On-site Wastewater Management Training Course

Wastewater Characterisation

What is Wastewater?

Wastewater – the water arising from domestic activities in dwellings, institutions or commercial facilities consisting of all wastewater

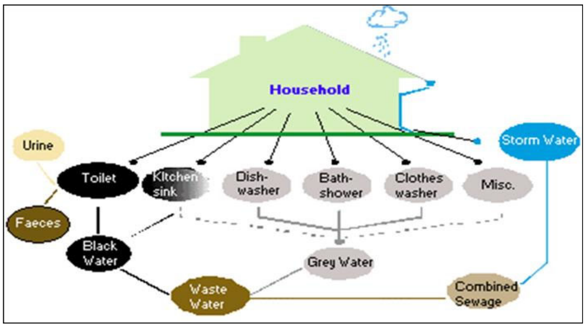
- **Domestic wastewater** - derived from household waste streams: kitchen; bathroom (basin, bath and shower); laundry and toilet
- **Industrial and Commercial wastewater** - varies widely in character - often requires specialised treatment processes as it may contain substances that are harmful to the biological processes utilised for treatment processes

Wastewater Terms

Domestic wastewater is commonly described as any of three forms:

- Blackwater – "water grossly contaminated with human excreta" e.g. toilet water, composting toilet solids
- Greywater – "water that is contaminated by but does not contain human excreta" e.g. kitchen, bath and laundry water. Also referred to as 'sullage'
- Combined – "a combination of both black and grey water"

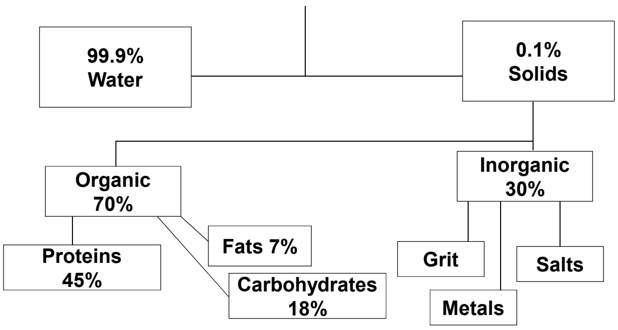
Domestic Wastewater Streams



Sewage

- Contains faecal and urinous matter, sullage (washing water), grit, bacteria, viruses, plus a variety of other liquids and solids
- Consists of approximately 99.9% water and 0.1% solids (every 1,000 kg or 1,000 litres of wastewater contains about 1 kg of solids)
- About 70% of solids are made up of organic compounds either suspended or dissolved in wastewater (proteins, carbohydrates and fats)
- Organic solids are readily broken down into more stable inorganic compounds by bacteria and other micro organisms

Sewage Composition



Treatment Processes

- Domestic wastewater begins to change immediately after generation (both physically and chemically), due to the action of bacteria and other organisms

Treatment may involve:

- Physical Processes - the separation of the suspended solids from the liquids - use of screens, sedimentation tanks, filters
- Biological Processes - various processes involving the oxidation of organic matter, carried out by micro-organisms
- Advanced Processes - disinfection/nutrient removal

Typical Domestic Wastewater Quality

Parameter (mg/L)	Raw Effluent	Septic Tank	AWT Effluent	Sand Mound Effluent
BOD_5	300-340	120-150	5-80	1-10
SS	260-300	40-190	5-100	5-20
TN NO_3–N (% of TN)	50-60 (0%)	40-50 (0%)	25-50 (80%)	30-50 (85%)
TP PO4 – P (% of TP)	10-15 (45%)	10-15 (90%)	7-12 (85%)	5-10 (90%)
Faecal coliforms org/100ml	10^5-10^7	10^5-10^7	10-10^3	10-10^3

BOD_5 - Biochemical Oxygen Demand; TN - Total Nitrogen
SS - Suspended Solids; TP - Total Phosphorus

Organic Material

- Organic material consists of chemical compounds based on carbon skeletons (proteins, carbohydrates and fats)
- Typically measured by a standardised laboratory test referred to as 5-day Biochemical Oxygen Demand (BOD_5) - results typically expressed as mg/L
- Usually present in domestic wastewater in dissolved, suspended or colloidal form
- BOD_5 refers to the amount of oxygen used as the biodegradable wastewater fraction is decomposed by bacteria and other microbes (oxygen demand)

Biochemical Oxygen Demand

- Oxygen demand measured by determining the amount of oxygen consumed by microorganisms during organic matter degradation
- Organic content of waste obtained by measuring amount of oxygen required for its stabilisation i.e. 5 day test

SOURCE	BOD mg L^{-1}
Natural Waters	1 - 5
Sewage	250 - 300
Septic systems	150 - 200
Stormwater	200 - 600
Industrial Water	500 - 5000
Landfill Leachate	10 000 - 35 000

Total Suspended Solids

TSS comprise the proportion of particulate material retained after passing through a glass fibre filter

- May comprise material ranging from coarse solids to colloidal particles
- Suspended solids may be organic or inorganic in origin
- Typically measured by a standardised laboratory test and referred to as either Total Suspended Solids (TSS) or Non-filterable Residue (NFR)
- Results typically expressed as milligrams per litre (mg/L)

Oil and Grease

- Used to describe the fats, oils, waxes and other related constituents of wastewater - builds up as a layer in septic tank
- Can cause problems in downstream wastewater treatment processes if not managed correctly (carryover etc.)
- Oil and grease content in domestic wastewater is determined using an analytical extraction method
- Results typically expressed as mg/L or as a thickness (mm) on the surface of a water sample
- Can be determined qualitatively by inspection

Nutrients

Nutrients, along with trace quantities of other elements are essential for biological growth. Phosphorus (P) and Nitrogen (N) are the principal nutrients of concern with regard to on-site wastewater management systems

- In excess, they may encourage nuisance growth of algae and aquatic plants in sensitive surface water systems and in some cases (nitrate) may pose a threat to human health
- Both N and P are found in a variety of forms in domestic wastewater

Nitrogen

Nitrogen in wastewater is typically found in one of four forms: ammonia (NH_3) / ammonium (NH_4^+) (dependent on pH); nitrite (NO_2^-); nitrate (NO_3^-) and organic nitrogen

- In domestic wastewater the ammonia/ammonium and organic nitrogen forms dominate
- Typically measured using a range of standardised laboratory tests including colorimetric and physico-chemical methods and expressed in mg/L or g/m^3
- Nitrate nitrogen is highly mobile in the soil/water environment and can potential public health risks

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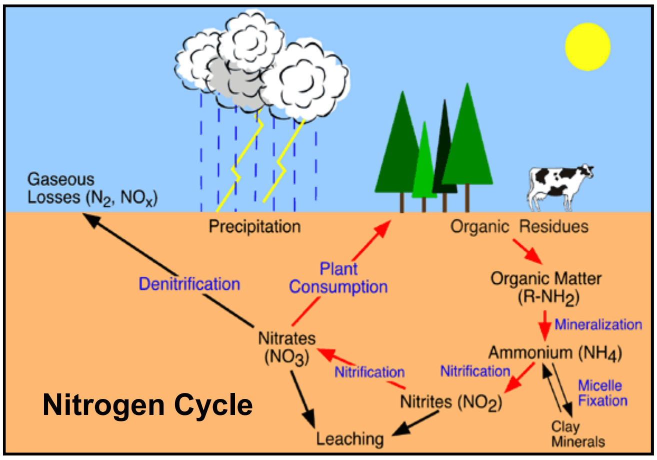

Nitrogen Source

Most common sources of N present in domestic wastewater (~50-60mg/L) include:

- Urine
  - Urea (46% N) or ~8.6g N/EP/day
- Faeces
  - ~0.1g N per kg bodyweight per day
  - 65kg woman (6.5g) 90kg male (9.0g)
- Hygiene
  - Body exudates (hair, sweat, skin etc.)
  - Personal care (shampoo) and cleaning
- Laundry products contain little N

Source: Patterson 2003

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Nitrogen Source

Our diet (consumption and preparation) is a major N contributor:

- Red meat - ~45g per kg consumed
- Cheese - ~42g per kg consumed
- Eggs and bread - ~1.9g per 100g consumed
- Leafy greens can contain up to 1g per kg consumed
- Large portion of organic N derived from vegetable scraps (including washing) during preparation
- Drinks (water, milk, sports drink etc.) also contain varying amounts of N

Source: Patterson 2003

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Phosphorus

- Typically found in one of three forms in domestic wastewater: orthophosphate complexes (e.g. PO_4^{-3}, HPO_4^{-2}, $H_2PO_4^-$); polyphosphate (e.g. P_2O^{-4}) and organic phosphate
- Orthophosphates - readily available for biological metabolism, while poly and organic phosphates must first undergo some form of conversion
- Measured using a range of standardised laboratory tests - analytical results typically express the combined values for all forms of P as total P - results are expressed as mg/L or µg/L in natural waters

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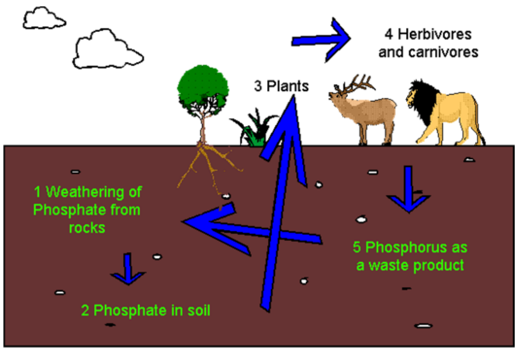
Phosphorus Cycle



Phosphorus Source

Most common sources of P present in domestic wastewater (~10-15mg/L) include:

- Blackwater
  - ~5-10mg/L or up to 1g/EP/day
- Greywater
  - ~10-15mg/L or up to 1.5g/EP/day
- Depending on diet food can contribute a large proportion of the household P load (cheese, soft drinks etc.)
- Laundry products are the other major contributor, containing as much as 7.8g P per wash cycle

Source: DLG 1998 and Minnis (undated)

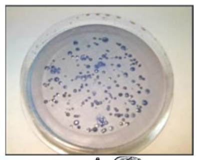
Microorganisms

The principal groups of organisms found in natural waters and wastewater include: bacteria; fungi; protozoa; parasites; rotifers; algae and viruses

- Not all pose potential human and public health risks
- Organisms with the potential to pose health risks to humans are known as "pathogenic"

DISEASE	H_2O RELATIONSHIP
Cholera Hepatitis Paratyphoid Typhoid Amoebic Dysentery Bacillary Dysentery Gastroenteritis	Waterborne
Conjunctivitis Leprosy Scabies Tinea Trachoma	Water-washed
Malaria Sleeping Sickness Yellow Fever	Water-related insect

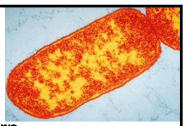
Bacteria



Domestic wastewaters contain a wide variety and concentration of pathogenic and non-pathogenic bacteria

- Many infectious diseases are waterborne e.g. typhoid, cholera and infectious doses can lead to illness in some people
- Testing for pathogens difficult and expensive; therefore, common bacteria used e.g. coliform bacteria such as Escherichia coli used as an <u>indicator</u> of potential faecal contamination in water

Parasites



Two dominant protozoan parasites of concern in the treatment of wastewater:

1. *Cryptosporidium*, and
2. *Giardia*.

- Resistant to standard disinfection methods
- Pose considerable risk to susceptible members of the community (children, elderly and immuno – compromised)
- Helminths or Intestinal worms are also commonly found in wastewater e.g. tapeworms, roundworm
- They release millions of environmentally resilient eggs throughout their lifespan

Viruses

- Contamination by virus may lead to major outbreaks
- *Hepatitis* A is the dominant water borne virus, referred to as infectious hepatitis
- Causes widespread illness in epidemic patterns
- Exposure to faecally contaminated water can transmit the diseases caused by waterborne virus
- Polio Virus is also transmitted in wastewater
- Virus are more common and diverse than bacteria in the aquatic environment

Pathogen Survival in Different Environmental Media

Pathogen	Survival in Freshwater (days)	Survival in Saltwater (days)	Survival in Soil (days)
Viruses	11-304	11-871	6-180
Bacteria-Salmonellae	<10	<10	15-100
Bacteria-Cholera	30	+285	<20
Bacteria-Faecal coliforms	<10	<6	<100
Protozoan cysts	176	365	+75

Quantifying Wastewater Volumes (Hydraulic Load)

- Liquid flow required to be managed by the wastewater system over time period
- The volume discharged from a household during a 24-hour period i.e. "daily hydraulic load"
- Key consideration when designing and sizing an on-site wastewater management system (L/day or m^3/day)
- Systems need to be adequately sized and offer sufficient treatment/storage capacity for a number of days prior to surcharge to additional treatment

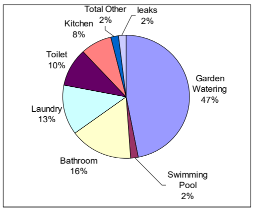
Household Water Use

- Average household (residential) water usage across NSW in 2021 (SoE, NSW EPA)
  - Local Water Utilities (LWUs) – 171kL/yr (467L/day)
  - Sydney Water – 189kL/yr (516L/day)
  - Hunter Water – 156kL/yr (426L/day)
  - MidCoast Water – 160kL/yr (437L/day)
- Sewer charges typically calculated at ~80% of water usage (70%-90% seasonal)
- Calculate = 462L/day (average) household wastewater generation (equivalent ~2.5EP @ 150L/day)

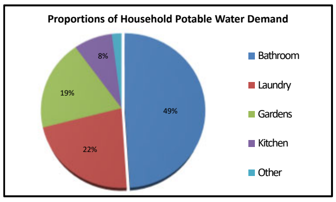
Water Use for Individual Fixtures

Fixture	Daily flow (DF) L/p/d
Basin	7
Bath/shower	32
Laundry trough/washing machine	31
Dishwashing machine/kitchen sink	30
Toilet	50
Total	**150**

Source: SA Health



Source: NSW Basix and WELS rating scheme



Source: DSE 2012

Determining Hydraulic Load

Firstly, important to define 'design' occupancy

- Many Councils assume No. of bedrooms (+1) (DLG, 1998)
- AS/NZS 1547:2012 suggests No. of bedrooms (+2)
- SCA (Current Recommended Practice) – designates design flows based on number of 'potential' bedrooms (assumes 2 EP/bedroom)
- Other methods may include – No. of bedrooms x (design) occupancy factor (i.e. 1.6) based on known population characteristics

Typical Flow Allowances (L/unit/day) - Domestic Uses

- AS/NZS 1547 (Table H1) and SCA CRP, 2023 (Table 2.5) – flow allowances based on supply – e.g. town or tank
- DLG (1998) provides 'general' guidance ranges of 150-300 L/person/day (town) and 100-140 L/person/day (tank)
- NSW Health (2016) SMF accreditation - 150L/person/day

No. of Bedrooms	2	3	4	5
Occupancy (equivalent persons (EP)	4	5	6	7
Reticulated (Town) supply				
SCA CRP (300L/bedroom/d)	600	900	1,200	1,500
AS/NZS 1547 (150L/EP/d)	600	750	900	1,050
Rainwater (Tank) supply				
SCA CRP (200L/bedroom/d)	400	600	800	1,000
AS/NZS 1547 (120L/EP/d)	480	600	720	840

Other Examples including Organic Load

- Various guidelines, codes or older references may use different flow allowances or other ‘loading’ criteria
- Allowances are also available for commercial, i.e. other than domestic applications and split-system designs
- Possible also to size on the basis of organic material e.g. BOD_5 loading, describing wastewater ‘strength’.

Table

Number of bedrooms	Volume of wastewater (litres)	
	Blackwater system	Combined system (blackwater and greywater)
2 or less	188	564
3	254	761
4 or more	276	829

Type of premises	Blackwater	Combined
School (boarding)	70	140
School (day) .... ….	30	45
Public building (frequent use)	15	30
Public building (infrequent use)	5	10
Caravan park	90	140

Source: WA Health Regulations 1974

Organic Loading considerations

- Medium – High strength wastewaters often associated with ‘non-residential’ activities
- Frequent examples in OWMS applications:
  - Boutique brewery = <1,500mg/L BOD and <3,000mg/L COD
  - Small-batch distillery = 10,000-30,000mg/L BOD
  - Wineries = <10,000mg/L (vintage) and <3,000mg/L non-vintage
  - Bar Service (unconsumed alcohol) =
    - Vodka 360,000mg/L BOD and 845,000mg/L COD
  - Dairy food production (cheese) = 2,000-3,000mg/L BOD
  - Meat processing = 2,200-7,200mg/L BOD

Wastewater Calculations

Question 1.

The load of a material, solute or pollutant is the mass transported over a given time period. It can be carried by a watercourse or conveyed to the point of discharge along a pipe. The load is calculated by multiplying the concentration of the pollutant by the volume of flow, while taking into account the time over which the discharge or flow occurred. It can be simply calculated using the following relationship:

$$L = c \times Q \times t$$

where;

L = load or mass of pollutant
c = concentration of pollutant
Q = stream discharge or volume of pipe flow
t = time base of calculation

Note: Units must be consistent between variables to undertake calculations. When undertaking calculations, it is important to show all workings and conversions clearly.

Example

Calculate the daily pollutant load to a receiving water body (in kilograms per day) given that average concentration in effluent is 20 mg/L and the discharge volume per day is 20 ML (a Megalitre is a million litres).

c = 20 mg/L, Q = 20 x 10^6 litres per day
In 1 ML there are 20 x 10^6 milligrams of pollutant per day
In 20 ML there are 400 x 10^6 milligrams of pollutant per day
As there are 10^6 milligrams in 1 kilogram, the daily load of pollutant is **400 kg**.

(i) Calculate the annual pollutant loads of Suspended Solids, Total Nitrogen and Total Phosphorus reaching a septic tank where the concentrations of Suspended Solids, Total Nitrogen and Total Phosphorus are, 250 mg/L, 55 mg/L and 15 mg/L respectively and the daily hydraulic load (flow) is 1000 L. Express results for each pollutant in kilograms.

Wastewater Calculations

ANSWERS

Question 1.

Suspended Solids

L = 250 mg/L x 1,000 L x 1 day

L = 250 x 1,000 x 365 mg/year

L = 91,250,000 mg/year

L = 91.25 kg/year

Total Nitrogen

L = 55 mg/L x 1,000 L x 1 day

L = 55 x 1,000 x 365 mg/year

L = 20,075,000 mg/year

L = 20.08 kg/year

Total Phosphorus

L = 15 mg/L x 1,000 L x 1 day

L = 15 x 1,000 x 365 mg/year

L = 5,475,000 mg/year

L = 5.48 kg/year