Lecture 2

Water cycle

Water resources

Water demand

Tasks of water supply

- Water supply *(Wasserversorgung)* is a branch of water management.

- The requirements for the water supply are to supply drinking water in sufficient quantity, of perfect condition, at any time and with sufficient pressure *(Druck)*.

Maxims of the European Water Charta of the European Council (6th May of 1968)

1. Without water there is no life, water is a precious and indispensable good for humanity.

2. Water reserves are not inexhaustible. Therefore it becomes more and more urgent to deal with it economically.

3. Water pollution *(Wasserverschmutzung)* causes damage to humans and all organisms.

4. Water quality must meet the requirements of public health and guarantee the intended use.

5. „Used" water is to be reintroduced into the water cycle *(Wasserkreislauf)* in a condition, in which it doesn't compromise the further use for the public sector as well as for the private sector.

6. The cover of the ground with vegetation, in particular forests, plays a substantial role in the preservation of water reserves.

Maxims of the European Water Charta of the European Council (6th May of 1968)

7. Available water resources must be inventoried.

8. The necessary order in water management requires the control by the responsible authorities.

9. Water protection requires an increase of scientific research, formation of experts and public education campaigns.

10. Water resources planning should be orientated less by the administrative and political borders, but more by the catchment area *(Einzugsgebiet)* borders.

12. Water does not know state borders, it requires an international cooperation.

10. For the well-being of the “general public”, each human has the obligation to use water economically and with care.

Selected terms after DIN 4046

Water supply:
(Wasserversorgung)

Supply of the water demand from habitation and working sites of the human society. […]

Drinking water:
(Trinkwasser)

Suitable water for the human use and consumption meeting the standards of legal regulations as well as by DIN 2000 and DIN 2001.

Service water:
(Betriebswasser)

Suitable water for commercial, industrial, agricultural or similar purposes with different quality characteristics. Drinking water can be included.

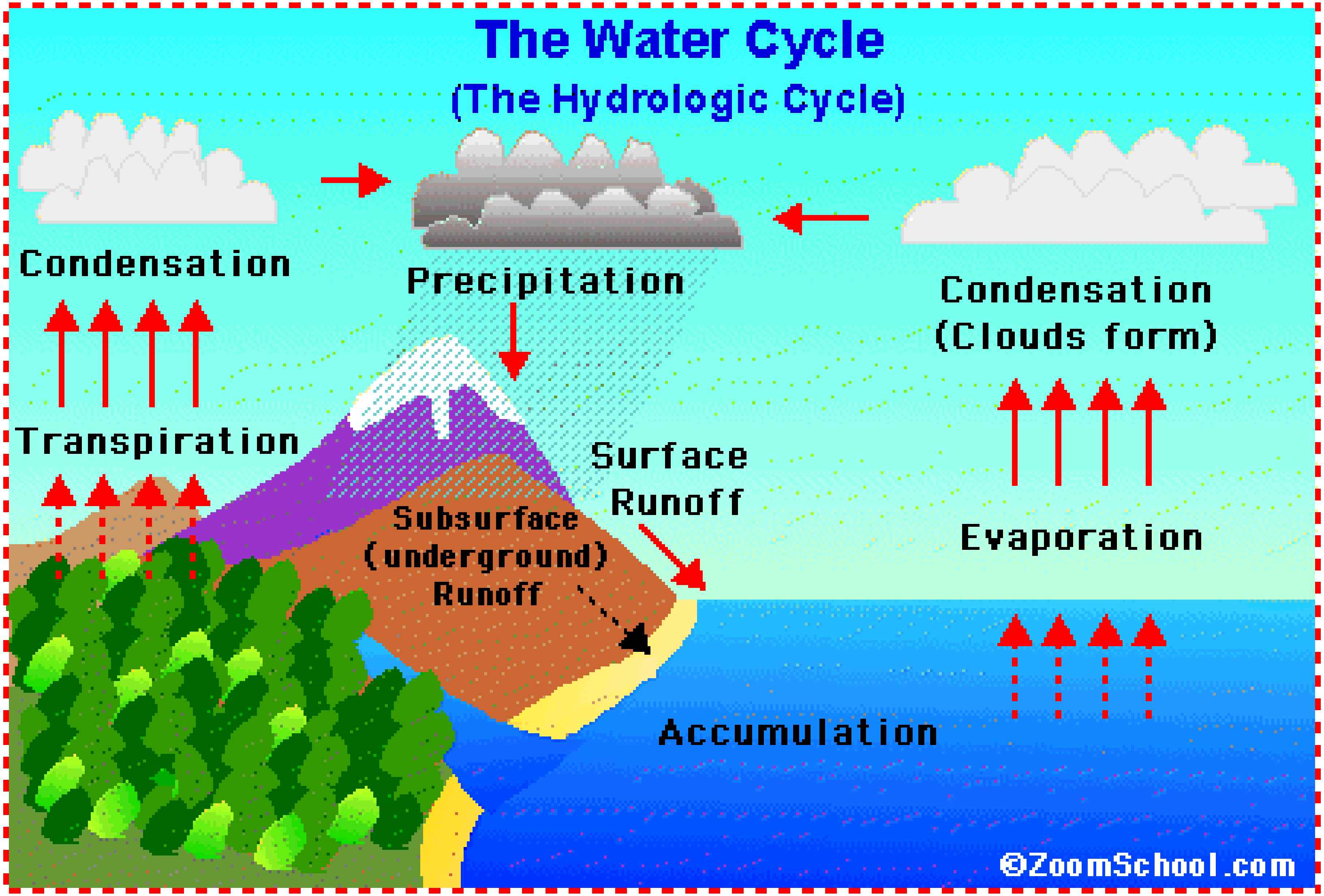
Public water supply:
(Öffentliche Wasserversorgung)

Supply of water that serves the general public (regardless of the type of legal entity).

Private water supply:
(Eigenwasserversorgung)

Provision of water that does not serve the general public and that is operated with own private facilities.

Schematic presentation of the hydrologic water cycle



Source: http://www.enchantedlearning.com/wgifs/Watercycle.GIF

Water reserves on earth

Oceans (salt water)	1.338 x 10^6 km^3 ≅ 97,5 %
Ice on polar caps	24,4 x 10^6 km^3 ≅ 1,76 %
melting off Δ H = 68 m	
Fresh water on land areas	10,6 x 10^6 km^3 ≅ 0,77 %()
(lakes, groundwater, soil moisture, rivers, atmosphere)	
Sum: Fresh water	**35 Mio. km^3 ≅ 2,5 %**

Total amount : 1.373 x 10^6 km^3

Water balance

- Needed water for public water supply is taken out of surface waters *(Oberflächenwasser)* or out of the groundwater *(Grundwasser)*

- Total annual precipitation amount *(Jahresniederschlagsmenge)* in Germany amounts to about 800 mm

- 60% of the precipitation evaporates *(verdunsten)* and 40% runs off as surface or subsurface runoff

- By the term water balance is understood: The volumetric registration of the individual components of the water cycle

Water cycle equation

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Water cycle equation with consideration of surface and subsurface runoff:

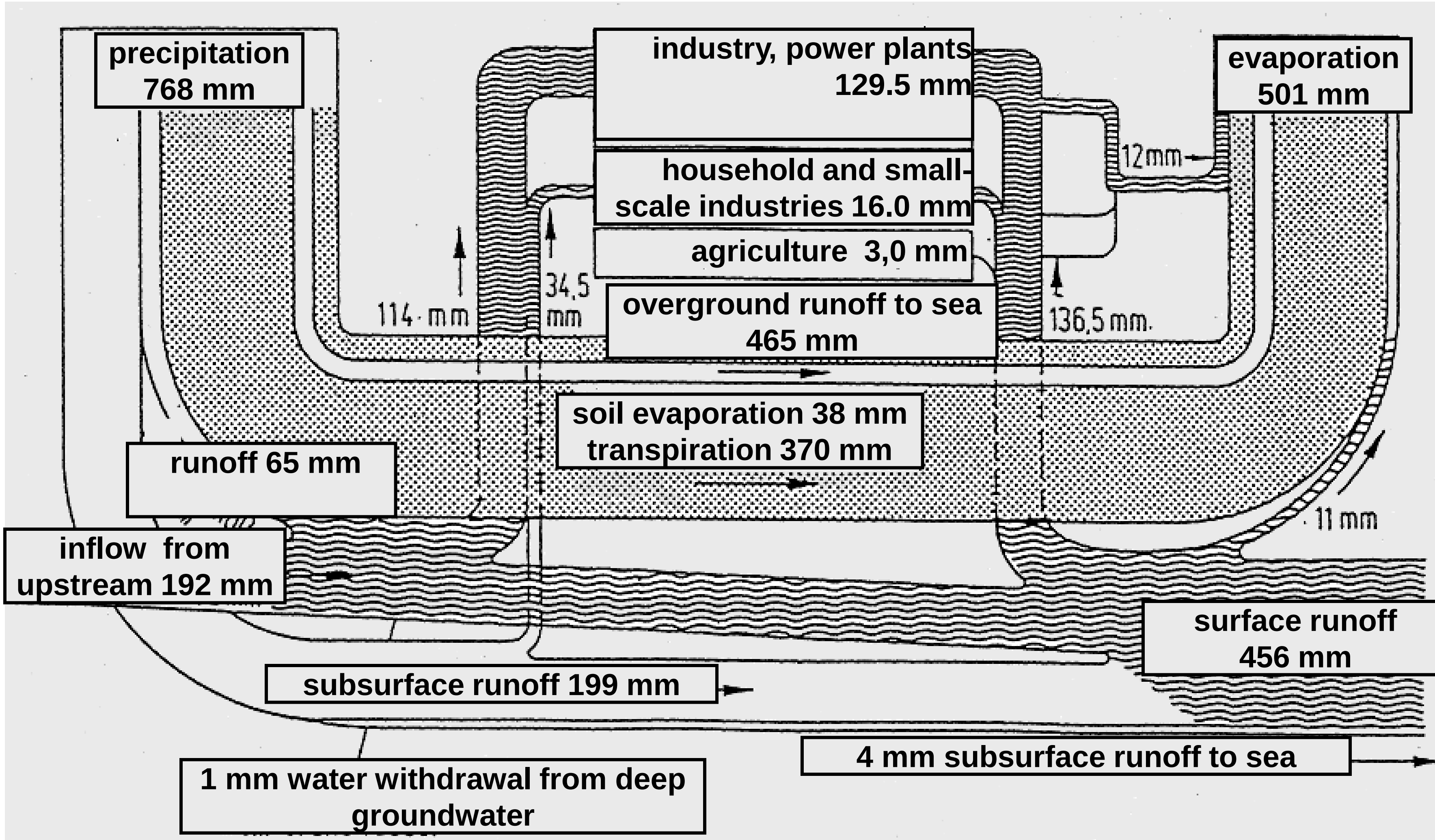
$$P = Q_O + Q_U + E \quad [mm]$$

Extended water cycle equation:

$$P = Q + E + (S - B) \ [mm]$$

with:		
	P	Precipitation *(Niederschlag)*
	Q	Discharge / runoff *(Abfluss)*
	Q_O	Surface runoff (overground) *(Oberirdischer Abfluss)*
	Q_U	Subsurface runoff (underground) *(Unterirdischer Abfluss)*
	S	Storage in groundwater *(Rückhalt im Grundwasser)*
	B	Groundwater withdrawal *(Aufbrauch aus dem Grundwasser)*
	E	Evaporation *(Verdunstung)*

Water balance of the Federal Republic of Germany, old west German states (1981)



Water resources, Water demand

- Out of the 6 billion people living on earth, more than 1.2 billion people lacking sufficient access to safe drinking water and 2.7 billion people live without sanitary facilities.

- 50% of the world-wide stationary treated diseases concern stomach-intestine infections, frequently caused by the use of unsanitary water. [Wilderer 2004].

- The lack of adequate drinking water demands annually approx. 2.2 million victims.

- 6,000 people, most of them children under 5 years, die daily through impure drinking water, i.e. every 15 seconds one person.

The Millennium Development Goals (MDG)

1. Reduction of extreme poverty and hunger by 50% by the year 2015.
2. Implementation of the elementary school education.
3. Promote gender equality and the role of women in society.
4. Reduction of infant mortality.
5. Improvement of the health of mothers.
6. Combat HIV, Malaria and other diseases.
7. To ensure ecological sustainability.
8. Development of a world wide development-partnership.

Water resources, Water demand

How much water does a person need?

- 1 – 3 m^3/a are needed by one person for drinking and cooking.
- Approx. 50 m^3/a are consumed by a private household in Europe.
- The specific demand for private households, public services and industrial activities (without energy production) averages approx. 230 m^3/a.
- The total consumption (incl. food production) per person and year sums up to a total >1,700 m^3.

Demand of water in the food industry

Approximately: „1 m³ of water for 1 kg of bread“ applies only under optimal conditions.

→ The actually used water quantity is much higher. American farmers use for example for 1 kg bread up to 4 m^3 water. In the tropics the water demand for 1 kg rice lies around 5 m^3 instead of the necessary 2 m^3.

To ensure a sufficient nutrition of 2,500 kcal per day, 500-100 m^3 for a vegetarian person and 1,200-1,500 m^3 for a nutrition with 20% meet are needed nowadays.

→ Even with an optimal irrigation (with minimal water losses) it would need 250 m^3 and respectively 680 m^3 per person and year.

[Zehnder, 2002 and 2003]

Water Stress Index (WSI)

Annual recharged water volume per person [m³/P·a]	Water Stress Index
>1,700	Sufficient
1,000 – 1,700	Water stress
500 – 1,000	Chronic water scarcity
100 – 500	Absolute water stress
< 100	Minimum survival level

[EPA, 2004]

Availability of Water

- It varies from 200 m³ per year in Yemen to over 10,000 m³ per year in Austria or Canada.

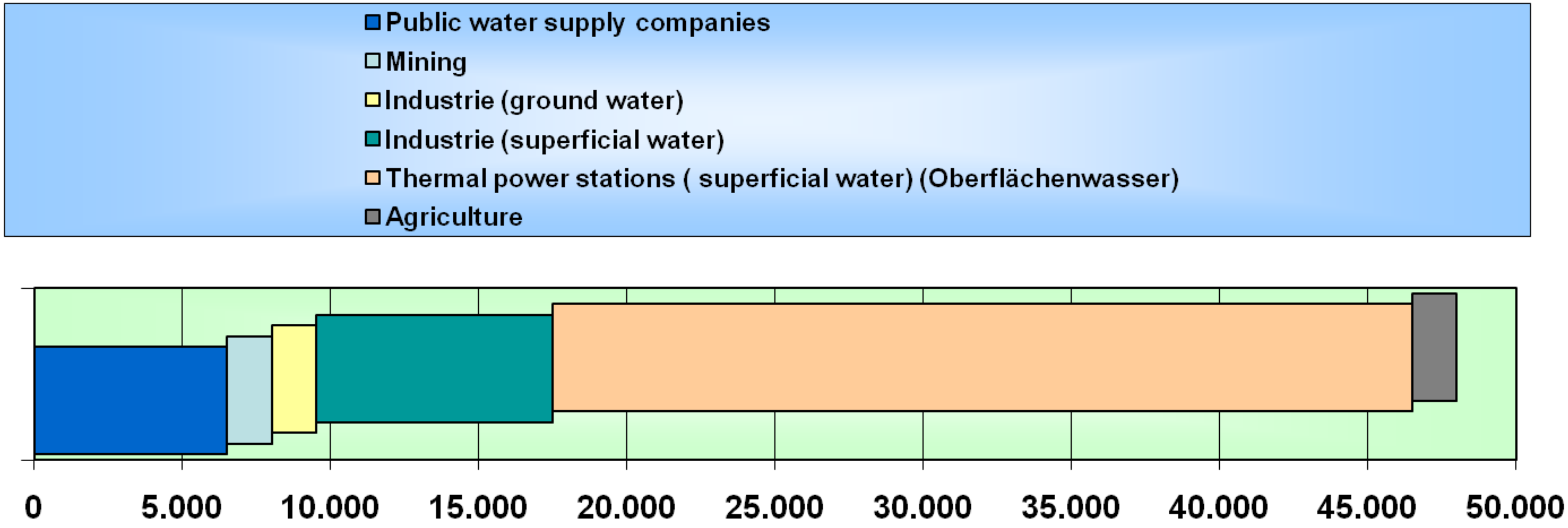
- In Germany only 5% of the agricultural surfaces are temporarily irrigated *(bewässert)*. Whereas in numerous countries in Central and South America, Africa and Asia between 70% and 90% of the annual water consumption *(Wasserverbrauch)* is used for agricultural irrigation.

- Somewhere between 9,000 and 14,000 km³ water are available for human consumption. This means that an average of 1,500–2,300 m³ are available per person and year.

- If the worst scenario occurs in the middle of this century, 7 billion people in 60 countries will suffer from water scarcity. At best 2 billion people in 48 countries will suffer from water scarcity.

Used water quantities in Germany, 1997

	Mio. m^3/a	
Public water supply companies	5,600	81 m^3/(P · a)
Mining + industry	9,000	
Thermal power plants (surface water)	27,800	
Agriculture	1,600	
Total	44,000	600 m^3/(P · a) ; 1,640 l/(P · d)



Household water demand

Household water demand depends on numerous influences:

- Number of persons per household
- Type of flushing toilet
- Water price and waste water fee
- Type of warm water production (centralized/decentralized)
- Consumption habits
- Water meter availability
- Equipment with water-saving devices

Household water demand

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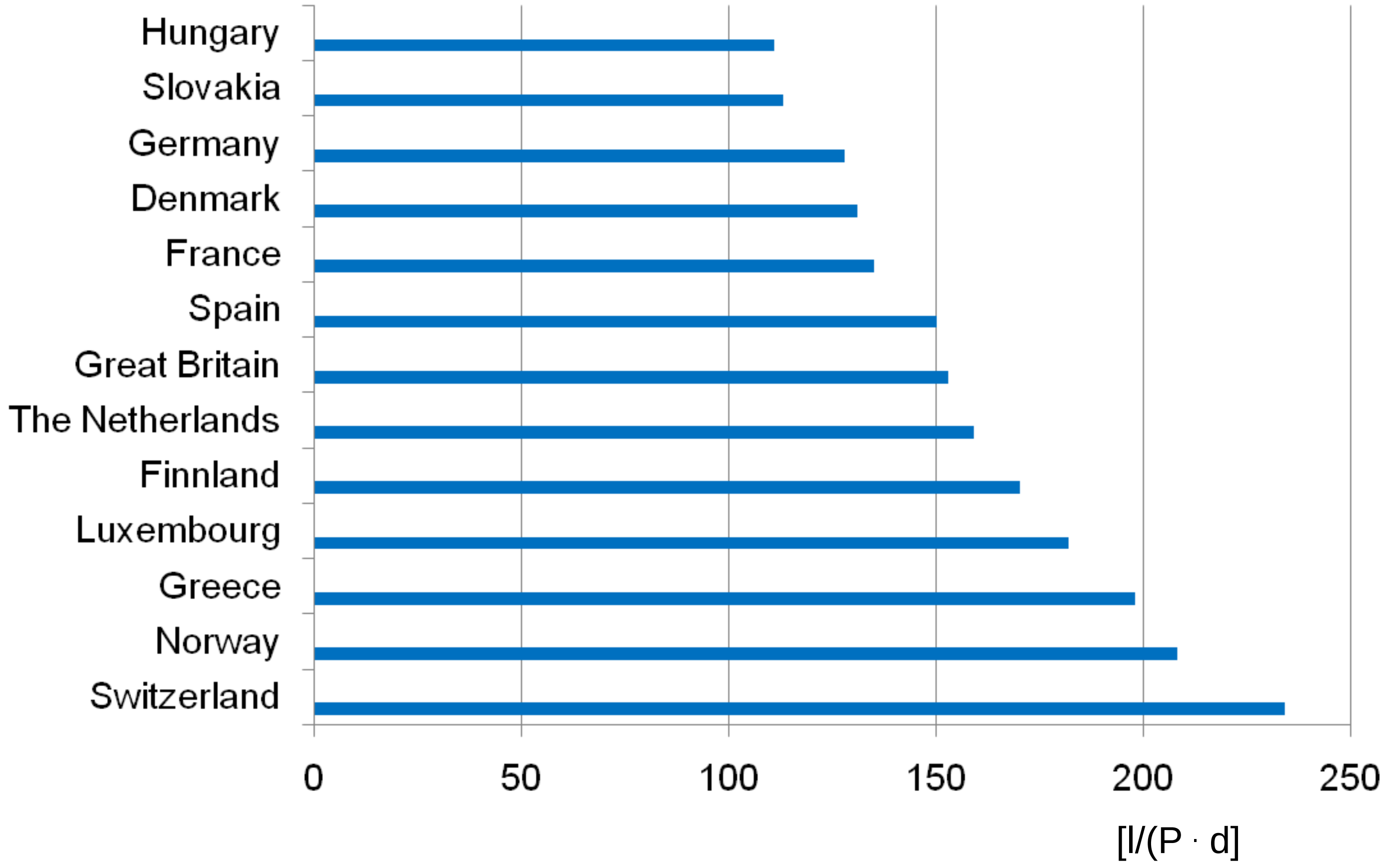
Type of use	Average values Shares of potable water	Specific water consumption l/(P · d)
Bath/ shower/ personal hygiene	36 %	46
Toilet flushing	27 %	35
Laundry	12 %	15
Dishwasher	6 %	8
Housekeeping, car washing, garden	6 %	8
Eating and drinking	4 %	5
Commercial water use	9 %	11
Total	100 %	128

[BGW, 2002]

European comparison -
Household water demand



[IWA, 2004]

Water demand for firefighting

Utilisation	Weekend Residen – tial area	Residen- tial area with trade	Residen -tial area	Central areas, only trade		Indus - trial area
Number of storeys	≤ 2	≤ 3	> 3	1	> 1	–
Floor space ratio	≤ 0,4	≤ 0,3 - 0,6	0,7 - 1,2	0,7 - 1,0	1,0 - 2,4	–
Cubic index	–	–	–	–	–	≤ 9

Needed quantity of firefighting water, with different fire spreading potentials	m³/h	m³/h	m³/h	m³/h
High	24 [4]	48	96	96
Middle	48	96	96	192
Low	96	96	192	192

Überwiegende Bauart

- High: feuerbeständige [5] oder feuerhemmende [5] Umfassungen, harte Bedachungen [5]
- Middle: Umfassungen nicht feuerbeständig oder nicht feuerhemmend, harte Bedachungen oder Umfassungen feuerbeständig oder feuerhemmend, weiche Bedachungen [5]
- Low: Umfassungen nicht feuerbeständig oder nicht feuerhemmend; weiche Bedachungen, Umfassungen aus Holzfachwerk (ausgemauert). Stark behinderte Zugänglichkeit, Häufung von Feuerbrücken usw.

Water losses in public supply systems

Real losses *(Tatsächliche (echte) Verluste)*

- Water losses because of pipe bursting
- Water losses through leakages in pipings or in piping seals
- Water losses through leaky armatures e.a fire-hydrant valves
- Germany < 9%, England approx. 25%

Apparent losses *(Scheinbare (unechte) Verluste)*

- Measuring differences between the water suppliers main water meter and the sum of the building water meters
- Missing registration of creeping losses *(Schleichverluste)* in the building water meters
- Measuring differences because of unsynchronized readings of water meters in buildings
- Measuring differences because of different water levels in the storage tanks in the beginning and at the end of a year

Design values for the water demand

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Q_a [m³/a] **Average annual water demand**

For water-management planning, licensing procedures, comparison of water requirement with water demand, for financial plans, success plans, earning and expenditure computation.

Q_{mtl} [m³/Mtl] **Average monthly water demand**

The value isn‘t of much importance, rather its fluctuation.

Q_d [m³/d] **Average daily water demand**

The daily maximum water demand $Q_{d,max}$ is used for planning and designing drinking water production, water treatment, water tank supply pipes, water storage.

$Q_{d,max} = f_d \times Q_d$, with Q_d as average value

Design values for the water demand

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Q_h [m³/h] Hourly water demand

The peak consume of the maximal water demand per hour on a day with maximal consumption $Q_{h,max(Qdmax)}$ is decisive for the system, where the hourly consume fluctuations cannot be balanced by the storage (e.g. main and service pipelines).

The average hourly water demand on a day with maximal consumption $Q_{h,max(Qdmax)}$ is required for the system, in which a balance by storage is given (e.g. water catchment, water treatment, water supply and conduction to storage)

$\mathbf{Q_h = Q_d/24}$ (average hourly consumption on day of average consumption)

$\mathbf{Q_{h,max} = f_h \times Q_d}$ (maximum hourly consumption on day of maximum consumption

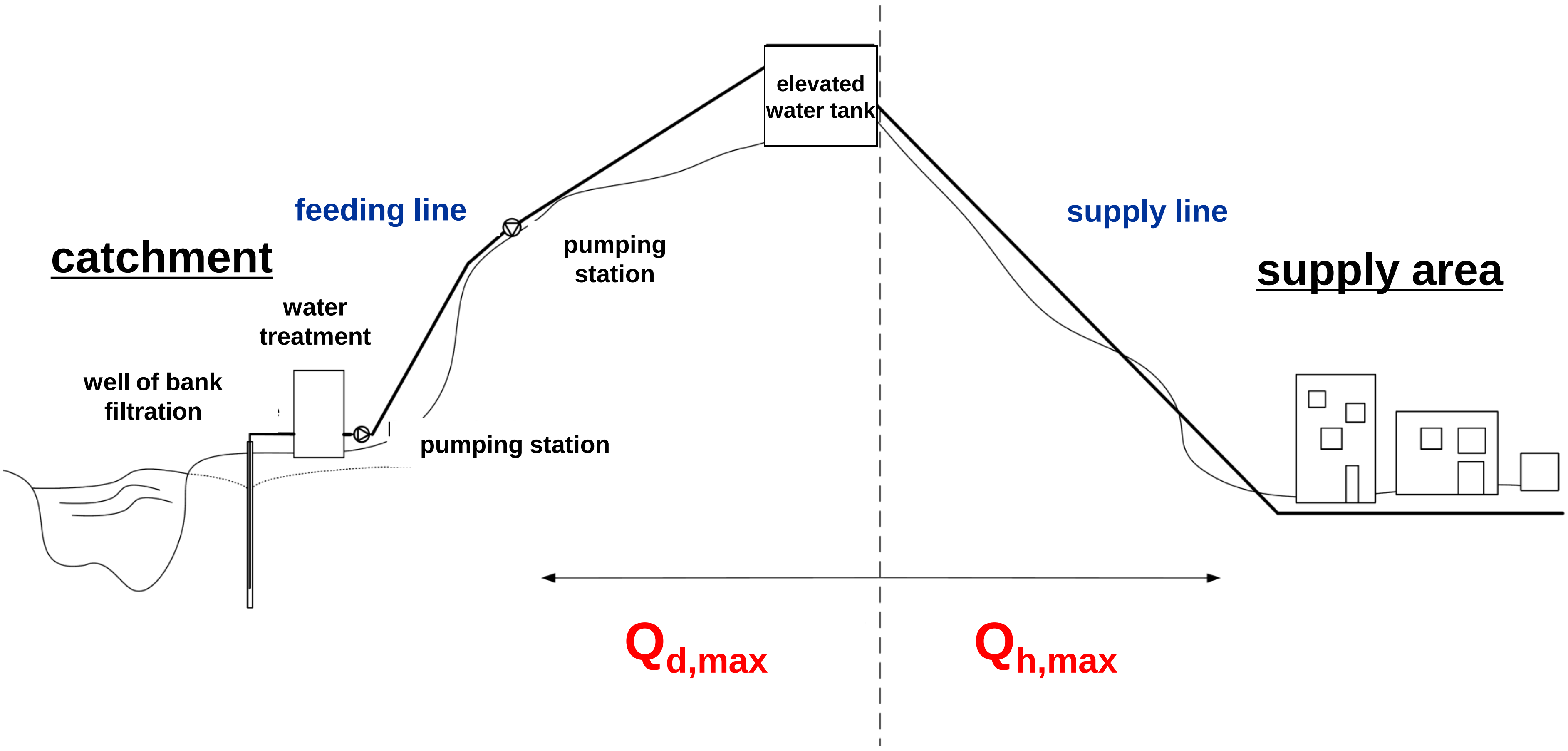
Peak factors for the hourly consumption: $f_h = 2 – 6$

Minimum value related to the average delivery: $f_{d,min} = Q_{d,min}/Q_{d,average} = 0.5 – 0.75$

Water demand of water supplier: Well flushing approx. 1 – 2.0%

Pipe network flushing approx. 1 – 1.5%

Design values for the water demand



Average daily peak factor f_d

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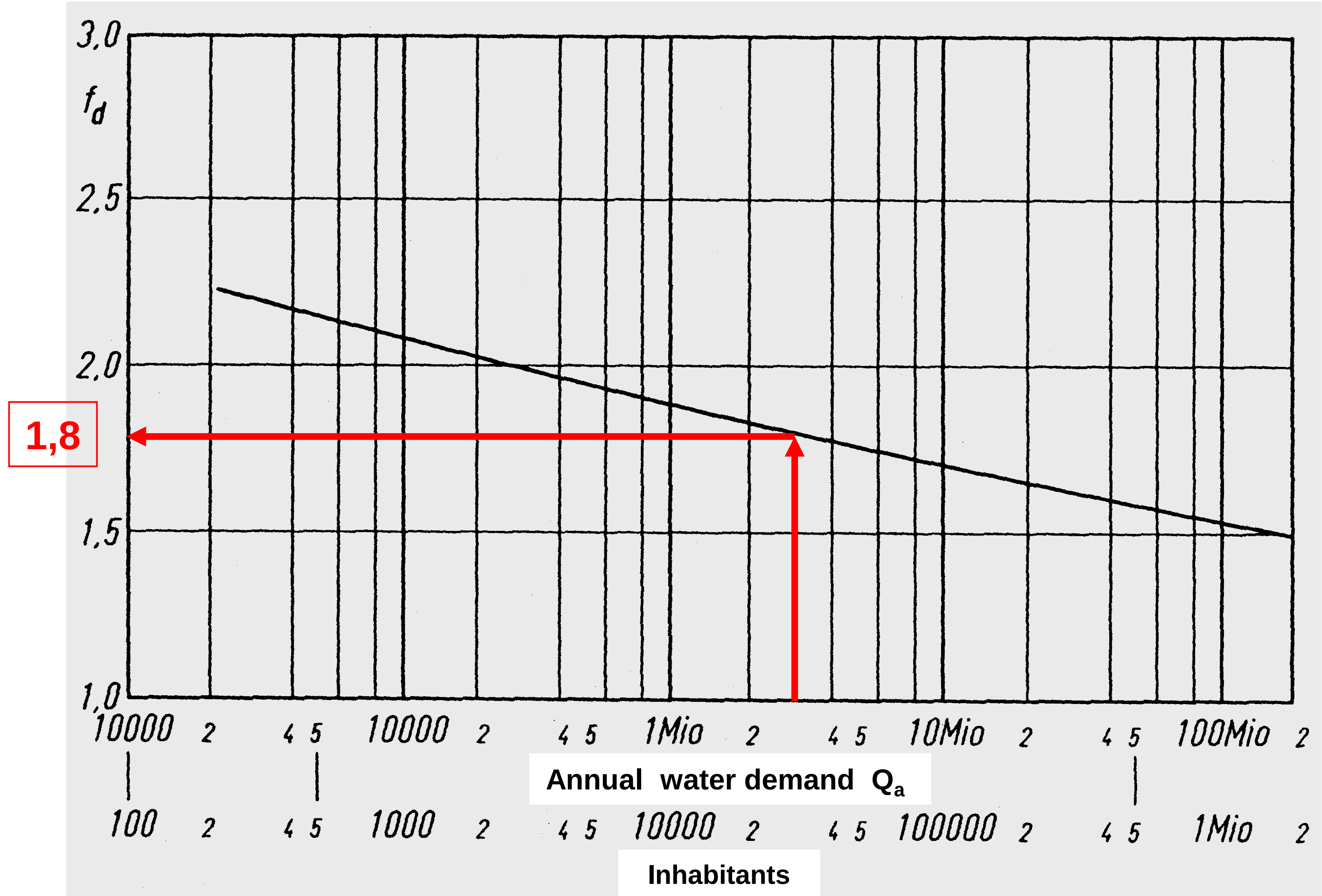
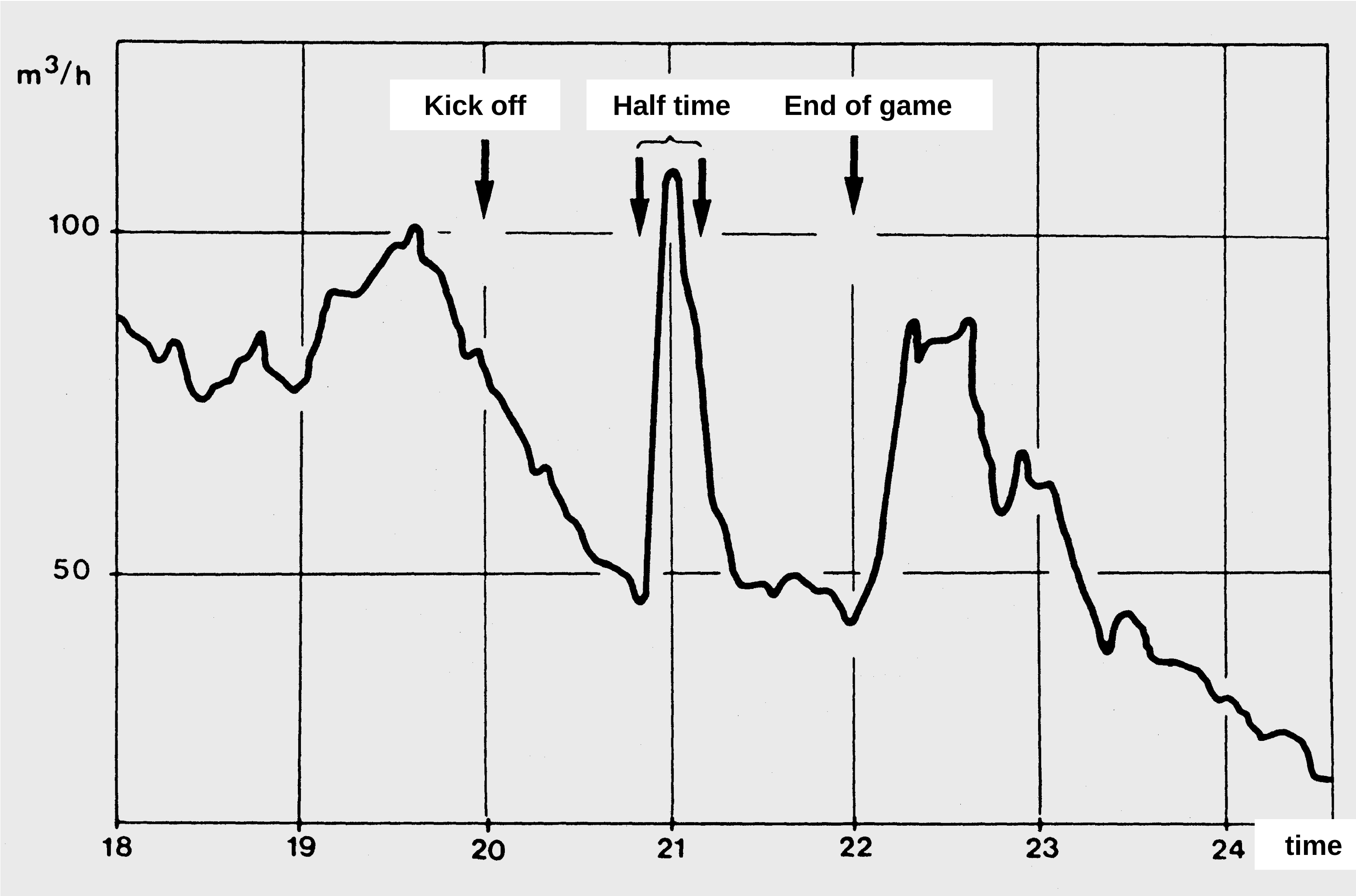


Water consumption in a residential area during the finals of the Soccer World Championship Italy vs. Germany 11.07.1982



Average per consumption-unit

Planning period 50a for tanks, pipelines, pumping stations

	Consumers	Unit	Liter
1.	**Household, incl. small trade**		
1.1	**Household**		
	1. Old single- and double-family houses	l/(P · d)	70
	2. Simple multi-family houses, year of constr. before	l/(P · d)	90
	1940	l/(P · d)	120
	3. Multi. storey houses with social apartments	l/(P d)	150
	4. New single-family terrace houses, multi-storey	l/(P · d)	180
	houses	l/(P · d)	200
	5. Buildings with comfort apartments	l/(P · d)	275
	6. Single- and double-family houses in good residential		
	area		
	7. Modern mansions in best residential area		
1.2	**Small trade**		
	1. Baker, 1 P / 200 Employee	l/(Employee · d)	150
	2. Confectioner, 1 P / 1000 Employee	l/(Employee · d)	200
	3. Butcher, 1 P / 300 Employee	l/(Employee · d)	250
	4. Coiffeur, 1 P / 300 – 600 Employee	l/(Employee · d)	200
	5. Car-wash	l/car	80
	6. Commercial enterprises	l/(Employee · d)	250
	7. Restaurants	l/(Guest +	50
		Employee) * d	
1.3	**Agriculture**		
	1. Cattle	l/(Cattle · d)	50
	2. Cattle without litter	l/ (Cattle · d)	60
	3. Cattle with litter	l/ (Cattle · d)	75
	4. Small domestic animals =1/5 cattle)	l/animal	1,5
	5. Milk collection station, per liter milk	l/(m^2 · d)	1,0
	6. Intensive agricultural irrigation)	l/(m^2 · d)	

[Mutschmann/Stimmellmayr, 1995]