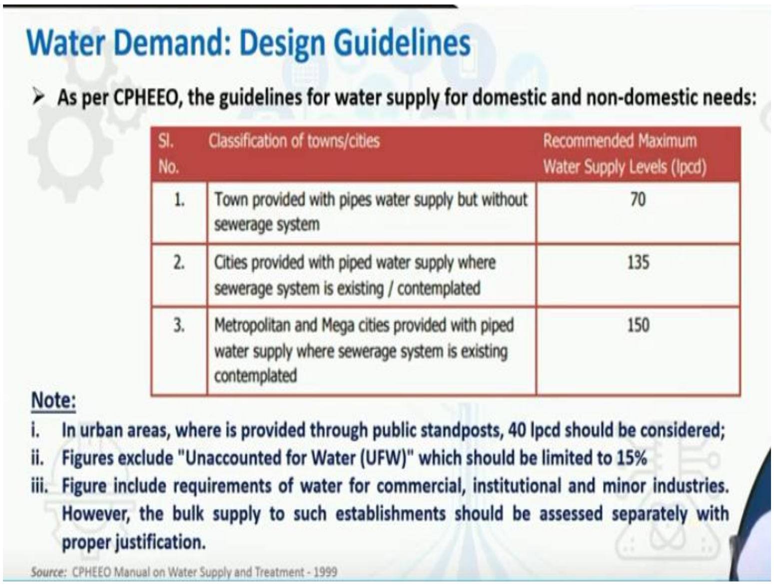

The CPHEEO Manual has its own design guidelines. So as per CPHEEO Manual again town provided with piped water supply but without sewerage system is 70 which is similar to the IS standard. Again the cities provided with piped water supply where sewerage system is existing or kind of contemplated is 135 lpcd.

And in metropolitan areas and mega cities provided with the piped water supply, it is 150 lpcd which should be considered for the design purpose. Now it is important to note here that in urban areas where kind of water is provided through stand post the CPHEEO guideline also suggest 40 lpcd can be considered for stand post.

So depending on a stand post how many people it is serving the supply at stand post can be considered as 40 litres per capita per day okay. The numbers shown here like 71, 35 and 150 lpcd does not consider water losses, which can again be taken up to around 15% if utility or designer is willing to. So that much provision for the water losses can be made, okay.

However, it is like a time should be made to keep the water losses to minimum. These figures though include requirements for water for commercial, institutional and minor or small industries, okay. But for larger industries or that kind of setup like separate calculation would be needed.

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Water Demand: Design Guidelines

S. No	Agency	Physical Standard
1	Manual on water supply and Urban Development, Govt. of India, 1991	• Small cities: 70-100 lpcd* • Large cities: 150-200 lpcd • Public stand Posts (PSP): 40 lpcd
2	National Master Plan (NMP), India, International Water Supply and Sanitation Decade, 1981-90, MoUD, 1983	House connections: • 70-250 lpcd (average of 140 lpcd) • Public stand Posts: 25-70 lpcd (average 40 lpcd)
3	Basic Minimum Services Under Minimum Needs Programme, 9th Five Year Plan, Government of India, 1997-2002 (1999)	100 per cent coverage by safe drinking water in urban areas. • With Sewerage: 125 lpcd • Without Sewerage: 70 lpcd • With spot sources & public stand posts: 40 lpcd
4	Report on Norms and Space Standards for Planning Public Sector Project Towns, TCPO, Ministry of Works & Housing, Government of India, 1974	• 180 lpcd
5	Committee on Plan Projects for Industrial Townships (COPP), 1973	• 180-225 lpcd

Source: cseindia.org/userfiles/buildings.pdf

So this is the some of the design practices which are or design guidelines which are used. Again, even the design guidelines are not consistent okay. So the different agencies have recommended different numbers. Agencies **not** means not necessarily a regulatory bodies, okay. Like several committees or several like norms that are set up from the different ministry or agency have recommended different numbers and if we see the history of that.

So like municipal urban water supply and urban development, Government of India suggest again for small cities 7200, large cities 150 to 200 and public stand post 40 lpcd. So similar to the IS standard okay. The National Master Plans considers an average of 140 lpcd per house connection. So 70 to 250 lpcd and for public stand post 25 to 70 lpcd, again with an average of 40 lpcd, okay.

There is a basic minimum service under minimum needs program which was there in the ninth five year plan by the Government of India. So they considered that with sewerage it should be 125 lpcd, without sewerage 70 lpcd and stand post 40 lpcd. Similarly, the other reports like there was a committee on the plant project for industrial township. So they considered 180 to 225 lpcd for the township area, okay.

There are like report on the norms and space standards so for planning public sector projects, so they considered 180 lpcd demand.

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Water Demand: Design Guidelines

S. No	Agency	Physical Standard
6	Zakaria Committee (ZC on Augmentation of Financial Resources of Urban Local Bodies, 1963.	• Small: 45 lpcd • Medium: 67.5 - 112.5 lpcd • Large : 157.5-202.0 lpcd • Super metropolitan: 270 lpcd
7	Operations Research Group (ORG), Delivery and Financing of Urban Services, 1989	• Small: 80 lpcd • Medium: 80-150 lpcd • Large: 180 lpcd
8	National Institute of Urban Affairs (NIUA); Maintaining Gujarat Municipal Services - A Long Range Perspective, 1987	• Small: 95-125 lpcd • Medium: with Industrial base - 150 lpcd ▪ Problem areas: 90 lpcd; ▪ Average: 80-150 lpcd • Large: With Industrial base 170-210 lpcd ▪ Problem Areas: 120-125 lpcd ▪ Average: 115-210 lpcd
9.	World Health Organization (WHO), 2003	• no access (water available below 5 lpcd) • basic access (average approximately 20 lpcd) • inter-mediate access (average approximately 50 lpcd) • optimal access (average of 100-200 lpcd)

Source: cseindia.org/userfiles/buildings.pdf

Zakaria Committee which was a famous one again considered of the similar for small 45 lpcd, medium houses 67.5 to 112.5, large was greater than 150 and super metropolitan area they even suggested that it could be up to 270 lpcd, which was a very huge number, okay. The ORG group again for smaller 80 lpcd, medium 80 to 150 lpcd, larger 180 lpcd.

And the WHO says that if there is absolutely no access or water below 5 lpcd is considered as no access. For basic access minimum 20 lpcd water should be made available. For intermediate access 15 litres per capita per day water should be made available. While optimum access is on the order of 100 to 200 litres per capita per day. So these are the different agencies presenting different numbers.

If you see the most of the numbers fall somewhere in between 100 to 200 lpcd. And for major cities in fact around 150 to 200 lpcd. So these numbers can be used for designing the system. So with this we conclude the discussion in this particular class and we will now see the other aspects of water demand like how the variations in the demand is considered in the next class. So see you in the next class, thank you for joining.