Understanding Faecal Sludge & Septage and its Charecterstics

Problems & Challenges

Shantanu Kumar Padhi

Research Associate – Water Management, CSE

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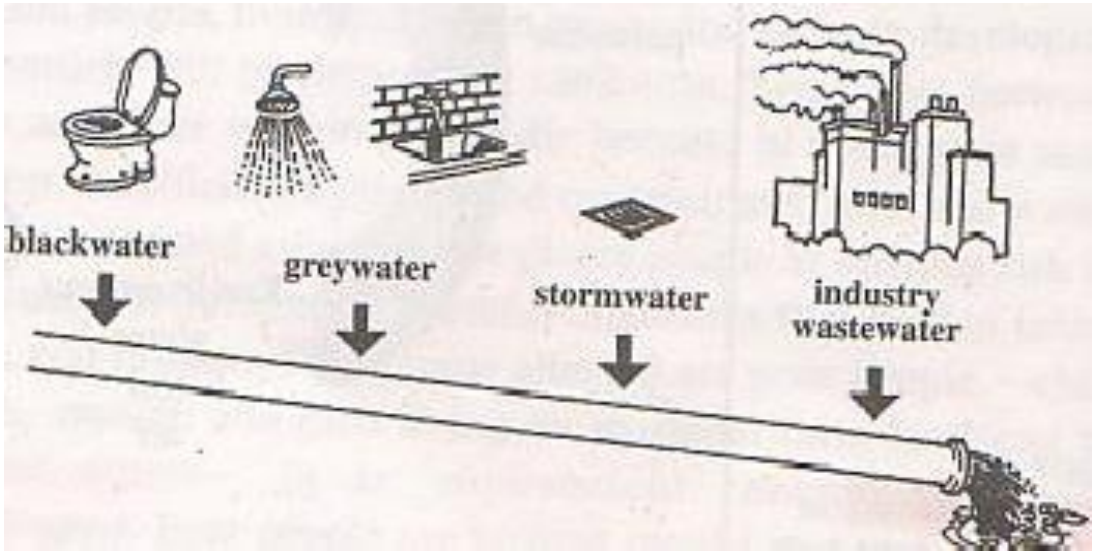
What is?

- **Offsite Sanitation**
  - **Wastewater/Sewage**
- **Onsite Sanitation**
  - **Faecal Sludge**
  - **Septage**
  - **Supernatent/Effluent**

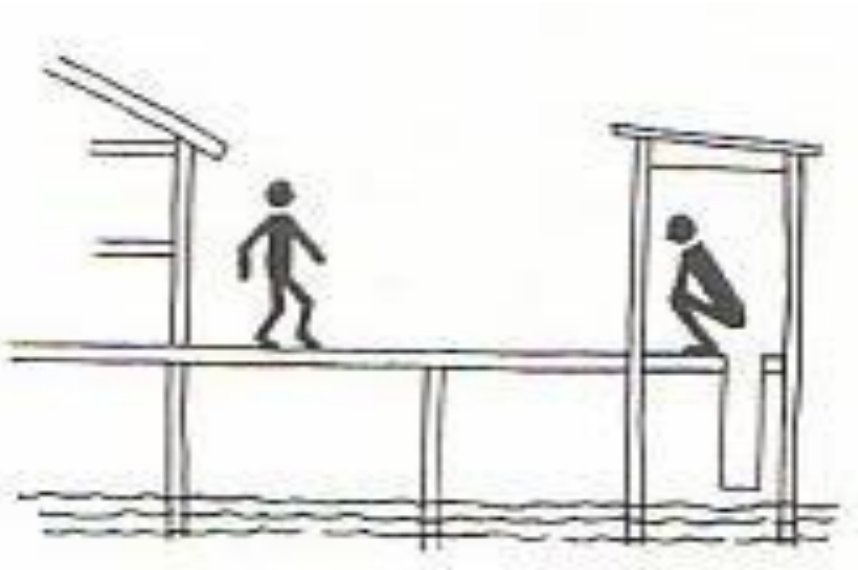


Off-site Sanitation

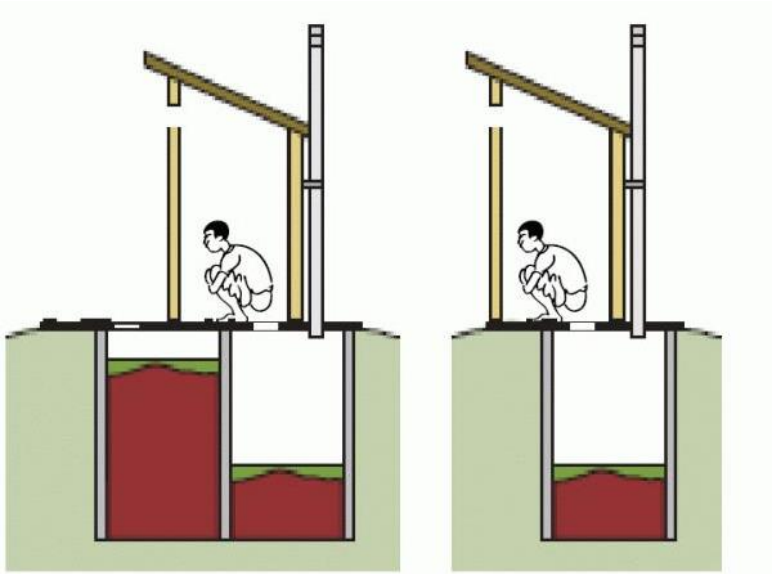
- Flush & forget
- Very high costs

On-site Sanitation

- Drop & hide
- Emptying can be difficult

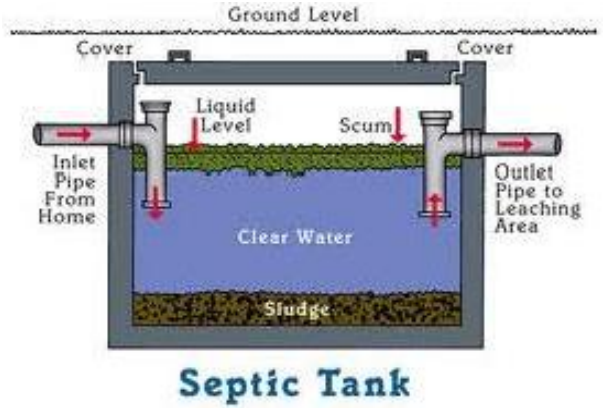


- On-site Sanitation systems: Pit latrines, Septic tanks, unsewered public latrines;



Twin pit latrine

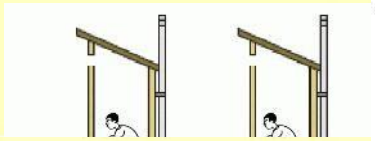
Ventilated improved pit latrine

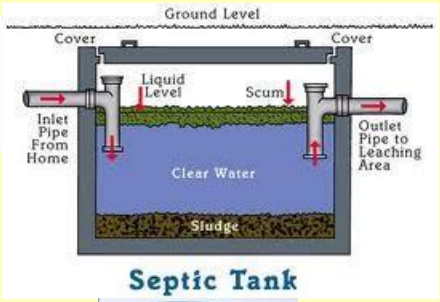


Septic Tank

- On-site Sanitation systems: Pit latrines, Septic tanks, unsewered public latrines;

IN:
- Faeces
- Urine
- Flush water
- Anal cleansing water/material





OUT:
- Faecal Sludge/ Septage

What is Faecal Sludge?

- Undigested or partially digested slurry or solids, resulting from storage or treatment of black water or excreta (Eawag/Sandec, 2008);

- Sludges of variable consistency accumulating in septic tanks, aqua privies, family pit or bucket latrines and unsewered public toilets. These contents comprise varying concentrations of settleable or settled faecal solids as well as of other, non-faecal matter (Heinss et al., 1998)

What is Septage?

“Septage” is semi-solid matter desludged from an onsite system like septic tank/other OSS. It includes the liquids, solids (sludge), as well as the fats, oils and grease (scum) that accumulate in septic tanks over time.

It has offensive odour, appearance and contents significant levels of grease, grit, hair, debris and pathogenic organisms

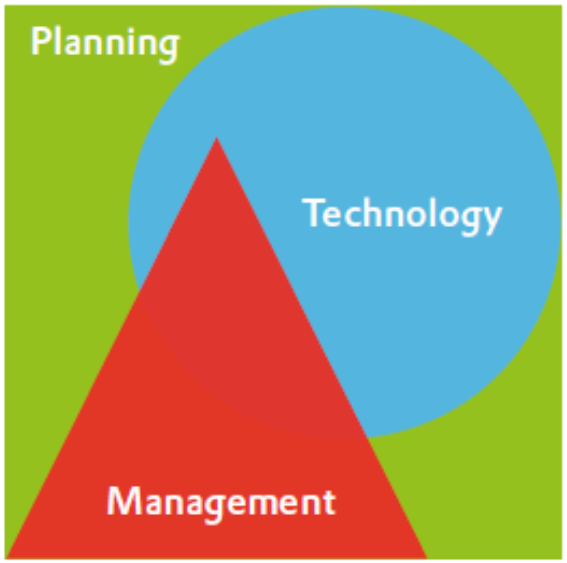
Septage is limited to septic tank contents whereas faecal sludge is a wider term that includes contents from other on-site sanitation technologies as well, not only from septic tanks.

The term "septic" in septage implies that the sludge has gone through some anaerobic biological degradation and thus is at least partly stabilised.

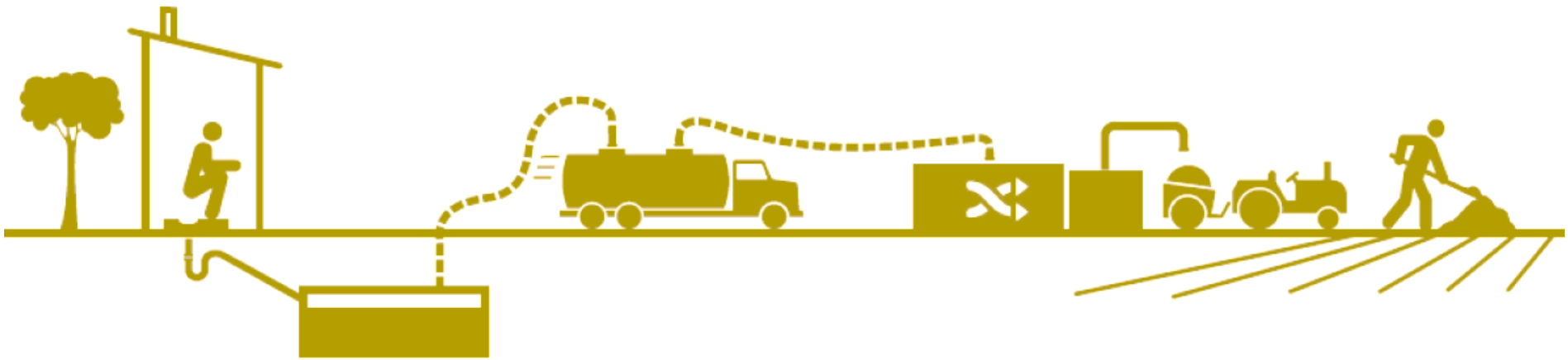
Septage Management

- **“Septage Management”** is the process of managing onsite sanitation systems including septage collection, transportation, treatment and disposal / recycle / reuse of its contents

Requires planning, technology and management



Septage value chain



Containment	Emptying & Transport	Treatment	Disposal/Reuse
Septic tank		Land application	Fertilizers and Manure
Pit Latrine	Mounted Tractors	Co –treatment at STP	
Soak pit	Vacuum Trucks	Constructed Wetland	
Cesspool	Vacuutug/ Carts	Dewatering, Composting	

Septage Management

- Septage is poorly managed

- Septage management is invisible to policy makers – seen as ‘a temporary’ or stop-gap solution for primarily for illegal or informal settlements and sewerage is always seen as ‘proper’ solution

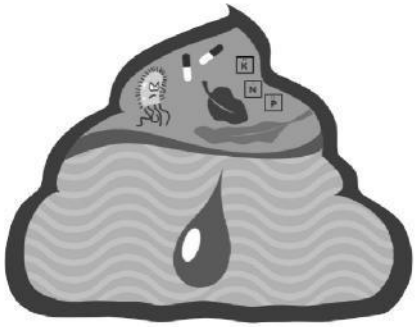
- Technical and institutional issues requiring attention – illegal dumping, quality of household containment is generally inadequate, lack of treatment facilities for septage / faecal sludge

- Lacks mechanisms for formal reuse of septage

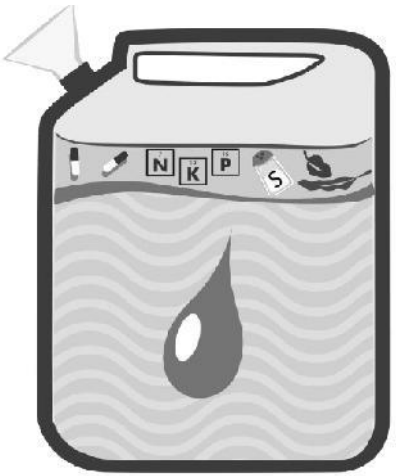
- Septage /Sludge accumulation rates vary widely

FS contents

- Water:
  - On average 91-96% of urine is water and 75% of faeces are water (Rose et. al. 2015);
  - Liquid content in FS is about 97%

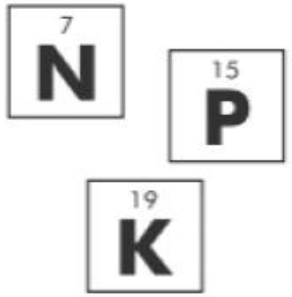


- Organic materials:
  - 25% of faeces are solid, of which 84-93% is organic material;
  - 4-9% urine is dissolved and suspended solids, of which 65-85% is organic material;



FS contents

- Nutrients:
  - Nitrogen (N), Phosphorous (P), Potassium (K)

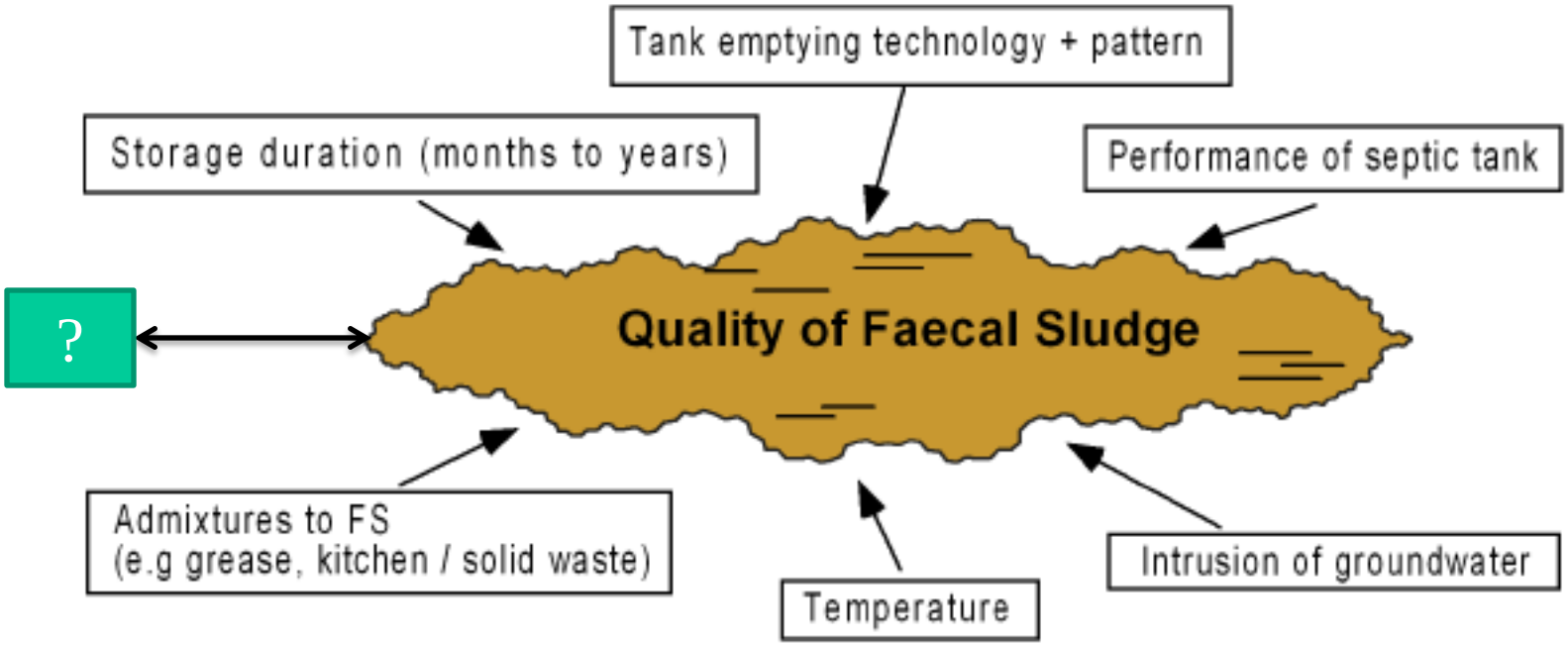


Nutrients	Urine (%)	Feces (%)
Nitrogen	88	12
Phosphorous	67	33
Potassium	73	27

(Jonsson & Vinneras, 2004)

- Pathogens:
  - Bacteria, viruses, protozoa, helminths
- Chemicals:
  - Heavy metals, hormones and pharmaceuticals;
  - Usually not a big concern in FSM

Factors Influencing FS Quality



Location	Wet weight (g/person/day)
high income countries[1]	100-200
low income countries, rural[2]	350
low income countries ,urban[2]	250
China[3]	315
Kenya[4]	520
Thailand[5]	120-400

[1] Lentner *et al.* (1981); Feachem *et al.* (1983); Jönsson *et al.* (2005); Vinnerås *et al.* (2006)

[2] Feachem *et al.* (1983)

[3] Gao *et al.* (2002)

[4] Pieper (1987)

[5] Schouw *et al.* (2002)

Influencing factors

- Storage duration:
  - Depends on the type & volume of technology, quality of construction, toilet usage, inflow and infiltration;
  - Digestion of organic matter that occurs during storage affects the FS characteristics;
  - FS from public toilets – not stabilized and have high BOD and COD concentrations (low storage duration)
  - FS from septic tank more stabilized and have low BOD and COD concentrations (high storage duration)

Influencing factors

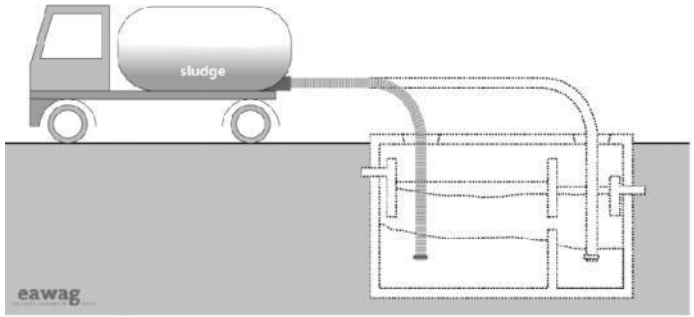
- Toilet usage:
  - TS concentration depends on factors such as dry vs. flush toilet, volume of water flushed, inclusion or exclusion of grey water;
  - Fat, oil and grease concentration increases with inclusion of kitchen wastewater – reduces microbial degradation;
  - Filling rate increases as more waste streams enter the toilet and the number of people using the toilet;
  - Chemical additives can be harmful for digestion process

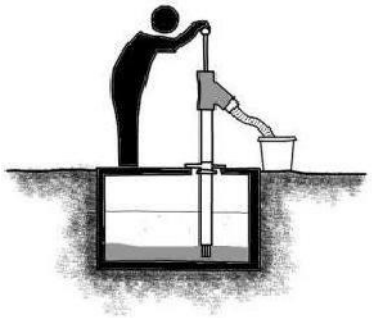
Influencing factors

- Inflow and infiltration:
  - Filling rate of systems will be slower if there is more leaching – resulting in thicker FS;
  - FS leaching leads to groundwater pollution;
  - Groundwater intrusion may increase the filling rate of systems – resulting in thinner FS;

Influencing factors

- Collection method:
  - FS at bottom is too thick to pump mechanically;
    - Usually manually emptied with shovels or water is added to decrease viscosity to enable pumping;
  - FS removed by pumping is generally more dilute and less viscous than FS emptied manually;
  - FS emptied from septic tanks is more dilute if more supernatant that sludge is collected, which is very common due to absence of strong vacuums & pumps.





FS CHARACTERIZATION AND FRACTIONATION

Fresh Faecal Sludge from unsewered public toilet

Discharge of untreated septage

FS Characterization

Parameter	Public Toilet	Septic Tank
Total solids (mg/L)	30,000-52,500	12,000-35,000
TVS (%TS)	65-68%	50-73%
COD (mg/L)	10,000-250,000	3,000-90,000
BOD_5 (mg/L)	7,600	840-30,000
TN (mg N/L)	-	190-1,500
TKN (mg/L)	3,400	1,000
NH_4-N (mg/L)	2,000-5,000	150-1,200
Total P (mg P/L)	450	40-300

Category	High strength		Medium strength		Low strength	
	Total COD (mg /L)	TN (mg /L)	Total COD (mg /L)	TN (mg /L)	Total COD (mg /L)	TN (mg /L)
Digested faecal sludge	90,000	1,500	45,000	400	3,000	200
Fresh faecal sludge	250,000	5,000	65,000	3,400	10,000	2,000

FS Characterization

Characteristics of faecal sludges and comparison with tropical sewage (Heinss et al., 1998)

Item	Type "A" (High-Strength)	Type "B" (Low-Strength)	Sewage (For comparison's sake)
Example	Public toilet or bucket latrine sludge	Septage	Tropical sewage
Characterization	**Highly concentrated, mostly fresh FS; stored for days or weeks only**	**FS of low concentration; usually stored for several years; more stabilized than Type "A"**	
COD mg/l	20,000-50,000	<15,000	500-2,500
COD/BOD	2:1 - 5:1	5:1 - 10:1	2:1
NH4-N mg/l	2,000 - 5,000	<1,000	30-70
TS mg/l	≥ 3.5%	< 3%	< 1%
SS mg/l	≥ 30,000	≈ 7,000	200-700
Helm. eggs, no./l	20,000 - 60,000	≈ 4,000	300-2,000

FS Characterization

Characteristics of faecal sludges in selected cities (EAWAG, 2004)

Parameters	Accra (Ghana)	Accra (Ghana)	Ouagadougou (Burkina Faso.)	Bangkok (Thailand)	Alcorta (Argentina)
Type of FS	*Public toilet sludge*	*septage*	*Septage*	*septage mean (range)*	*septage mean (range)*
TS (mg/L)	52,500	12,000	19,000	15,350 (2,200 – 67,200)	(6,000 – 35,000 SS)
TVS (% of TS)	68	59	47	73	50 (VSS)
COD (mg/L)	49,000	7,800	13,500	15,700 (1,200 – 76,000)	4,200
BOD_5 (mg/L)	7,600	840	2,240	2,300 (600 – 5,500)	(750 – 2,600)
TN (mg/L)	---	---	2,100	1,100 (300 – 5,000)	190
NH_4-N (mg/L)	3,300	330	-	415 (120 – 1,200)	150

Characteristics of FS is highly variable!!!

Characteristics of Septage

- **Solids concentration**
- **Chemical oxygen demand (COD)**
- **Biological oxygen demand (BOD)**
- **Nutrients**
- **Pathogens**
- **Metals**

Parameters are same as same considered for domestic wastewater analysis – but characteristics are much different

Organic matter, total solids, ammonium, and helminth egg **concentrations in are typically higher by a factor of ten or a hundred** compared to wastewater sludge (Montangero and Strauss, 2002).

Technical Characteristics of Septage :

- **Nutrients, Nitrogen, Phosporous,**
- **PH, TS**
- **BOD, COD**
- **Pathogens**

Nutrients

Excreta contains nutrients that originate from food consumption.

- 10-20% of nitrogen, 20-50% of phosphorus, and 10-20% potassium is excreted in the faeces

- 80-90% of nitrogen, 50-65% of phosphorus, and 50-80% of potassium in the urine

- Majority of ammonia in raw faecal sludge comes from the urine

- The nitrogen content in faeces is about 20% as ammonia, 17% as organic nitrogen in the cells of living bacteria, and the remainder as organic nitrogen

Nitrogen

Total nitrogen concentrations in FS is typically quite high (e.g. 10-100 times the concentration in domestic wastewater

Depending on factors such as pH, length of storage, the presence of oxygen, and the type of FS, nitrogen will be present in a combination of the following forms;

ammonium (NH4-N)/ammonia (NH3-N), nitrate (NO3-N)/nitrite (NO2-N), and organic forms of nitrogen (e.g. amino acids and amines).

Phosporus

Total phosphorus concentration in FS is quite high (e.g. 2-50 times the concentration in domestic wastewater)

Phosphorus in FS will be present as phosphate, the acid or base form of orthophosphoric acid (H3PO4 / PO4-P), or as organically bound phosphate (e.g. nucleic acids, phospholipids and phosphorylated proteins).

Fate of phosphorus in the various treatment processes will be based on factors such as sorption, precipitation, complexation, sedimentation, mineralisation, pH, plant uptake in planted drying beds, and redox potential.

PH

pH of FS from septic tanks is normally in the range of 6.5 to 8.0, *but can vary greatly from* 1.5 to 12.6.

A pH outside the range of 6 to9 indicates an upset in the biological process that will inhibit anaerobic digestion and methane production

This could result from a change in the hydraulic loadings, the presence of toxic substances, a large increase in organic loading, or that the systems are receiving industrial or commercial wastewater

TS concentration of FS comes from a variety of organic (volatile) and inorganic (fixed) matter, and

is comprised of floating material, settleable matter, colloidal material, and matter in solution –

including grit, sand and municipal waste

BOD and COD

FS typically has a much higher BOD than that of 'strong' wastewater.

BOD only represents biodegradable organics, whereas COD represents the oxygen equivalent of the organic matter that can be oxidised chemically with dichromate, a powerful chemical oxidant.

The oxygen demand is reduced through stabilisation, and can be achieved by aerobic or anaerobic treatment.

FS dewatering technologies do not necessarily decrease oxygen demand.

Pathogens

Exposure to untreated FS should always be considered as a pathogenic health risk

Adequate reductions in pathogens need to be determined based on the intended end use or disposal option for treated sludge and liquid effluents.

Some common pathogens of concern that may be excreted in faeces, and their importance in disease transmission, are presented :

Pathogens & Health Risk

Group	Pathogen	Disease symptoms
Bacteria		
	Aeromonas spp.	Enteritis
	Campylobacter jejuni/coli	Campylobacteriosis - diarrhoea, cramping, abdominal pain, fever, nausea, arthritis, Guillain-Barré syndrome
	Escherichia coli (EIEC, EPEC, ETEC, EHEC)	Enteritis. For EHEC there are also internal haemorrhages that can be lethal
	Salmonella typhi/paratyphi	Typhoid/paratyphoid fever – headache, fever, malaise, anorexia, bradycardia, splenomegaly, cough
	Salmonella spp.	Salmonellosis – diarrhoea, fever, abdominal cramps
	Shigella spp.	Shigellosis – dysentery (bloody diarrhoea), vomiting, cramps, fever; Reiters syndrome
	Vibrio cholera	Cholera – watery diarrhoea, lethal if severe and untreated

Pathogens & Health Risk

Group	Pathogen	Disease symptoms
Virus		
	Adenovirus	Various; respiratory illness, here added due to enteric types (see below)
	Enteric adenovirus types 40 and 41	Enteritis
	Enterovirus types 68-71	Meningitis; encephalitis; paralysis
	Hepatitis A	Hepatitis – fever, malaise, anorexia, nausea, abdominal discomfort, jaundice
	Hepatitis E	Hepatitis
	Poliovirus	Poliomyelitis – often asymptomatic, fever, nausea, vomiting, headache, paralysis
	Rotavirus	Enteritis

Pathogens & Health Risk

Group	Pathogen	Disease symptoms
Parasitic protozoa		
	Cryptosporidium parvum	Cryptosporidiosis – watery diarrhoea, abdominal cramps and pain
	Cyclospora histolytica	Often asymptomatic; diarrhoea; abdominal pain
	Entamoeba histolytica	Amoebiasis – often asymptomatic, dysentery, abdominal discomfort, fever, chills
	Giardia intestinalis	Giardiasis – diarrhoea, abdominal cramps, malaise, weight loss

Pathogens & Health Risk

Group	Pathogen	Disease symptoms
Helminths		
	Ascaris lumbricoides	Generally no or few symptoms; wheezing; coughing; fever; enteritis; pulmonary eosinophilia
	Taenia solium/saginata	Taeniasis
	Trichuris trichura	Trichuriasis - Unapparent through to vague digestive tract distress to emaciation with dry skin and diarrhoea
	Hookworm	Itch; rash; cough; anaemia; protein deficiency
	Schistosoma Spp. (blood fluke)	Schistosomiasis, bilharzias

FS Characterization

Characterization ratios for FS (adapted from Henze et. al., 2008):

Ratios (g/g)	Public toilets	Septic tanks	Medium strength municipal wastewater
VSS:TSS	0.65-0.68	0.50-0.73	0.60-0.80
COD:BOD_5	5.0	1.43-3.0	2.0-2.5
COD:TKN	0.10	1.2-7.8	8-12
BOD_5:TKN	2.2	0.84-2.6	4-6
COD:TP	109	8.0-52	35-45
BOD_5:TP	17	5.6-17.3	15-20

- Useful to evaluate biodegradability for treatment purposes;

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- When the suspended solids in FS or wastewater have a high volatile component (VSS to SS ratio = 0.8 – 0.9) these can be successfully digested under anaerobic conditions;
- Low/Medium VSS:TSS ratio of FS indicates 23-50% inorganic contents – may not be suitable for anaerobic digestion;

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- FS with low organic content to nitrogen ratio may need external carbon source addition in order that biological denitrification functions fast and efficiently;
- Organic concentrations in FS are not sufficient for nitrogen removal by denitrification;
- FS should only be considered for co-treatment in processes that include nitrogen removal, if the influent WW has high COD:TKN or BOD_5:TKN ratio (12-16 and 6-8 respectively)

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- High COD:TP and BOD5:TP ratios in FS suggest that there could be sufficient organic matter for biological phosphorus removal.

FS fractionation

Fraction	COD			
	Digested FS	Fresh FS	Digested FS	
Soluble biodegradable	0.12	0.15	0.20	0.47
/ammonia Soluble	0.09	0.03	0.75	0.52
unbiodegradable Particulate	0.31	0.69	-	-
Particulate unbiodegradable	0.47	0.13	0.05	0.01

Biodegradable COD fraction Digested FS: 0.12+0.31 = 0.43

Biodegradable COD fraction Fresh FS: 0.15+0.69 = 0.84

FS fractionation

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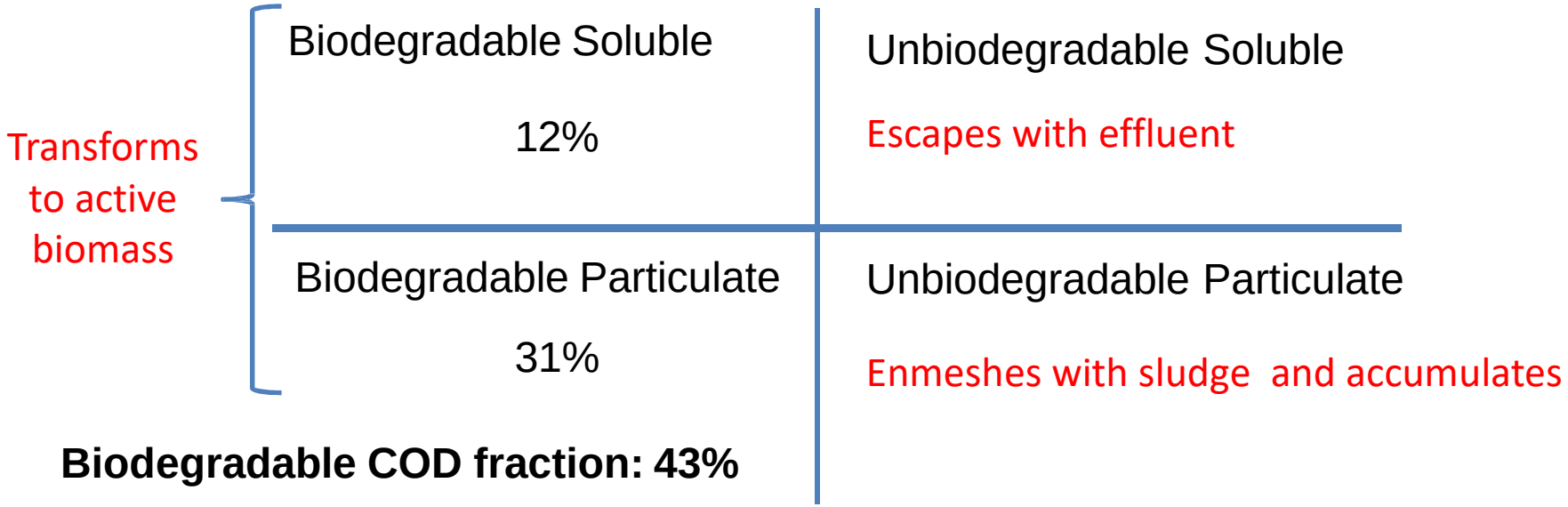
/ammonia Soluble	0.09	0.03	0.75	0.52
unbiodegradable Particulate	0.31	0.69	-	-
Particulate unbiodegradable	0.47	0.13	0.05	0.01

Biodegradable COD fraction Digested FS: 0.12+0.31 = 0.43

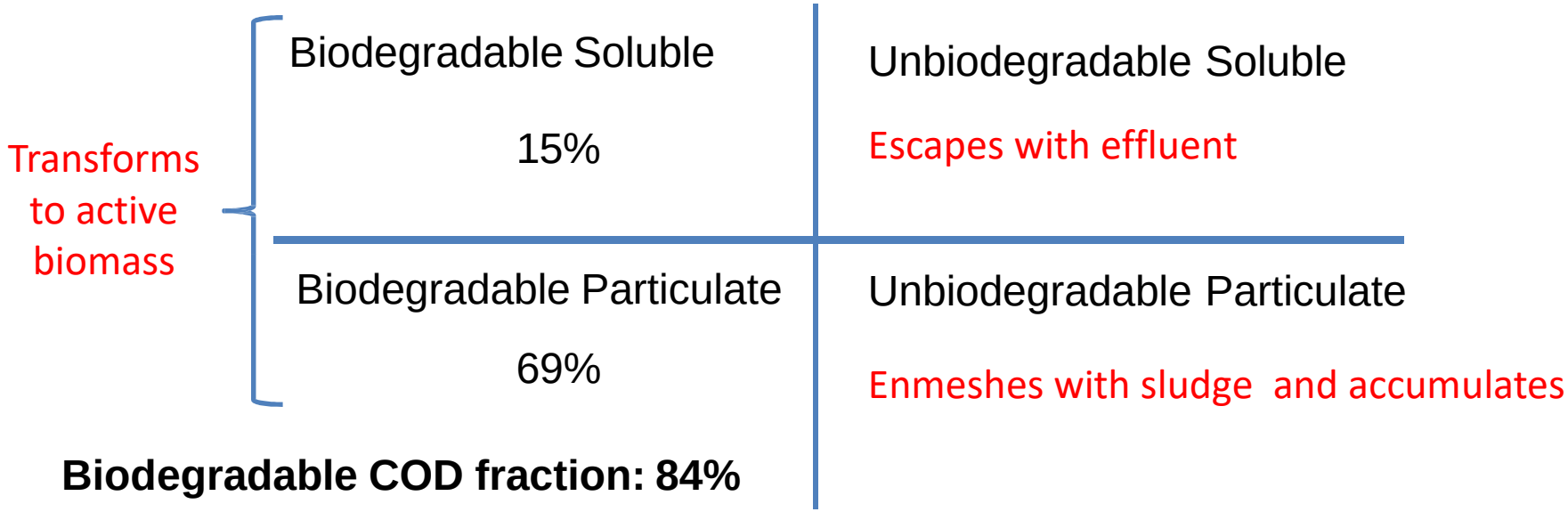
Biodegradable COD fraction Fresh FS: 0.15+0.69 = 0.84

Total COD – Digested FS



Biodegradable COD fraction: 43%

Total COD – Fresh FS



Biodegradable COD fraction: 84%

Conclusions

- FS is sludge generated from on-site sanitation systems (Septic tank, pit latrines, public toilets);
- FS characterization is important for FSM planning including designing the treatment systems;
- Characterizations of FS is highly variable;
- More field-based research is needed on FS characterization.

THANK YOU