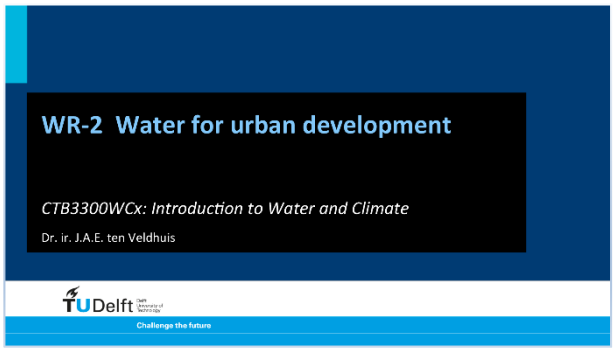
CTB3300WCx – Introduction to Water and Climate

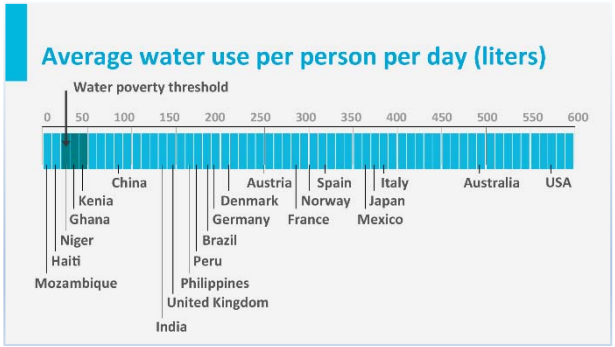
WR2 – Water for urban development

Marie-Clare ten Veldhuis



Welcome to the submodule, Water for urban development. My name is Marie-claire ten Veldhuis. I work as an assistant professor for urban water systems, at Delft University of Technology.

People need water to live and survive. In urban areas large numbers of people are living together in high concentrations and they need a lot of water. How do citizens get access to sufficient volumes of water? Where do cities get their water supply from? Are cities suffering from water stress or are waters suffering from urbanisation? In this submodule we will have a look at how cities and water systems interact. Since 2010, more than 50% of the world population is living in cities and this number is expected to rise in the next decades. Cities face the challenge of meeting water demands of their growing populations. So how much water does a city actually need?

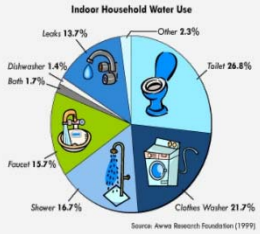


A good starting point to estimate urban water needs is to multiply the urban population by the average daily water use per person. This is also referred to as the per capita water use. Water use patterns vary a lot between countries, regions and even within cities, depending on access to drinking water, availability of water and costs. For instance, in Mumbai, India, per capita water use is 15 times higher in high-income suburbs with good water access compared to slum areas. Worldwide, average water use per person varies from less than 50 litres per day to over 500 litres per day.

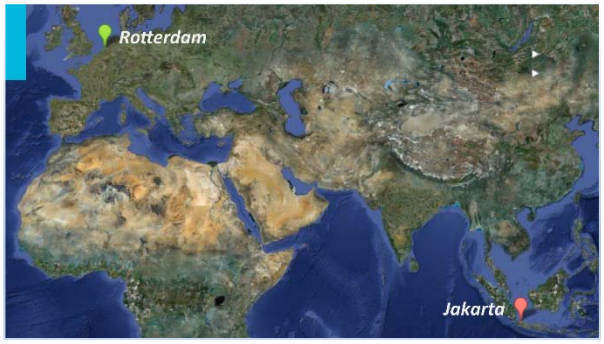
Per capita water consumption

Domestic water consumption

- *Drinking water*
- *Bathing and showering*
- *Toilet*
- *Washing clothes and dishes*
- *Watering of garden*



These numbers include direct consumption of water, bathing and showering, water usage for washing clothes and dishes and garden watering.



Now let's have a look at two different cities and estimate how much water is used by their citizens. Rotterdam is the second largest city in the Netherlands, located in the Rhine delta, at the North Sea coast. Jakarta is the capital of Indonesia, located in the delta of the Citarum and several other rivers. Rotterdam is a modern, industrial city with a large port area, Jakarta is a rapidly growing metropolis with large variations in economic development between the city's neighbourhoods.

Rotterdam and Jakarta

- *Urban population size?*
- *Average domestic water use?*
- *Total water need?*
- *Main water source?*

Now let's make an estimate of domestic water use for these two cities and answer the following questions:
- How large is the urban population of Jakarta and Rotterdam?
- What is the average domestic water use?
- What is the total water need of the city's population?
- What is the main source of domestic water use for the urban population?

Calculation: domestic water use

	Rotterdam	Jakarta
Urban population	*0.6 million*	*9.8 million*
City surface area (approx.)	*300 km²*	*700 km²*
Population density	*3000 / km²*	*15000 / km²*
Avg. domestic water use (per person, per day)	*150 liters*	*80 liters*
Total domestic water use (per day)	*0.09 million m³*	*0.78 million m³*
Total domestic water use (per year)	*33 million m³*	*280 million m³*

First, we'll fill in some numbers for general characteristics of the cities of Rotterdam and Jakarta. Total population, size of the city area, population density and average domestic water use. From these numbers we can compute average daily water use and total yearly water use. To get a grasp of these numbers: 1 million m³ water is about the equivalent in volume of 250 Olympic swimming pools. These volumes of water need to be made available in the city or need to be transported there, if not available locally. Let's look at some potential sources of water for Rotterdam and Jakarta and see how they compare to the daily and yearly domestic water use estimates we just found.

Available water sources: rainfall

	Rotterdam	Jakarta
Total domestic water use (per day)	*0.09 million m³*	*0.78 million m³*
Total domestic water use (per year)	*33 million m³*	*280 million m³*
Average annual rainfall	*850 mm*	*1850 mm*
Available rainwater (rainfall x surface area (m³ / year))	*250 million m³ / year*	*1300 million m³ / year*

A first option is using rainfall that directly falls on the city's surface. Jakarta, located in the tropics, receives a lot of rainfall: on average, 1850 mm yearly. Rotterdam, with a moderate climate, gets less rainfall, about 850 mm. If we multiply this by the city' surface area, we'll find the total yearly available amount of rainwater. As we can see by comparing the numbers, there is more than enough rainwater to cover the city's water needs, on an annual basis. That is, if we would be able to capture all rainwater.

And if rainfall would be spread nicely and evenly over all days of the year.

Available water sources: groundwater

	Rotterdam	Jakarta
Total domestic water use (per day)	0.09 million m^3	0.78 million m^3
Total domestic water use (per year)	33 million m^3	280 million m^3
Estimated available groundwater resources	Not suitable	60 million m^3

Another potential source of water, as we saw in a previous submodule, is groundwater. Available groundwater resources depend on natural replenishment by rainfall, size of the groundwater basin and thickness of the ground layers that groundwater can be pumped from. And it depends on the quality, too: groundwater near the sea turns saline as a result of salt intrusion and is not suitable for most water uses. This is why groundwater in the Rotterdam region is not used for consumption. In Jakarta estimates of groundwater availability and use vary as there are many private abstractions on top of the larger abstractions for industry and drinking water production. It is estimated that about 60 million m^3 of groundwater is abstracted annually for Jakarta's water supply. This is by no means sufficient to meet total water needs.

Available water sources: riverwater

	Rotterdam	Jakarta
Total domestic water use (per day)	0.09 million m^3	0.78 million m^3
Total domestic water use (per year)	33 million m^3	280 million m^3
Main river	Rhine-Meuse delta	Citarum
Annual mean flow (m^3 / s)	2500 m^3/s	180 m^3/s
Total annual flow volume (m^3 / year)	80 billion m^3	6 billion m^3

River water is an obvious third source of water, especially in delta cities like Jakarta and Rotterdam. Rivers in both cities transport water from large upstream catchments. In Rotterdam, the Rhine and Meuse rivers transport approximately 80 billion of m^3 annually and in Jakarta about 6 billion m^3 of water flow through Citarum rivers, on average. This is more than enough to cover urban water needs. But like rainfall, river flows are not equally distributed over the year, so intermediate storage is needed to cover periods of low flow.

Main sources for domestic water use

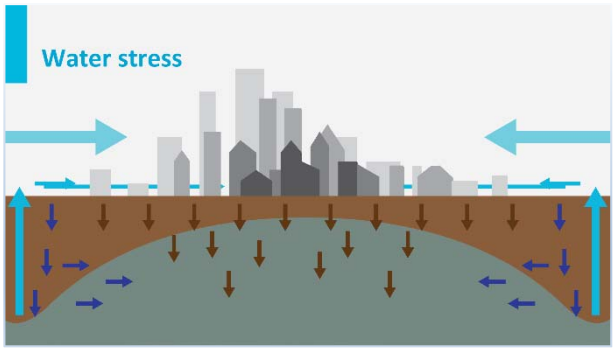
	Rotterdam	Jakarta
Total domestic water use (per day)	0.09 million m^3	0.78 million m^3
Total domestic water use (per year)	33 million m^3	280 million m^3
Main source	River water	River water, groundwater
% of people connected to central water supply system	100%	30% - 60%

So what can we conclude from these numbers? First, that in Jakarta and Rotterdam annual rainfall in principle is sufficient to cover the cities' water needs. Groundwater availability is limited and cannot on its own cover total water needs. River water is the largest source of water for the two delta cities, yet most of this water comes from large upstream catchments. Here, the city is competing with many other water demands, especially from agriculture.

Domestic versus other water uses

Domestic water use is small compared to water use by other sectors. Globally, domestic water use represents about 5-10%, industry about 15% and agriculture up to 80% of total water use. Again, these figures vary widely from region to region, depending on agricultural and industrial activity and water availability. In Northwestern Europe, for instance, agriculture represents less than 16% of total water use and more than half is used by industry. In most tropical regions, agriculture is the main water using sector by far, representing up to almost 100% of total water use.

Back to our two cities, what water resources are they using to cover domestic water needs? In Jakarta and Rotterdam, river water is the main source used to cover urban water needs. Because river flows are fluctuating between wet and dry periods, large reservoirs have been constructed in both cases, to store water and overcome periods of low flow. In Jakarta, river water is supplemented with groundwater abstracted from a few large wells and a lot of individual small wells at household level. An important reason for construction of these wells is the insecurity of Jakarta's central water supply. Interestingly, rainfall, a large source of locally available water in both cities is not used by the city's households. This applies to most cities worldwide: most cities are using river water, very few cities are using rainwater as a water resource. Now the question REMAINS: Why are cities not using clean, locally available rainfall to cover their water needs.



Part of the explanation is to be found in historical development. The following images illustrate how cities, as they grow, take in water from an increasingly large part of their surroundings. They start using groundwater as this is a more or less constant, locally available source of water. Gradually, local groundwater resources get contaminated and may even get depleted. This means water needs to be taken elsewhere and transported to the city. Groundwater is abstracted from the surrounding region and when this is no longer sufficient, river water is used as a supplement. This means constructing large dams to create reservoirs and store water to overcome periods of low river flow. Somehow, in this process, rainwater is forgotten as a potential, locally available resource.

In large cities worldwide, some 1.2 billion people primarily depend on river water sources. The remainder, about 20% of the urban population, depends mainly on groundwater. While groundwater is mostly drawn from within or close to the city boundaries, river water is taken from much larger catchment areas. Urban areas cover about 2 to 4% of the Earth's land surface. Upstream areas used for their water sources, their urban water footprints, cover more than 40% of the Earth's surface. So worldwide, the urban water footprint is about 10 times the size of the actual cities.

Bringing large volumes of water to the cities from such extensive areas requires a lot of water infrastructure. It is estimated that globally cities transport more than 500 billion of water liters daily over a total distance of 27,000 kilometers.

When laid in a straight line, urban water infrastructure could stretch halfway around the globe. Even so, many large cities are under water stress and cannot always supply their citizens and economic activities with sufficient water.

As cities continue to grow, new solutions will have to be found to meet urban water needs. Rainwater harvesting and water reuse are examples of new developments that will help to quench cities' thirst in a more sustainable way in the future.