Water Harmony
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What is wastewater

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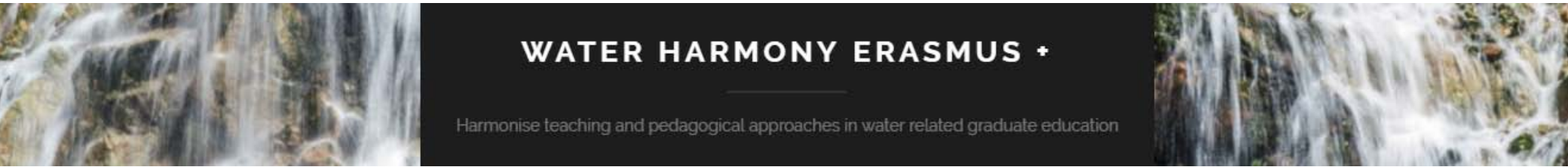

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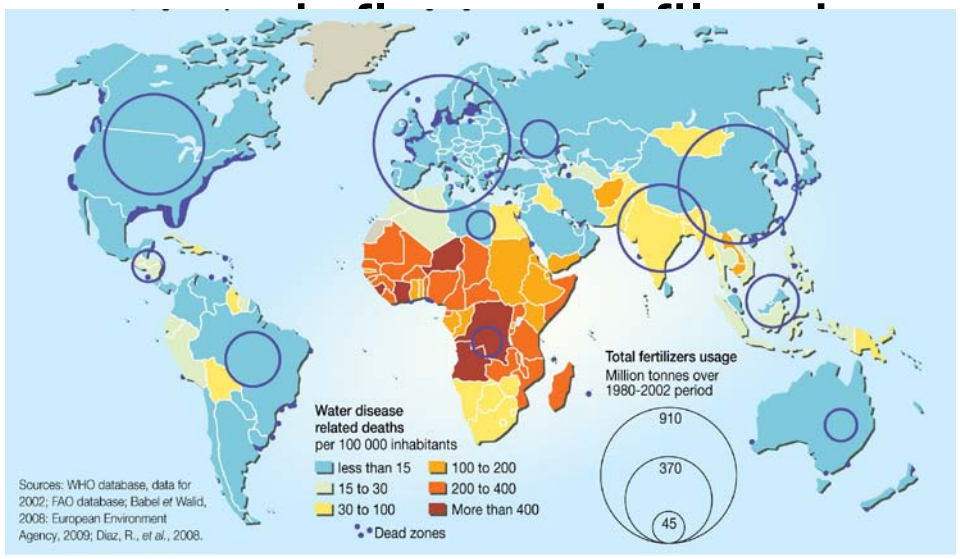
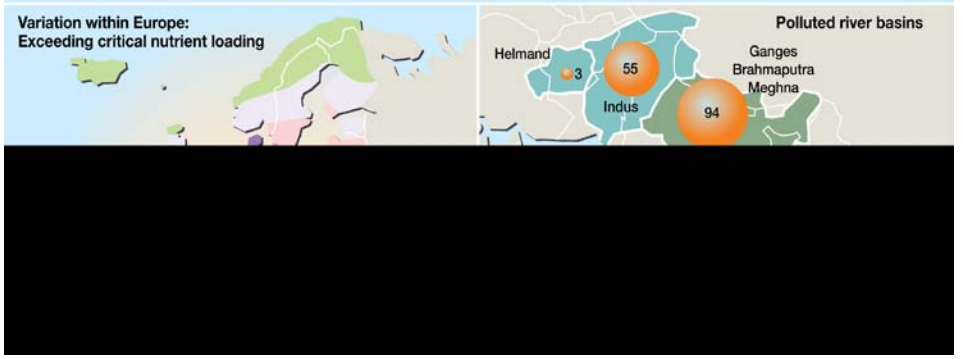
Definition of wastewater

- Any water that has been adversely affected in quality by anthropogenic influence
- originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, and from





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Origin of wastewater

- 1st classification method

Agricultural source	Domestic source	Industrial source

• Point sources
  • Poultry waste
  • Piggery waste
  • Silage liquor
  • Dairy farming waste
  • Slaughtering waste
  • Vegetable waste
  • Firewater
• Non-point sources
  • Sediment runoff
  • Nutrient runoff (Commercial fertilizer)
	• Washing/laundry
	• Shower
	• Kitchen
	• Toilet
	• Septic tank
	• School
	• Hospitals
	• Hotels/restaurant
	• Office
	• Small business activities, etc.
		• Abattoir
		• Fertilizer
		• Pulp and paper
		• Textile
		• Tanneries
		• Dye processing
		• Food processing
		• Pharmaceutical
		• Petrochemical
		• Metallurgical
		• Plastics industries, etc.

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Origin of wastewater

- 2nd classification method
  - Point source
    - Definition: any discernible confined and discrete conveyance including but not limited to a pipe, ditch, channel, or conduit from which pollutants are or may be discharged.
      - eg. municipal landfills, leaking gasoline storage tanks, leaking septic tanks, accidental spills and industrial waste disposal sites
  - Non-point source
    - Definition: comes from many diffuse sources
    - ie. runoff and seepage from agricultural lands

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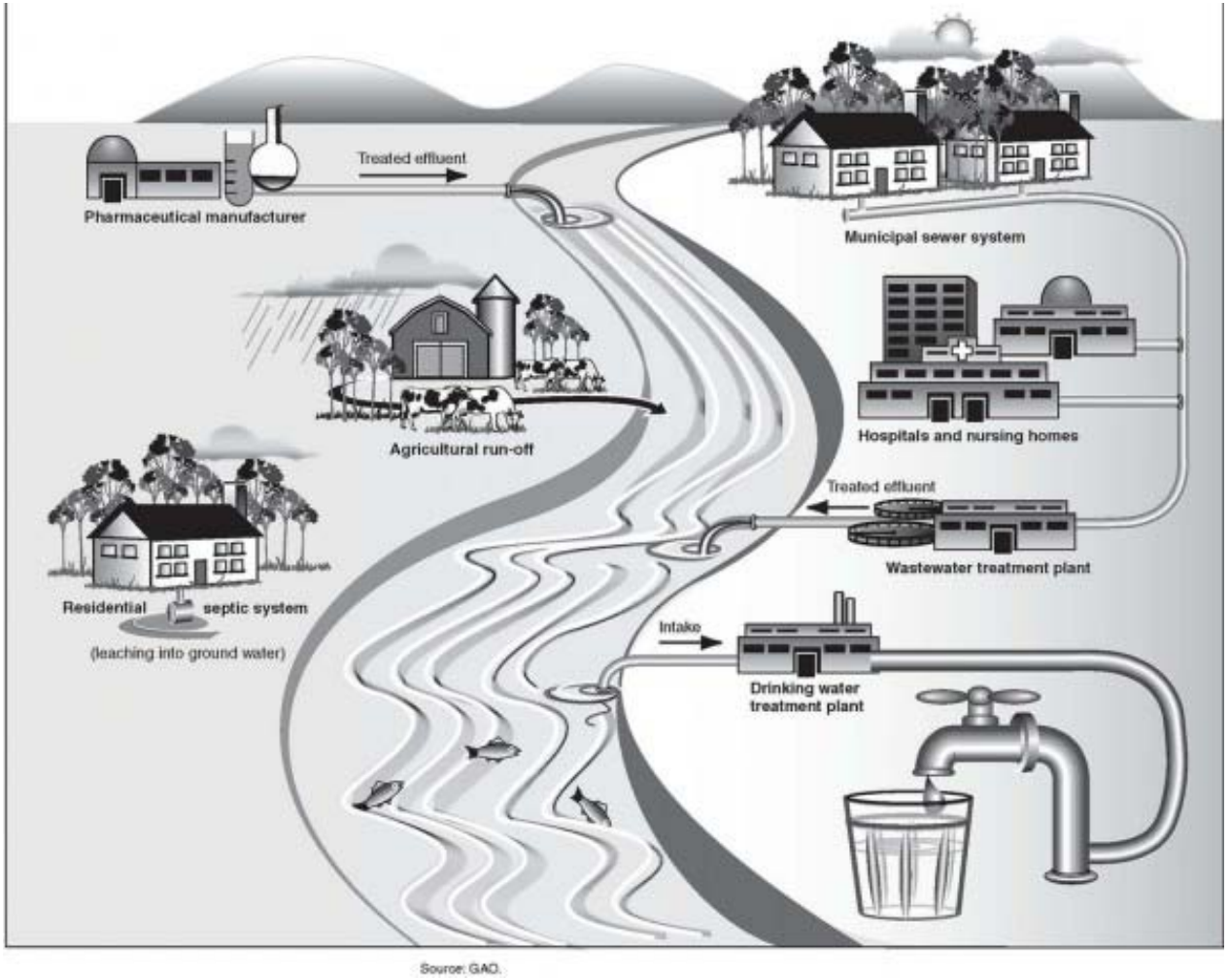
Source of wastewater



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Domestic wastewater

- Quantity of domestic wastewater calculation
  - **Wastewater Quantity Estimation**

$$Q=Nq$$

Q ——daily wastewater flow, m^3/d

N ——population to be served, capita

q ——Per capita sewage contributed per day, $m^3/d \cdot cap$

- Usually 60%~ 80% of the water consumption

Fluctuations in wastewater Flow

(i) $Q_{max}= 2\ Q_{average}$

(ii) $Q_{min} = 2/3\ Q_{average}$

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Domestic wastewater

- Domestic wastewater flowrate:
  - Where water supply and wastewater flow data are lacking. a gallon per capita per day (gpcd) allowance not exceeding those in the following table

Description	Gallons per capita per day (gpcd)
Non−SMSA cities and towns with projected total 10−yr population of 5,000 or less .	60−70
Other cities and towns	65−80

http://docs.legis.wisconsin.gov/code/admin_code/nr/100/110.pdf

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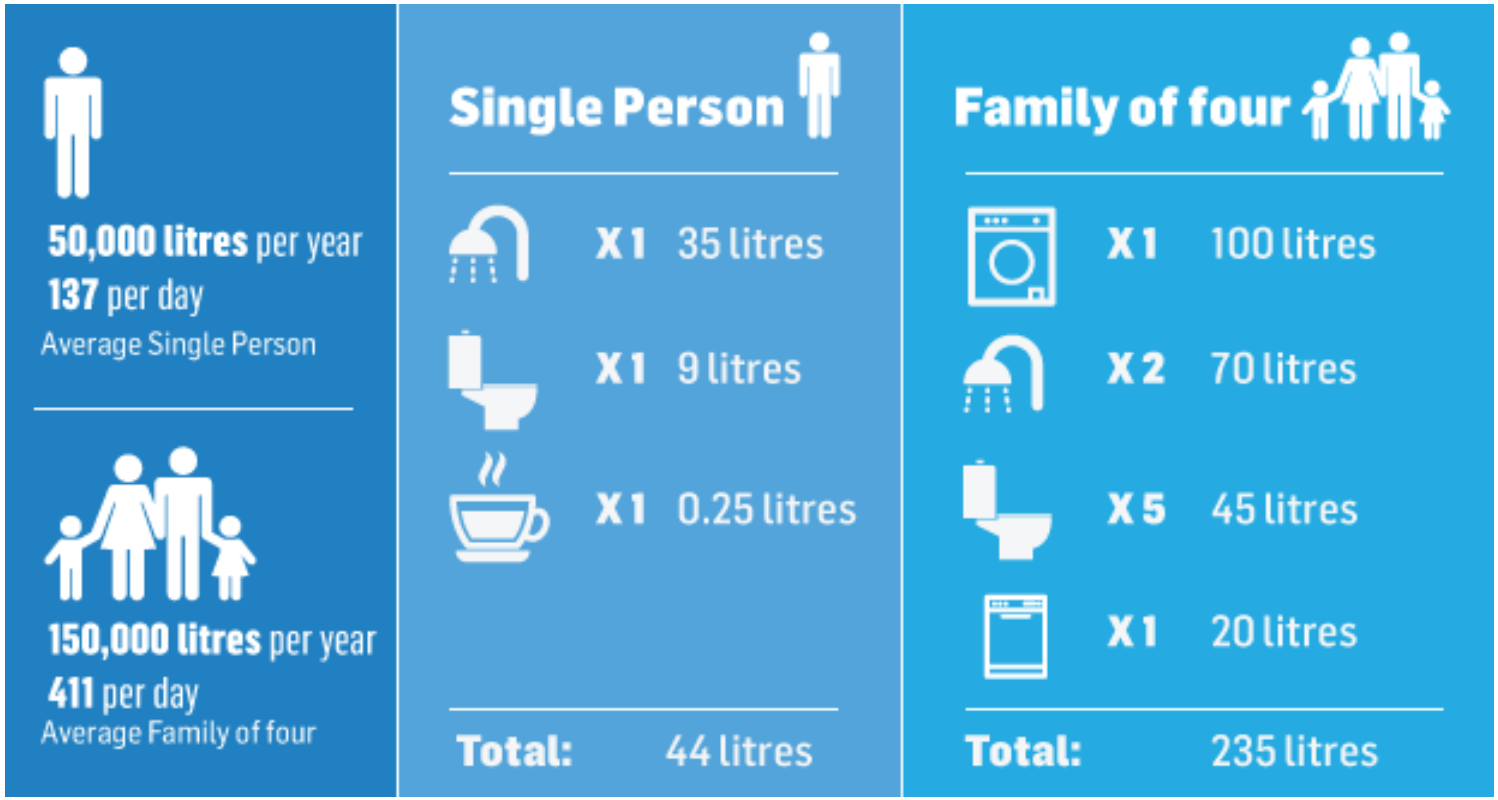
Water usage in households



A typical wastewater flow rate from a residential home in the United States might average 70 gal (265 L) per capita per day (gal/(c d).

http://www.home-water-works.org/calculator

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Water usage of miscellaneous facilities

- Table 1: Typical Wastewater Flow Rates for Miscellaneous Facilities

Type of establishment	Gallons/cap.d	Type of establishment	Gallons/cap.d
airports	5	Cottages and small dwellings with seasonal occupancy	75
Bathhouses and swimming pools	10	Country clubs (per resident member)	100
camps		Country clubs	25
campground with central comfort station	35	dwellings	
with flush toilets, no showers	25	boarding housed	50
day camps (no meal served)	15	rooming housed	40
luxury camps	100	Hospitals (per bed)	250

Illinois EPA, 1997

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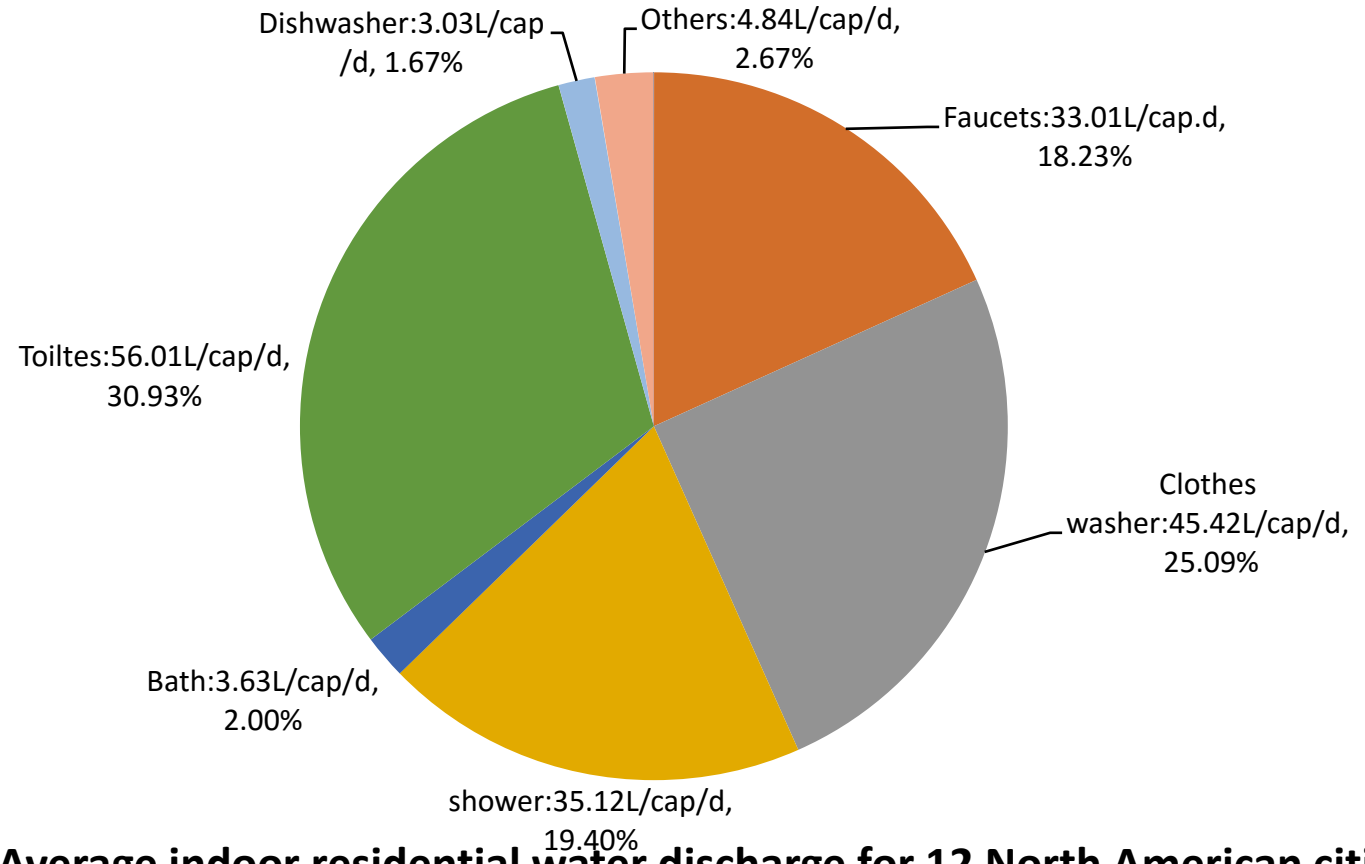
Domestic wastewater

- Quantity distribution of domestic wastewater



Average indoor residential water discharge for 12 North American cities.

Source: Data from AWWA 1999.

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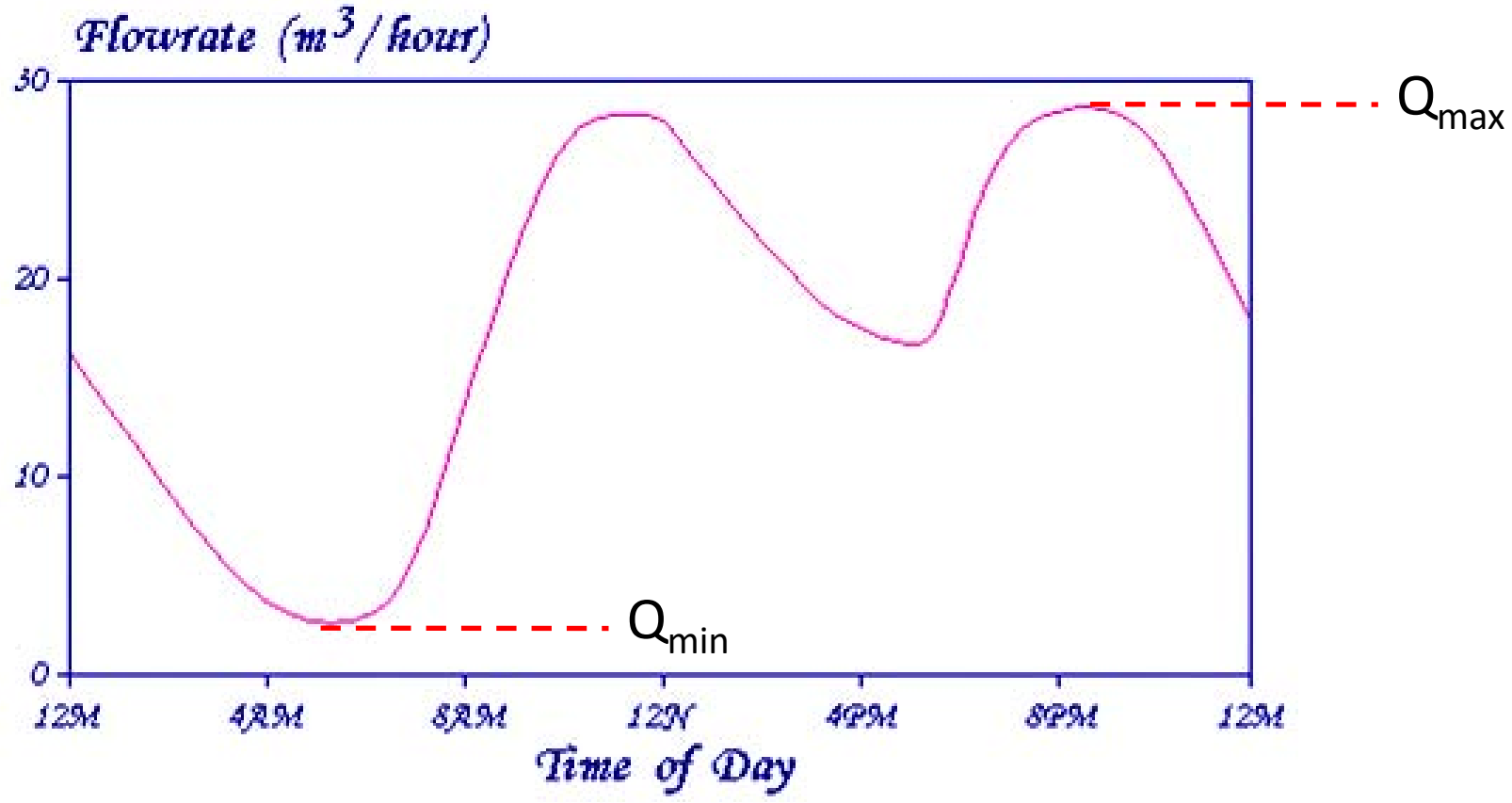
Domestic wastewater

- Wastewater production



Typical hourly variation in domestic WW flowrates

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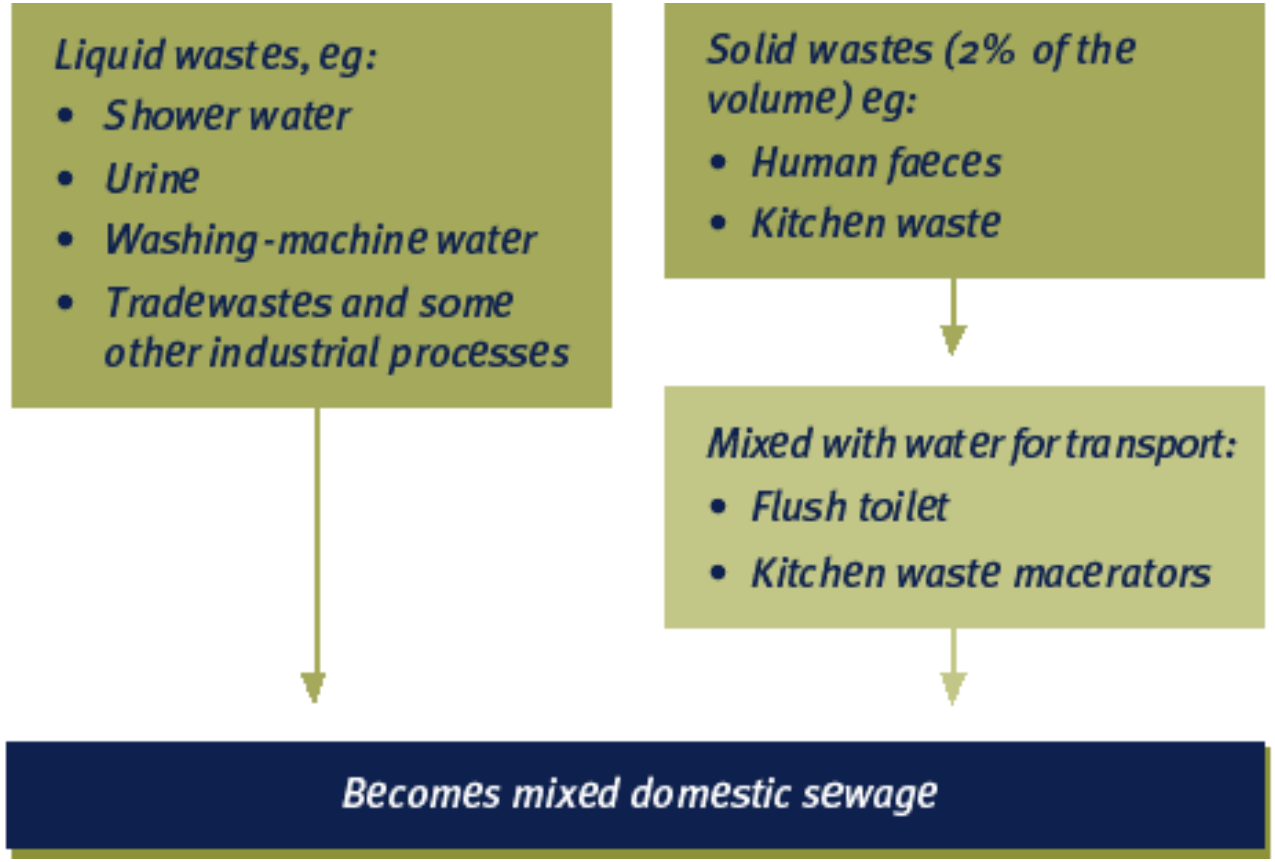
Domestic wastewater

- Quality of domestic wastewater:
  - Quality depends on the pollutant content



Water as a liquid waste and as a medium for solid wastes in the domestic situation

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Domestic wastewater

- Components in domestic ww:

Components in domestic WW		Comments
Organic matter	Human waste	faeces, urine, blood
	Food waste	usually from kitchen waste macerators
Oils and fats		usually from tipping down drains
Metals		found in foods, via human wastes
Solvents		tipping down drains, cleaning
Chemicals		via human wastes; via cleaners, soaps etc, washing, bathing and cooking
Paints		households

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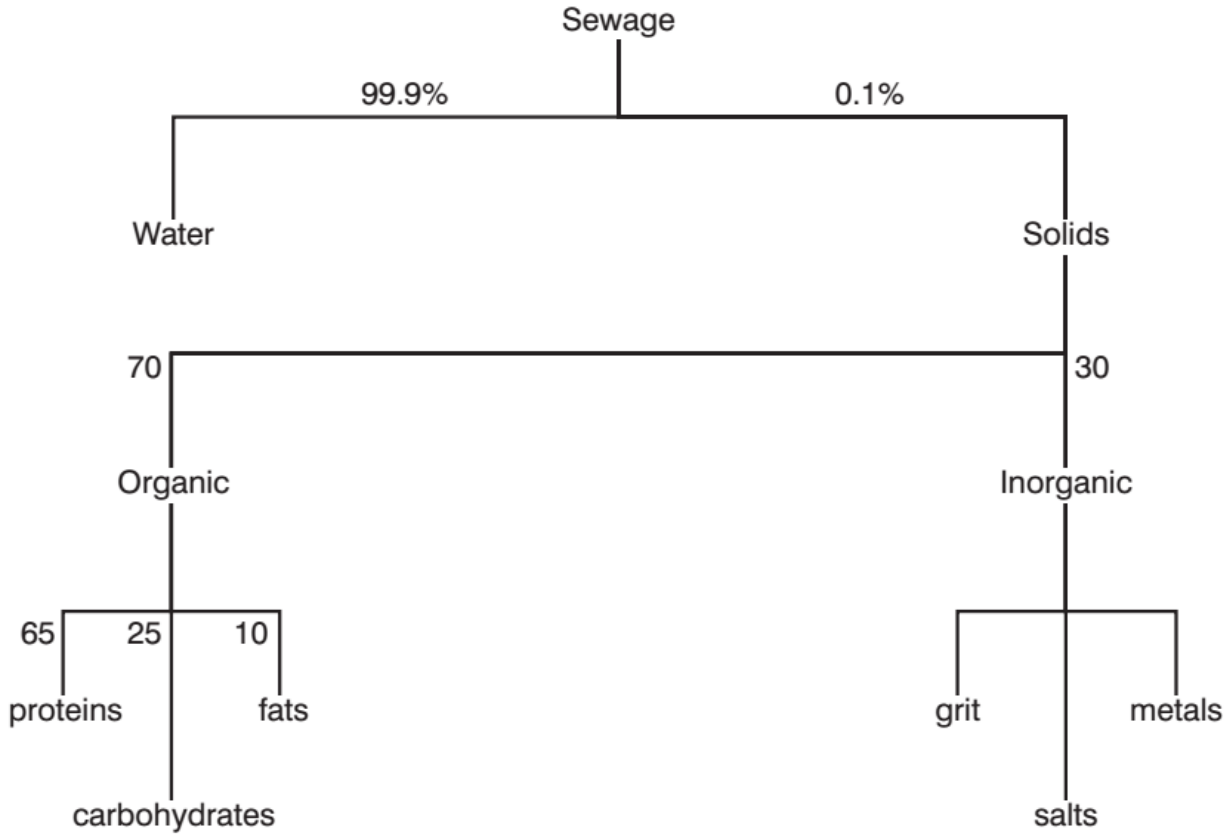
Domestic wastewater

- Components in domestic WW



Source: Tebbutt (1998)

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Domestic wastewater

- Typical domestic WW compositions

Pollutant	Concentration, mg/l		
	Weak	Average	Strong
Total solids	350	800	1200
Total suspended solids	100	240	350
Total dissolved solids	250	500	850
Settleable solids (ml/l)	5	10	20
Volatile suspended solids	80	180	280
Volatile dissolved solids	100	260	300
Ammonia nitrogen	10	20	35
Total nitrogen	20	35	80
Phosphorus	5	10	15
Alkalinity as $CaCO_3$	50	100	250
Oil & grease	50	100	150
5-Day biochemical oxygen demand	120	225	400
Chemical oxygen demand	175	325	575
Total organic carbon	65	125	220

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Domestic wastewater

- Classification of domestic wastewater
- What is **greywater**?
  - Low load
  - Generated from **wash hand basins, showers and baths** (not from a kitchen sink or toilet)
  - Can be recycled on-site for uses such as Water Closet (WC) flushing, landscape irrigation and constructed wetlands
- what constitutes greywater
  - UK: showers, bath tubs, wash basins,
  - excludes washing machines, kitchen sinks, toilet flushing
  - Israel: showers, bath tubs, wash basins, washing machines, kitchen sinks
  - Yemen: kitchen sink, hand wash basins, bath room showers, washing machine

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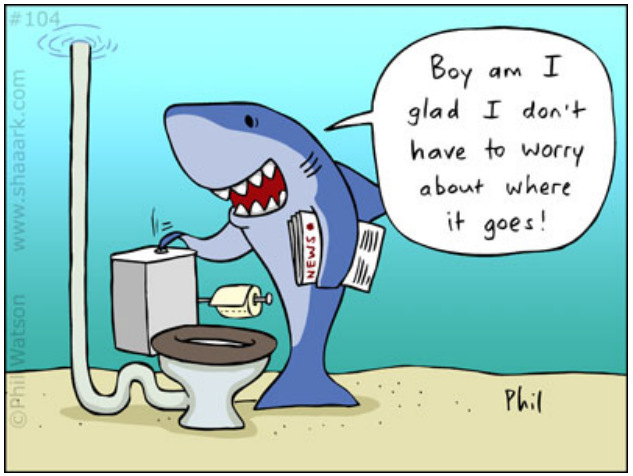
Domestic wastewater

- Classification of WW
- What is **blackwater**?
  - High load
  - From **WC flushing, kitchen sinks, (dish washers)**
  - High risk of contamination by bacteria, viruses and pathogens
  - Should not be reused in the home
  - Conponents: faeces, urine, toilet paper, flushing water



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Domestic wastewater—grey water-quantity

- Average quantity of grey water

Country/ region	Rural area	Big city
Jordan	14 L/c.d	59 L/c.d (Amman)
European communities	66 L/c.d	274L/c.d
Yemen		35L/c.d (Sana'a)
Australia	704L/d for family of two adults and four children	

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Domestic wastewater—grey water-quantity

- Grey water represents over 60% of the total wastewater stream

Table 2: Approximate generation percentage of wastewater and greywater [16]

Wastewater type	Total Wastewater		Total Greywater	
	% Total	(L/day)	% Total	(L/day)
Toilet	32	186	-	-
Hand Basin	5	28	8	28
Bath/shower	33	193	54	193
Kitchen	7	44	-	-
Laundry	23	135	38	135
Total	100	586	100	356

[16] DWE. 2008. NSW Guidelines for Greywater Reuse in Sewered, Single Houshold Residential Premises. Department of Water & Energy, NSW government. www.dwe.nsw.gov.au.

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Domestic wastewater—grey water-quantity

- in the western countries the high percentages of in-house greywater are produced from bathrooms and wash machines while the low percentages are produced from kitchens and hand wash basins

  - Table Household greywater quantities in the literatures

Location	kitchen sink	Hand wash basin	bathroom shower	washing machine	Greywater Percentage
Sydney	29		41	30	80
US	27.8		41.7	30.5	72
	11	55		34	
	11	7	48	34	68
Oman	34	7	51	8	82
Sana'a	37	32	18	13	87

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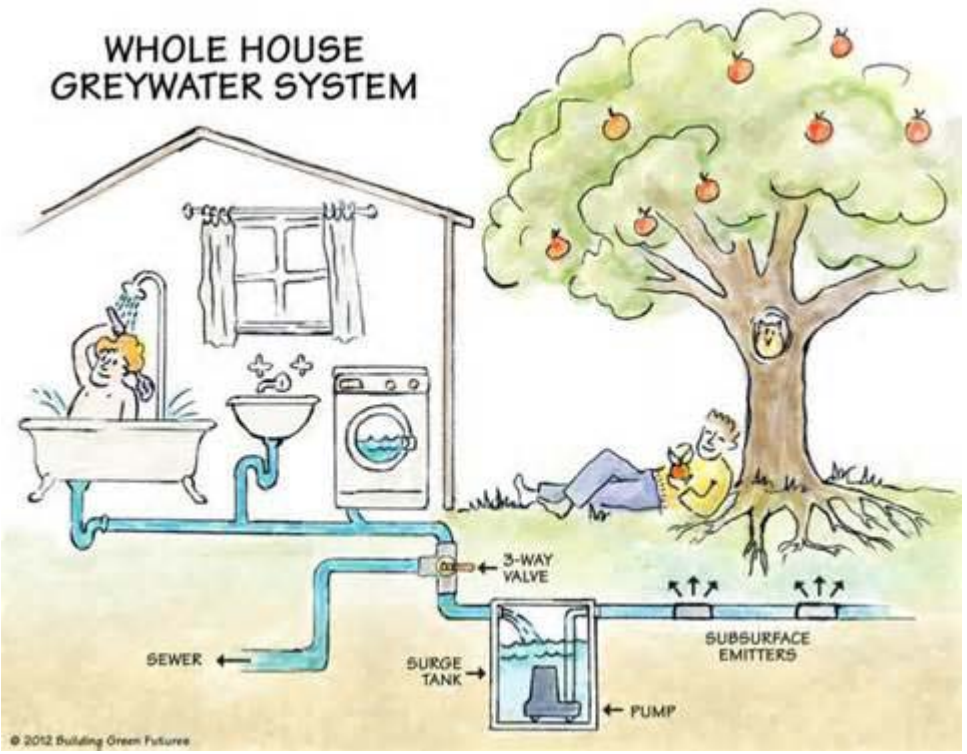
Domestic wastewater—grey water-quality

- Affecting factors:
  - Number of household occupants
  - Ages of household occupants
  - Health status
  - Lifestyle
  - Tap water sources
  - Water usage patterns
  - Household products used
    - Soaps
    - Shampoos
    - Detergents
    - Mouthwash
    - Toothpaste
    - Hair dyes
    - Shaving cream
    - Body oils



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Domestic wastewater—grey water-quality

- Houshold greywater quality in the Arab counties

Parameters	Unit	Qebia (Palestine)	Karak (Jordan)	Kuwait (Kuwait)	Sana'a (Yemen)	WHO/FAO guidelines
pH		6.60-6.86	5.93-7.82	7.5	6.0	6.5-8.4[b]
TSS	Mg/L	36-396	23-358	204	510.80	20[c]
Turbidity	FAU	-	-	120	618.60	-
NO_3^-	Mg/L	0-1.3	-	5	98.12	9.5–518.5[b]
NH_4-N	Mg/L	25-45	-	4.8	11.28	-
PO_4^-	Mg/L	-	-		16.10	-
BOD_5	Mg/L	941-997	110-1240	40	518	20[c]
COD	Mg/L	1391-2405	92-3330	-	2000	-
F.C	N/100 ml	10^4-37x10^4	-		19×10^6	200[a]

a WHO 1989 guidelines for public parks and crops likely to be eaten uncooked
b FAO guideline for water quality for irrigation
c WHO/AFESD Consultation, limit for vegetables likely to be eaten uncooked

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Domestic wastewater—grey water-quality

- Houshold greywater quality in some western counties

Parameters	Unit	USA	Sweden	Australia	Range
pH		6.8	-	7.3	6.6-8.7
TSS	Mg/L	-	-	-	45-330
Turbidity	FAU	-	-	113	22->200
NO_3^-	Mg/L	-	-	-	<0.1-0.8
NH_4-N	Mg/L	-	-	-	<1-25.4
PO_4^-	Mg/L	7.8	-		-
BOD_5	Mg/L	164	196	159	90-290
COD	Mg/L	366	-	-	-
F.C	N/100 ml	$8.8x10^5$-$13x10^6$	-	-	-

Sources: Jefferson, B., et al. 2000. Technologies for domestic wastewater recycling. Urban Water 1 (4): 285-292.

Jeppesen, B., et al. (1994) Urban Water Research Association of, A. 1994. *Domestic greywater reuse: overseas practice and its applicability to Australia:*Published for the Urban Water Research Association of Australia by the Melbourne Water Corporation.

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Domestic wastewater—black water-quality

- Blackwater samples were collected from 44 similar small houses consisting of 141 persons—92 adults and 49 children (Vibyasen South,Sweden)

Flows and concentrations of ordinary wastewater parameters

		Greywater (GW)			Blackwater (BW)		
		Average	Range		Average	Range	
			Min	Max		Min	Max
Q	m^3/h	0.54	0.16	1.02	0.17	0.16	0.18
P_{tot}	mg/L	7.53	4.6	11	42.7	21	58
N_{tot}	mg/L	9.68	8.0	11	150	130	180
BOD_7	mg/L	418	350	500	1037	410	1400
COD_{Cr}	mg/L	588	495	682	2260	806	3138
TS	mg/L	630	570	700	3180	920	4320
VS	mg/L	330	300	360	2560	420	3660
pH	–	7.50	6.06	8.38	8.94	8.87	9.08

Sources: Helena Palmquist, Jorgen Hanæus. Hazardous substances in separately collected grey- and blackwater from ordinary Swedish households. Science of Total Environment, 348 (2005) 151– 163

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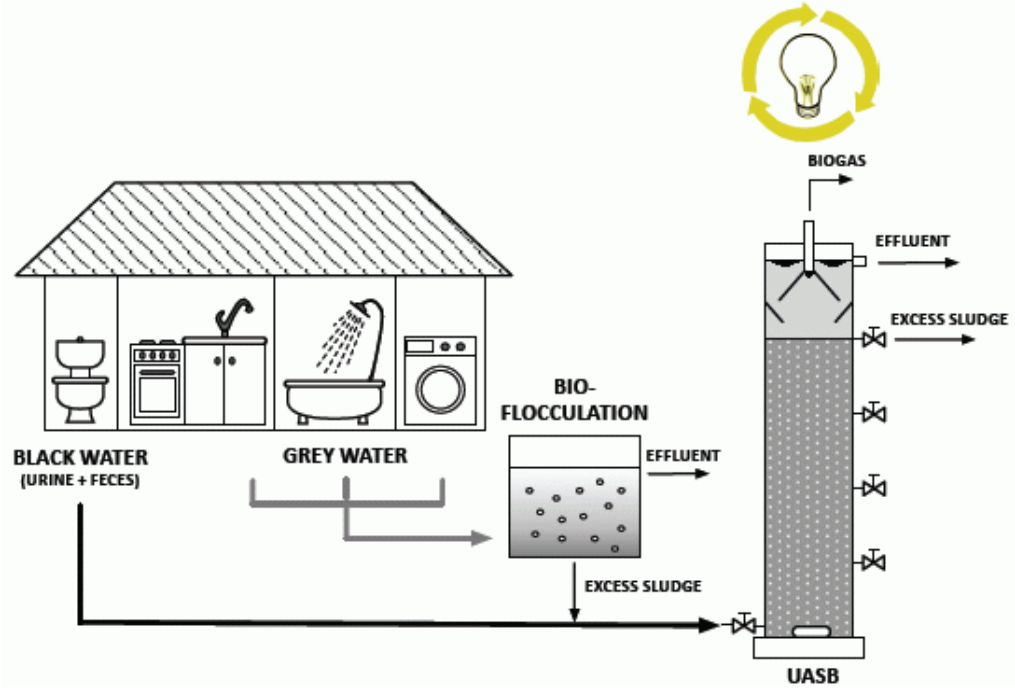
Domestic wastewater—black water-quality

- Each person on average excretes about 4 kg N and 0.4 kg P in urine, and 0.55 kg N and 0.18 kg P in faeces per year.
- In Sweden it has been estimated that the nutrient value of urine from the total population was equivalent to 15–20 % of chemical fertiliser use in 1993



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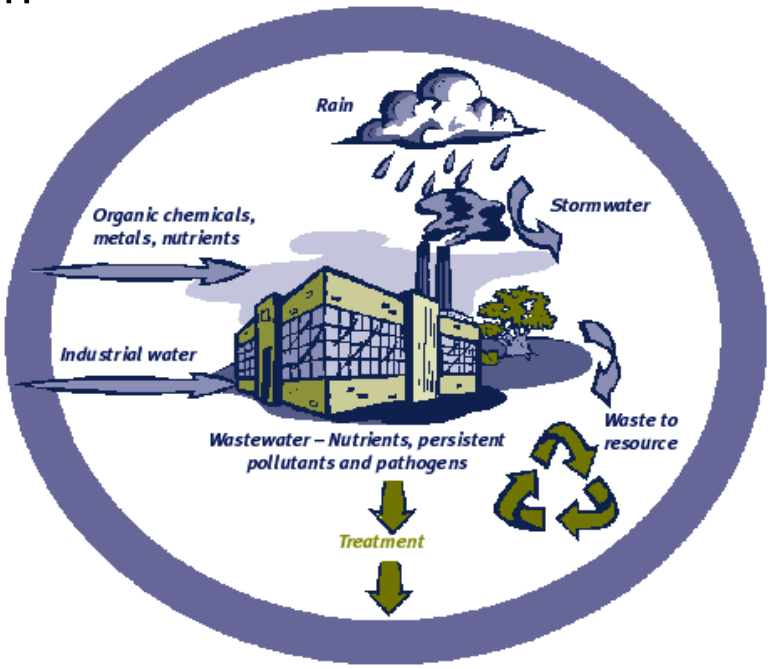
Industrial wastewater

- Concepts
  - Generated from various industrial activities
  - Causing serious environmental pollution
  - Generally difficult to be treated
  - Multi-component



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Industrial wastewater

- Sources of industrial wastewater
  - Mining industry
  - Mechanical industry
  - Chemical industry
  - Food industry
  - Manufacturing industry
  - Others

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Industrial wastewater

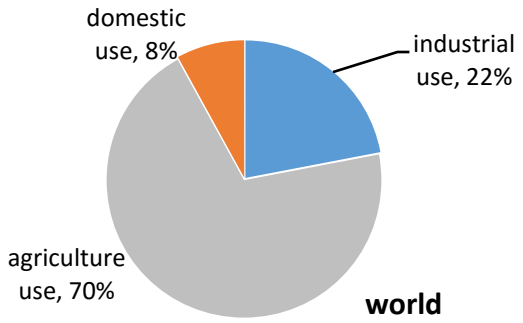
- Industrial water use

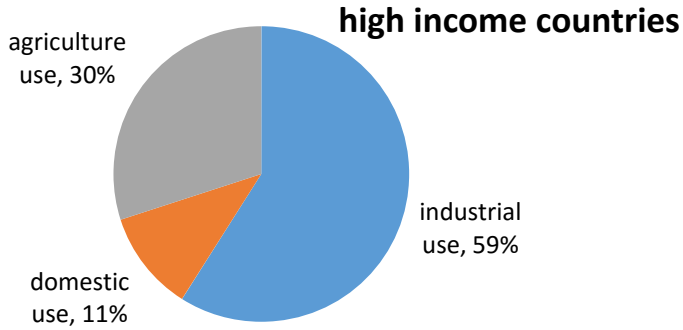
Water withdrawals for industry:

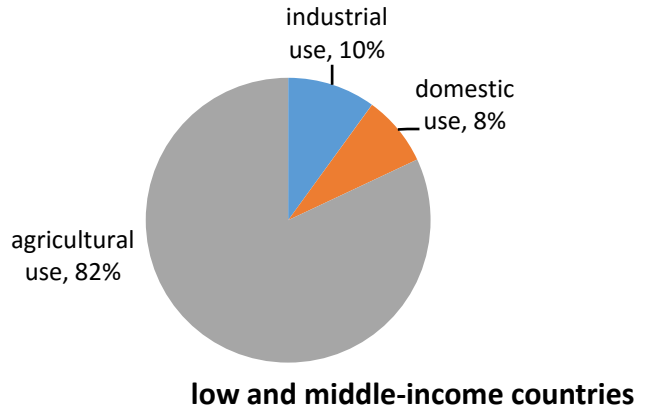
- World: 22% of total water use

- High-income countries: 59% of total water use.

- Low-and middle- income countries: 10% of total water use.







Source: Extracted from the Executive summary of the WWDR. World Bank, 2001. . Washington DC.

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Industrial wastewater

- Industrial water use

Sources : Ondeo IS , 2012 ,

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Industrial wastewater

- types of industrial wastewater and typical pollutants

sector	pollutant
Iron and steel	BOD, COD, oil, metals, acids, phenols, cyanide
Textiles and leather	BOD, solids, sulfates, chromium
Pulp and paper	BOD, COD, solids, chlorinated organic compounds
Petrochemicals and refineries	BOD, COD, mineral oils, phenols, chromium
Chemicals	COD, organic chemicals, heavy metals, SS, cyanide
Non-ferrous metals	Fluorine, SS
Microelectronics	COD, organic chemicals
Mining	SS, metals, acids, salts

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Industrial wastewater

- Classification of industrial wastewater
  - Inorganic industrial wastewater
    - Coal and steel industry
    - Nonmetallic minerals industry
    - Surface processing of metals(iron picking works, electroplating plants)

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Industrial wastewater

- Classification of industrial wastewater
  - Organic industrial wastewater
    - Manufacturing pharmaceuticals, cosmetics, organic dye-stuffs, glue and adhesives, soaps, synthetic detergents, herbicides
    - Tanneries and leather factories
    - Textile factories
    - Cellulose and paper manufacturing plants
    - Oil refining industry
    - Brewery and fermentation factories
    - Metal processing industry

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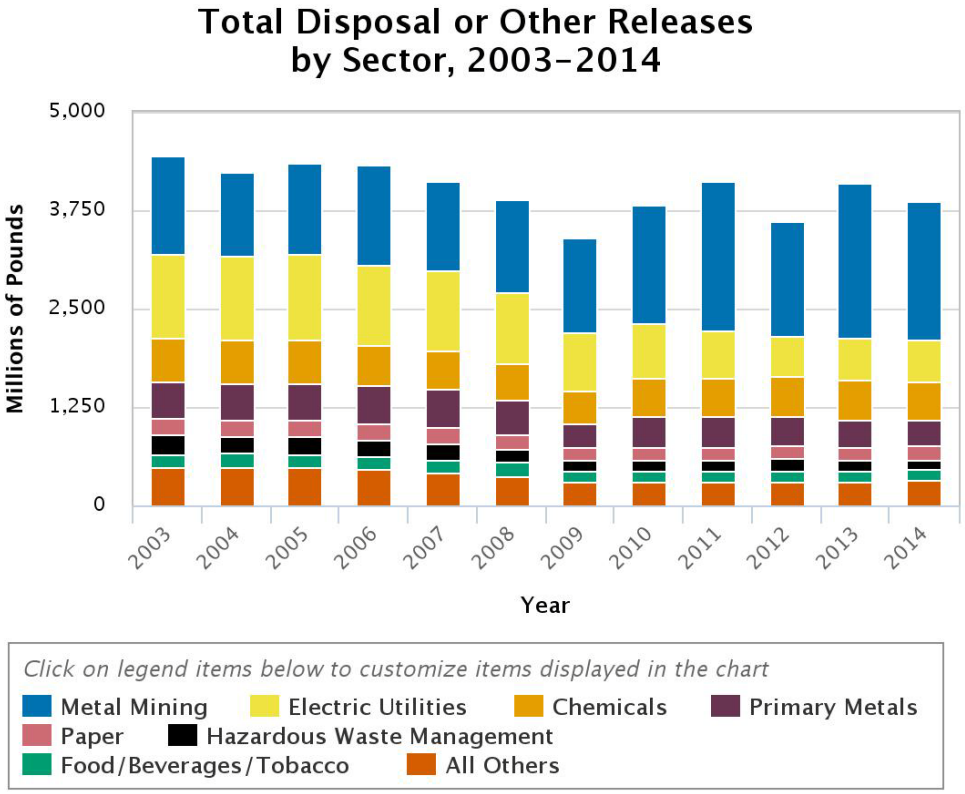
Industrial wastewater

- Water pollutants from industry

- Industrial pollutants were discharged in a large amount every year

- Most of the pollutants in wastewater is toxic

- This wastewater usually suffered from an untreated process in developing countries



Data from US Environmental Protection Agency (EPA)

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Industrial wastewater

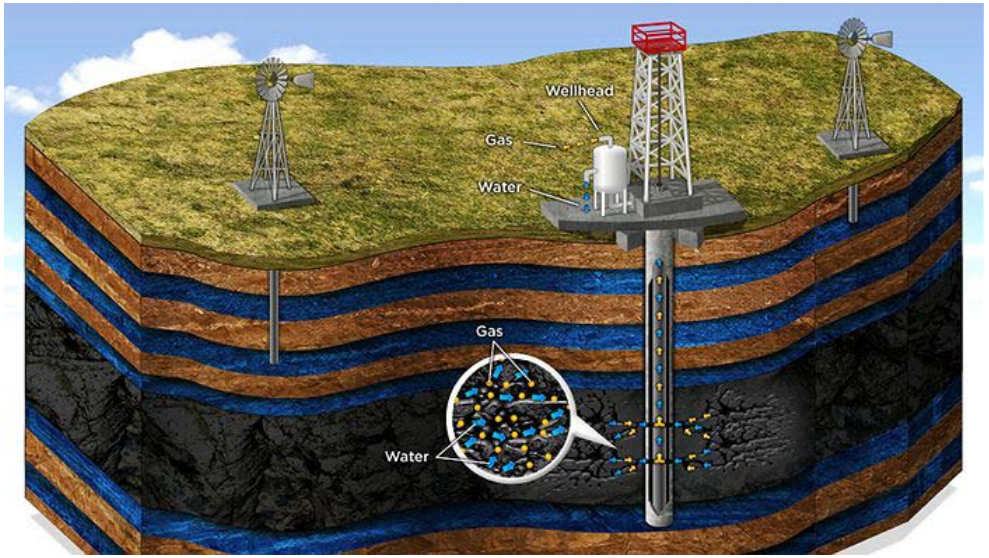
- Water pollutants from industry

  I. Mining industry

  – Ore washing wastewater and groundwater

  – Soluble ions, suspended solids

  – Floation agent



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Industrial wastewater

- Water pollutants from industry

II. Smelting industry

– Cooling water and dusting wastewater

– Heavy metal ions, suspended solids

– Acidic

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Industrial wastewater

- Water pollutants from industry

III. Mechanical industry

- Electroplating wastewater
- Lubricating oil, resin
- Chromium, zicn, cyanide

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Industrial wastewater

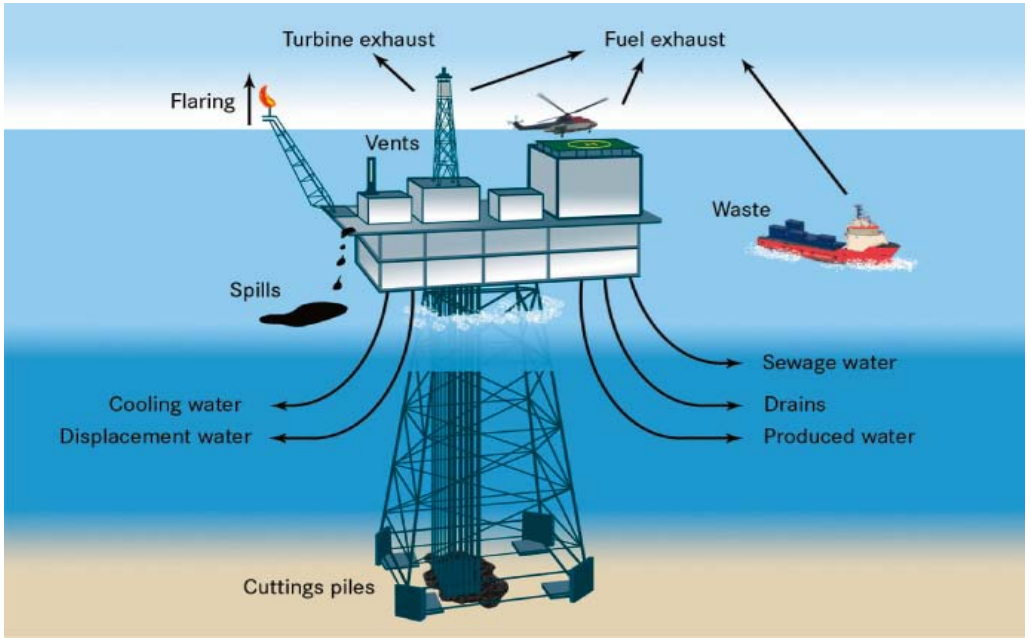
- Water pollutants from industry

  IV. Petroleum industry

  – Soluble salts, oil

  – Sulphur, alkali

  – Phenol, acetone, arene



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Industrial wastewater

- Water pollutants from industry

V. Chemical industry

– Soluble salts, acid, alkali, suspended solids, sulfide.

– Dye, coatings, wastewater from synthetic rubber etc.

– Heavy polluted

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Industrial wastewater

- Water pollutants from industry

  VI. Pulp and paper industry

  – Cellulose, lignin, volatile organic acids

  – Bad odour

  – Heavy polluted

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Industrial wastewater

- Water pollutants from industry

  VII. Textile printing and dyeing industry

  – Natural matters, fat, starch

  – Cellulose, lignin, dye, detergent

  – Sulfide, salts, alkali

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Industrial wastewater

- Water pollutants from industry

  VIII. Food industry

  – Washing water

  – Organic matters, suspended solids

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Industrial wastewater

- Wastewater characteristic
  - Major pollution composition
    - Acidic wastewater, alkaline wastewater, cadmium-containing wastewater, phosphorus-containing wastewater, COD-rich wastewater, etc.
  - Chemical characteristic
    - Biodegradable or persistent organic pollutants
    - Inorganic pollutants, e.g. sulfide, nitrate, cadmium

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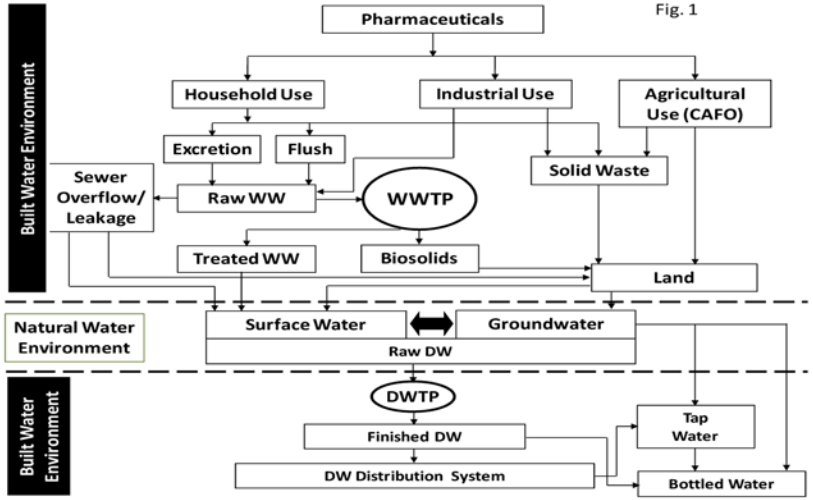
Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater from the pharmaceutical industries
    - Varies a great deal
    - Different kinds of effluent with widely varying qualities flow from the different production areas
    - Usually, COD 5000~15000 mg/L, BOD is relative low, the ratio of BOD_5/COD is lower than 0.30, bad color, high (or low) pH value



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Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater produced by tannery plants
    - In a tannery with chrome and bark tanning, the wastewater resulting from the different processes are as follows: soaking and washing 22.5%, liming 17.5%, rinsing 5.5%, plumping and bating 19%, chrome tanning 2%, bark tanning 2%, washing and drumming 31.5%
    - The wastewater flow is very uneven, the peak flow can be 2.5 fold of the average hourly flow rate
    - Fairly acid pH
    - High chloride content (up to 5g Cl/L)
    - High COD concentration (1500~2500mg/L)
    - High amount of settable substances (10~20g/L)
    - High emulsified fat, tends to form foam
    - Dichromate content can reach a peak value of 2000mg/L

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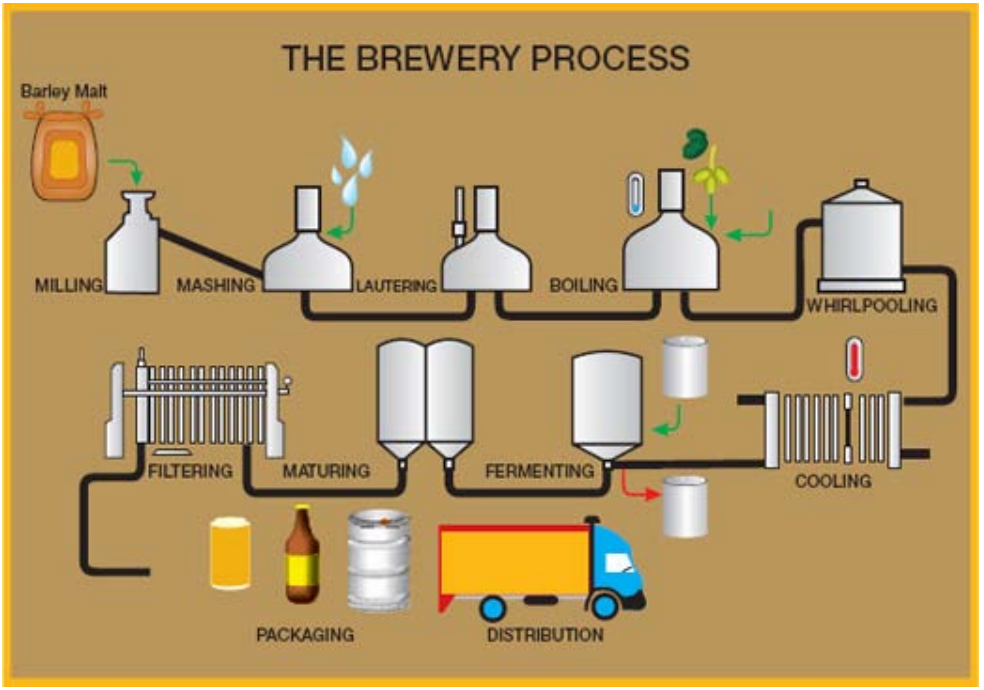
Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater produced by brewery industry
    - Wastewater come from:
    - (1) washing water
    - (2) rinsing water
    - (3) fermentation process



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Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater produced by brewery industry
    - No toxic contaminants
    - Easy biodegradable
    - Good carbon source for N and P removal
    - Concentration of the mixed wastewater: COD 1500~5000mg/L, BOD_5 1000~3000mg/L, TP 5~30 mg/L, PO_4^{3-}-P 2~5mg/L, settable solid 3~30mg/L

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Industrial wastewater

- Characteristics of industrial wastewater—brewery WW

Composition of wastewater produced by different processes

Type of wastewater	pH	Dry residue (mg/L)	SS (mg/L)	BOD5 (mg/L)
Barrel cleaning	7.1	980	250	21
Bottle cleaning				
a) Washing solution	11.5	71700	310	870
b) Rinsing water	7.2	940	95	16
Filter cloth washing				
a) Mash filter	6.7	1070	1846	325
b) Cooler sludge filter	6.7	1290	456	694
Fermentation				
a)Fermenting without yeast	5.3	2060	3944	3550
b) Fermenting with yeast	5.0	------	------	70250
c) Storage without yeast	6.8	1010	164	502
d) Storage with yeast	5.2	------	10900	84500
e) Beer filter	5.9	1940	37835	2000

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Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater produced by petroleum refineries

Pollution	Approximate Quantities
Cooling systems	3.5-5 m^3 of wastewater generated per ton of crude
Polluted wastewater	BOD 150-250 mg/l COD 300-600 mg/l phenol 20-200 mg/l oil 100-300 mg/l (desalter water) oil 5000 mg/l in tank bottom benzene 1-100 mg/l heavy metals 0.1-100 mg/l

all this figures depend on the process configuration but we give here a general guide

Resource: Pollution Prevention and Abatement Handbook World Bank Group

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Industrial wastewater

- Characteristics of industrial wastewater
  - Wastewater produced by cooling towers
    - high temperature
    - high dissolved solids
    - High concentration of biocides residues
    - High concentration of anti-fouling agents

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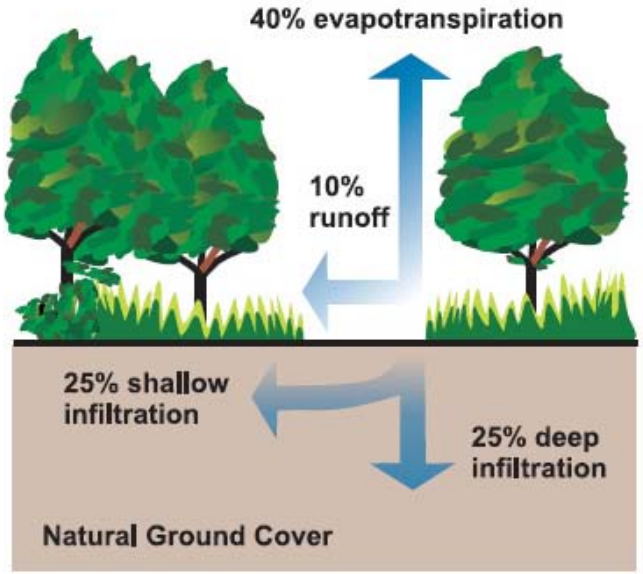
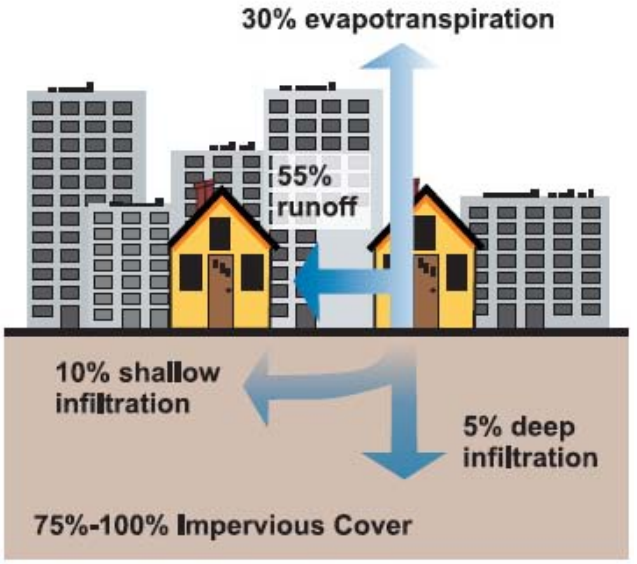
Stormwater

- Characteristics of stormwater
  - Stormwater includes any surface runoff and flows resulting from precipitation, drainage or other sources
  - Component:
    - suspended sediments, metals, petroleum hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAHs), coliform, etc.





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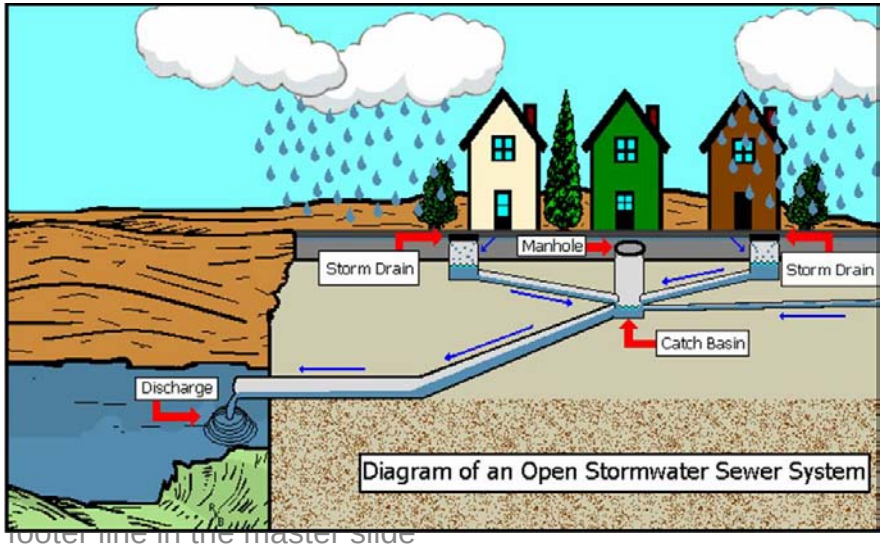
stormwater

- Factors Influencing the quantity and quality
  - Intensity, duration, and areal extent of storms
  - time intervals between successive
  - Land contours, land uses, population densities
  - incidence and nature of industries
  - size and layout of sewer systems



stormwater

- Stormwater quality highly variable, and some of this variability can be explained by land use and source area (much variability also due to rain characteristics).
  - Water color was high (over 200) in runoff from land with dense vegetations
  - Water color was not correlated with turbidity
  - row crop runoff had the highest TSS concentrations

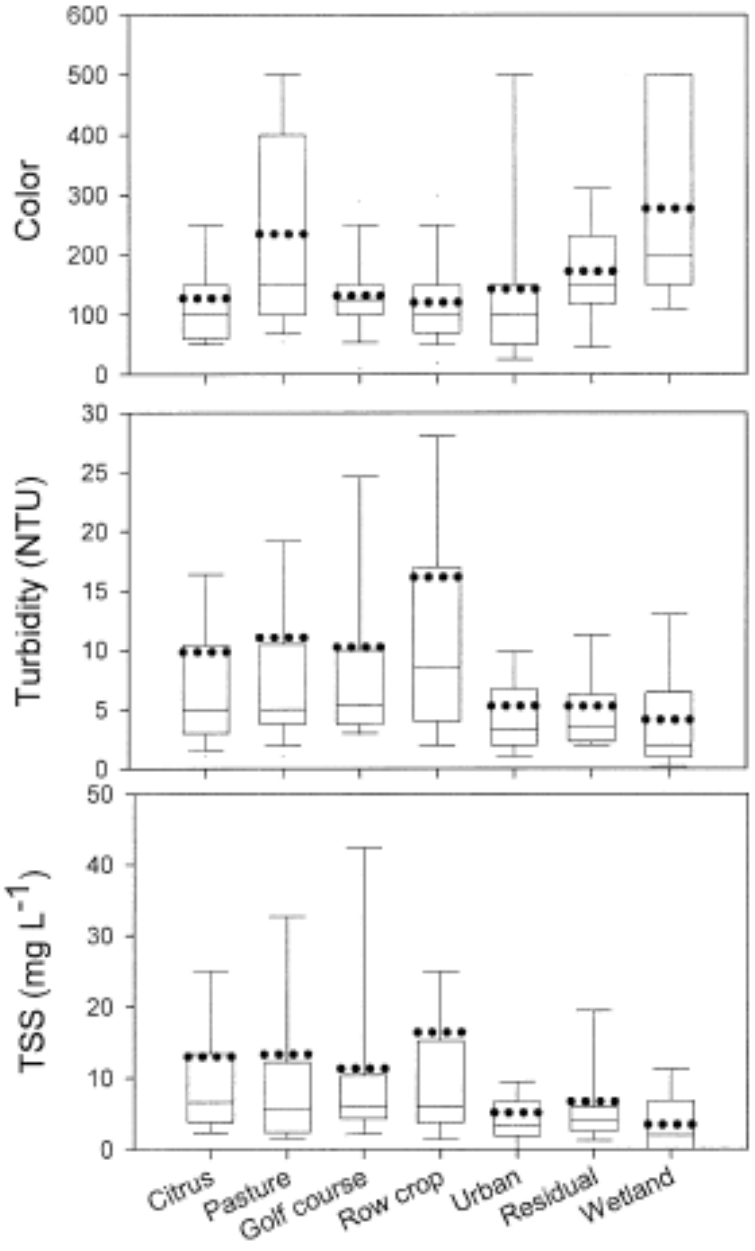


Figure 4. Whisker Box Plots of Color, Turbidity, and TSS Concentration of Storm Water from Major Land Use

stormwater

- Dairy land runoff has the highest nutrient concentration
- Row crop runoff has the second highest nutrient concentration
- The runoff from urban, wetland and residual are slightest polluted

TABLE 2. Mean and Median Nutrient Concentrations in Storm Water Runoff From Eight Land Use Types Sampled in the Study Area.

Land Use	No. of Samples	Total P (mg L^{-1})		Total N (mg L^{-1})		Organic N (mg L^{-1})		Inorganic N (mg L^{-1})		NH_3-N (mg L^{-1})		NO_x-N (mg L^{-1})	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Citrus	127	0.29	0.16	1.37	1.23	1.11	1.05	0.26	0.13	0.13	0.06	0.14	0.04
Pasture	53	0.29	0.22	1.46	1.09	1.32	0.94	0.15	0.08	0.11	0.06	0.03	0.01
Urban	115	0.22	0.09	1.07	0.82	0.92	0.72	0.13	0.05	0.06	0.03	0.07	0.01
Golf Course	28	0.24	0.19	1.62	1.51	1.27	1.22	0.32	0.22	0.20	0.10	0.12	0.07
Wetland	30	0.02	0.01	1.18	0.94	1.10	0.99	0.14	0.02	0.14	0.02	0.00	0.00
Row crop	20	0.63	0.45	1.88	1.31	1.14	0.97	0.77	0.33	0.20	0.04	0.57	0.27
Residual	21	0.26	0.20	1.09	0.87	0.87	0.81	0.21	0.14	0.09	0.05	0.11	0.05
Dairy	8	12.54	8.86	38.9	24.6	9.98	7.39	28.9	11.5	28.5	11.0	0.39	0.03

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Thank you for your listening!

Any Questions?

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