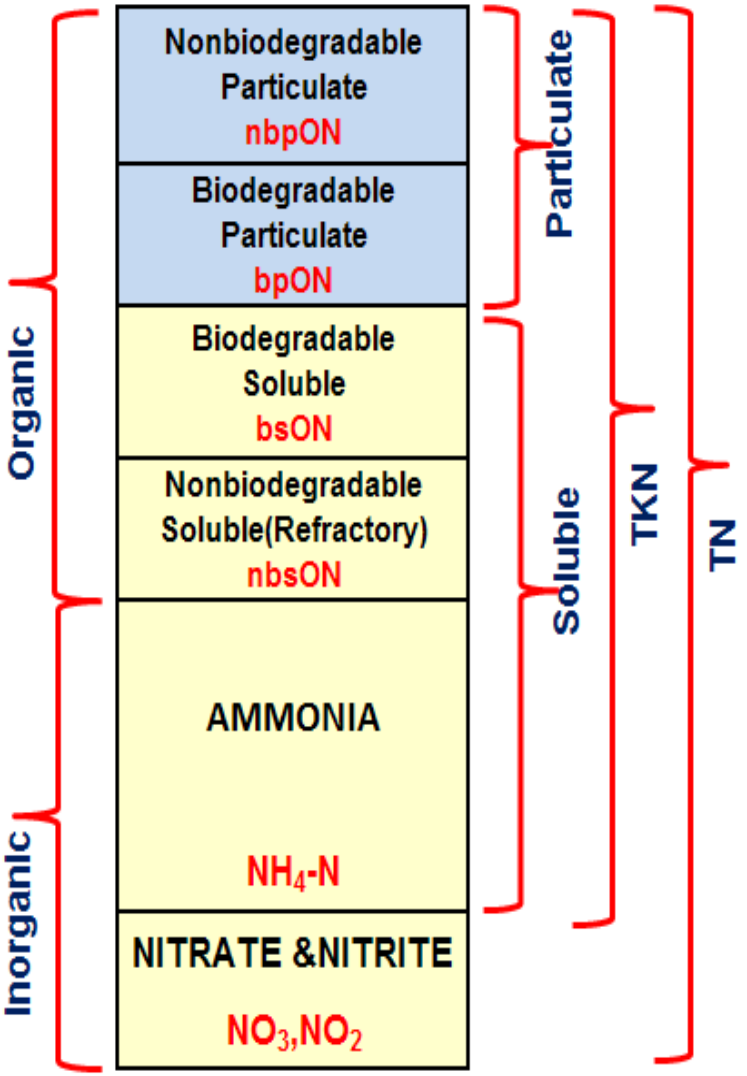
NITROGEN FRACTIONS

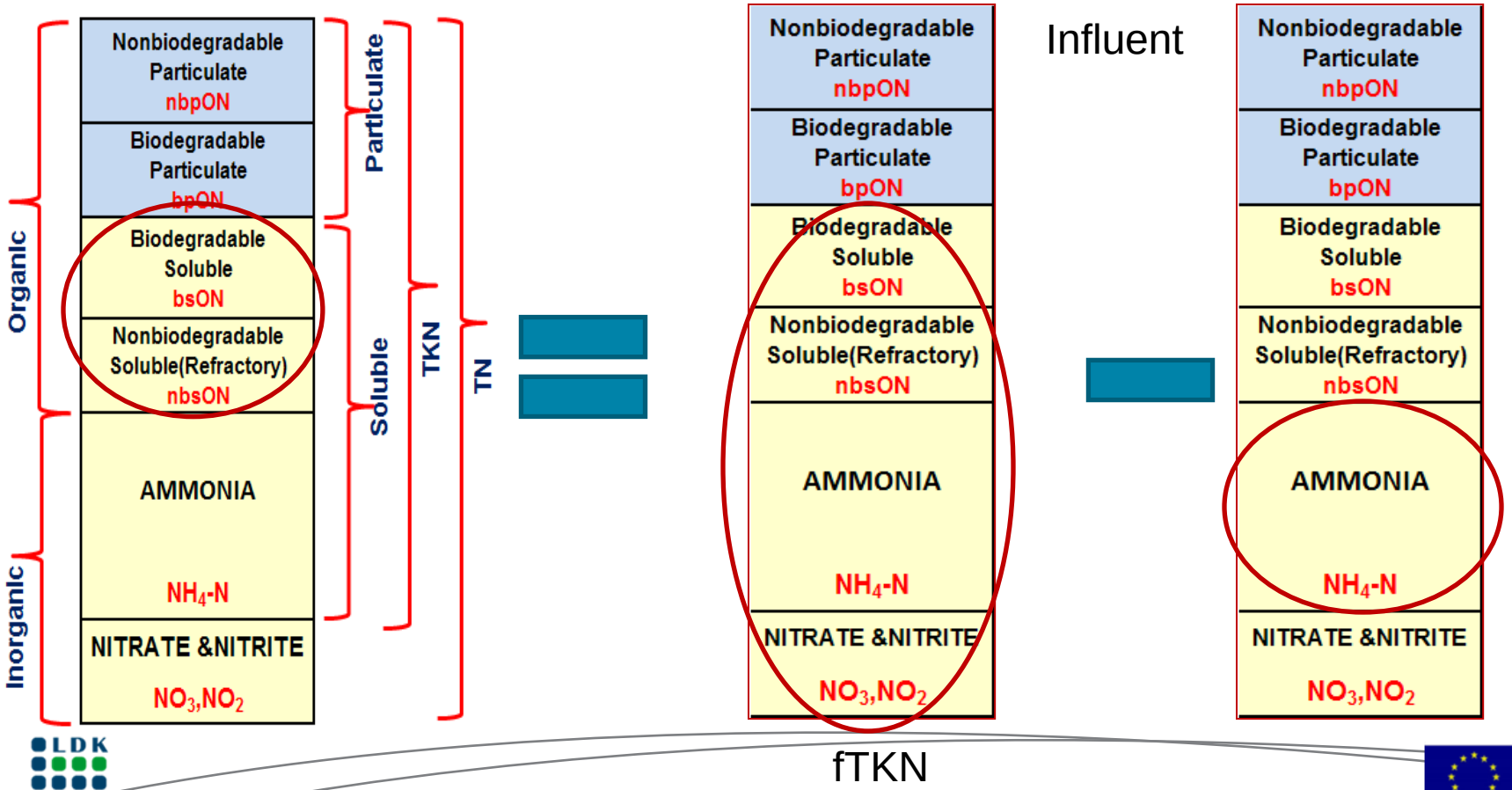
NITROGEN FRACTIONS

- Ammonia makes up to 60% to 75% of TKN.
- For measurement the nitrogen fractions directly, standard analysis of TKN on both filtered and unfiltered samples as well as standard analyses of ammonia need to be done.
- Nitrate/nitrite should be measured in influent wastewater only if a significant industrial source present or in side stream.

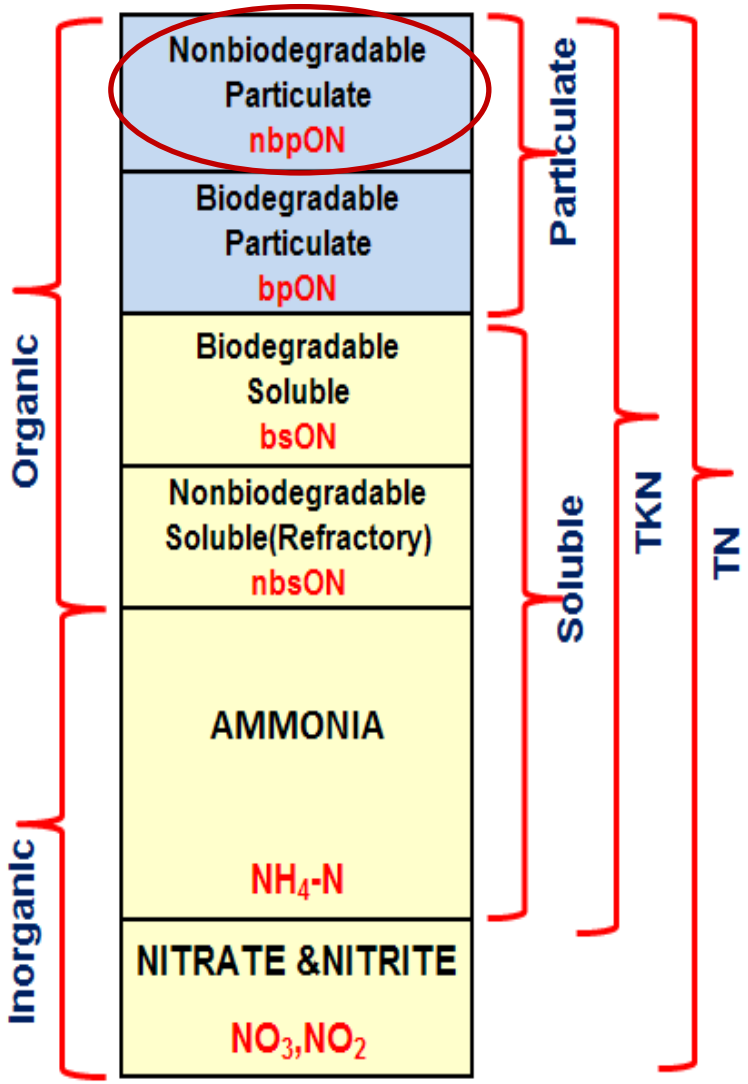


NITROGEN FRACTIONS sON

- Soluble inorganic nitrogen = ammonia + nitrate/nitrite
- Soluble organic nitrogen =filtered TKN-ammonia
- Particulate organic nitrogen = TKN-filtered TKN



NITROGEN FRACTIONS
NONBIODEGRADABLE PARTICULATE TKN



NITROGEN FRACTIONS
NONBIODEGRADABLE PARTICULATE TKN

Method-1

nbpON is associated with nbpCOD.
Calculate the fraction FupN

$$FupN = \frac{pTKN}{pCOD}$$

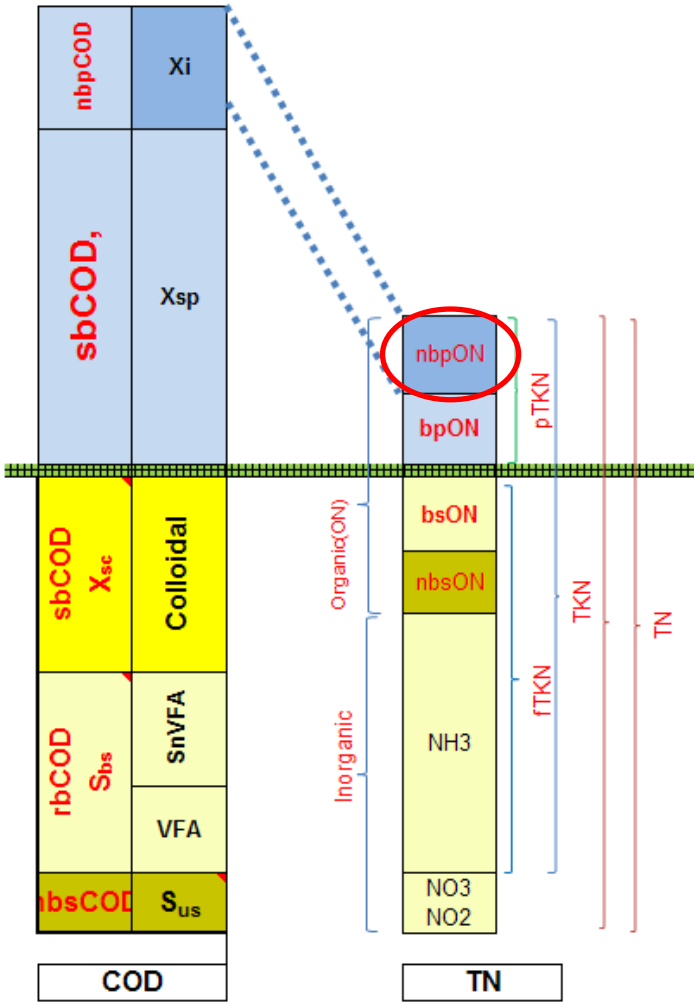
FupN= N:COD ratio for un-biodegradable particulate COD

$$pTKN = (TKN - sON - NH4\_N)$$

$$\frac{nbpON}{nbpCOD} = \frac{pTKN}{pCOD}$$

$$nbpON = \frac{pTKN}{pCOD} \times nbpCOD$$

$$nbpON = FupN \times (nbpCOD)$$



NITROGEN FRACTIONS
NONBIODEGRADABLE PARTICULATE TKN

Method-2

- nbpON is associated with nbVSS.
- nbpON can be estimated from VSS and nbVSS

$$pTKN = (TKN - sON - NH4\_N)$$

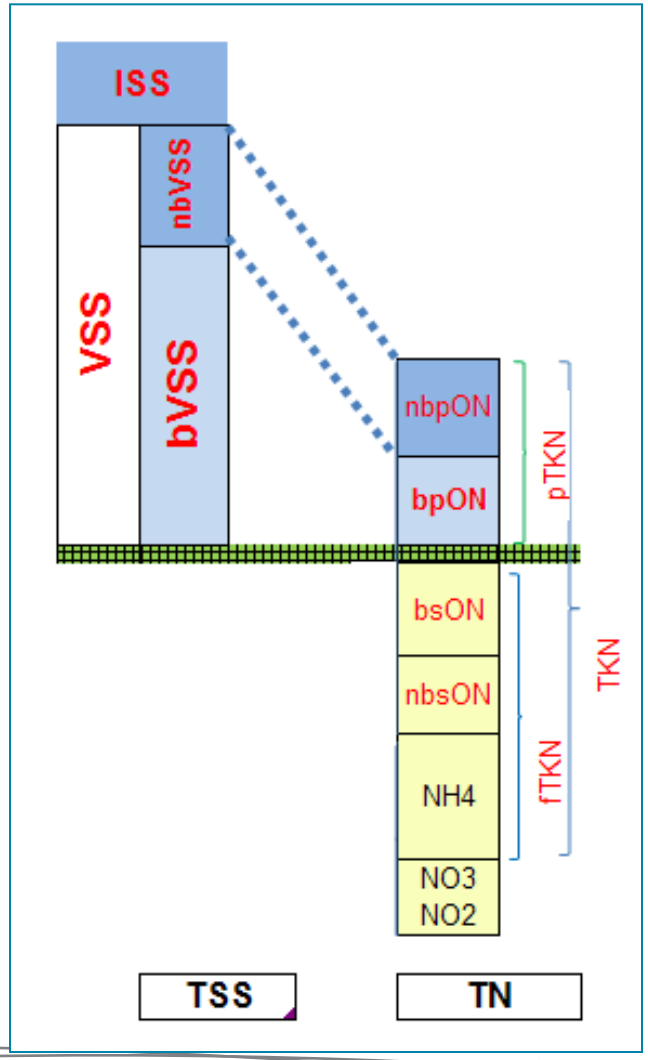
$$fN = \frac{pTKN}{VSS}$$

fN= fraction of organic nitrogen in VSS , g N/g VSS

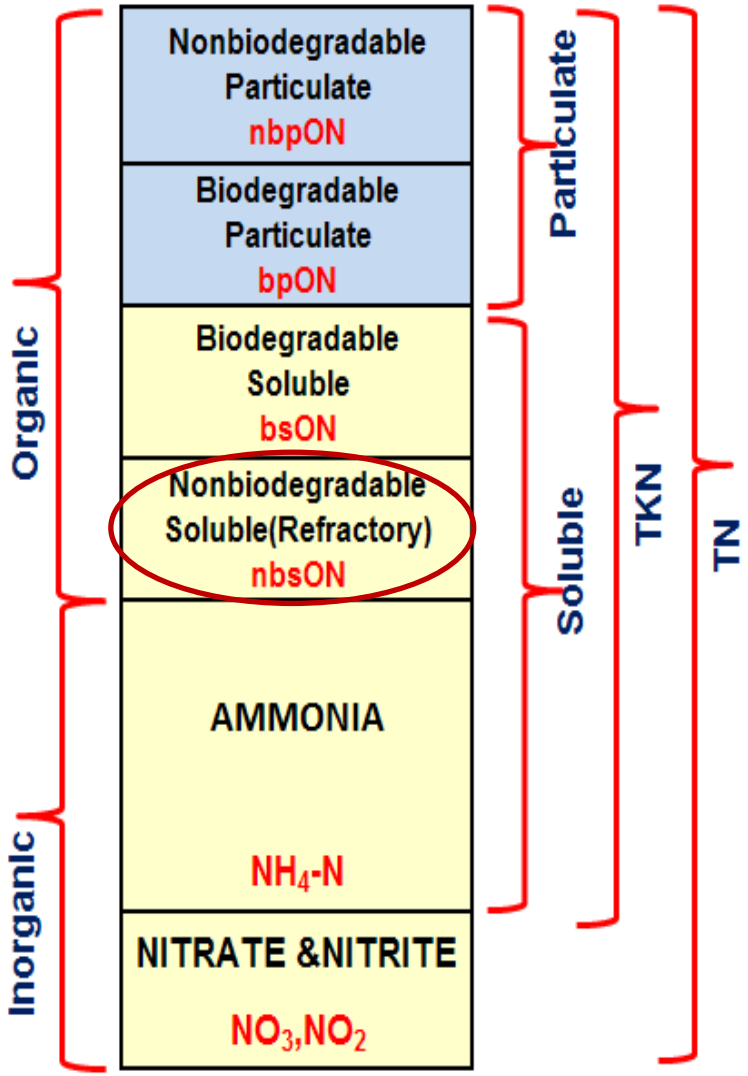
$$nbpON = fN \times (nbVSS)$$

$$\frac{nbpON}{nbVSS} = \frac{pTKN}{VSS}$$

$$nbpON = \frac{pTKN}{VSS} \times nbVSS$$



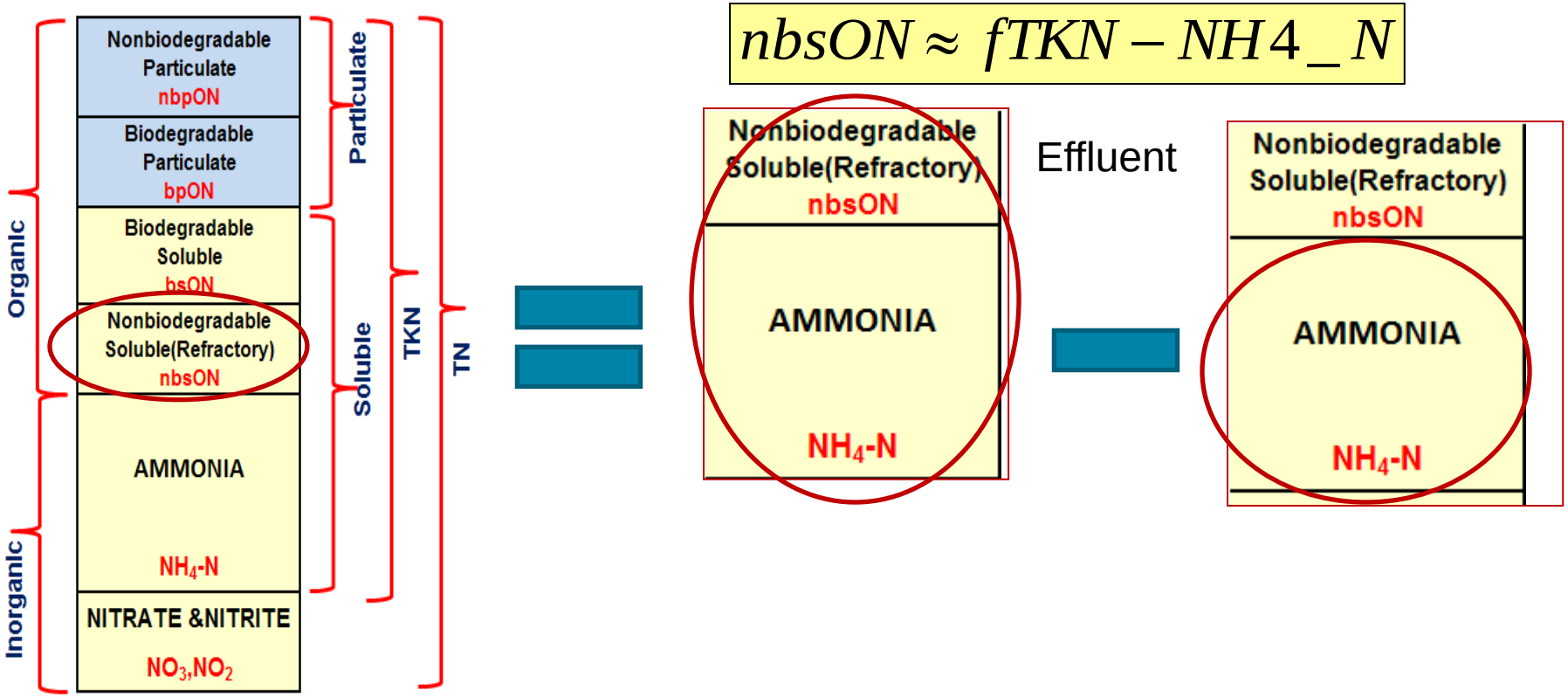
NITROGEN FRACTIONS
NON-BIODEGRADABLE SOLUBLE TKN(nbsON)



NITROGEN FRACTIONS
NON-BIODEGRADABLE SOLUBLE TKN(nbsON)

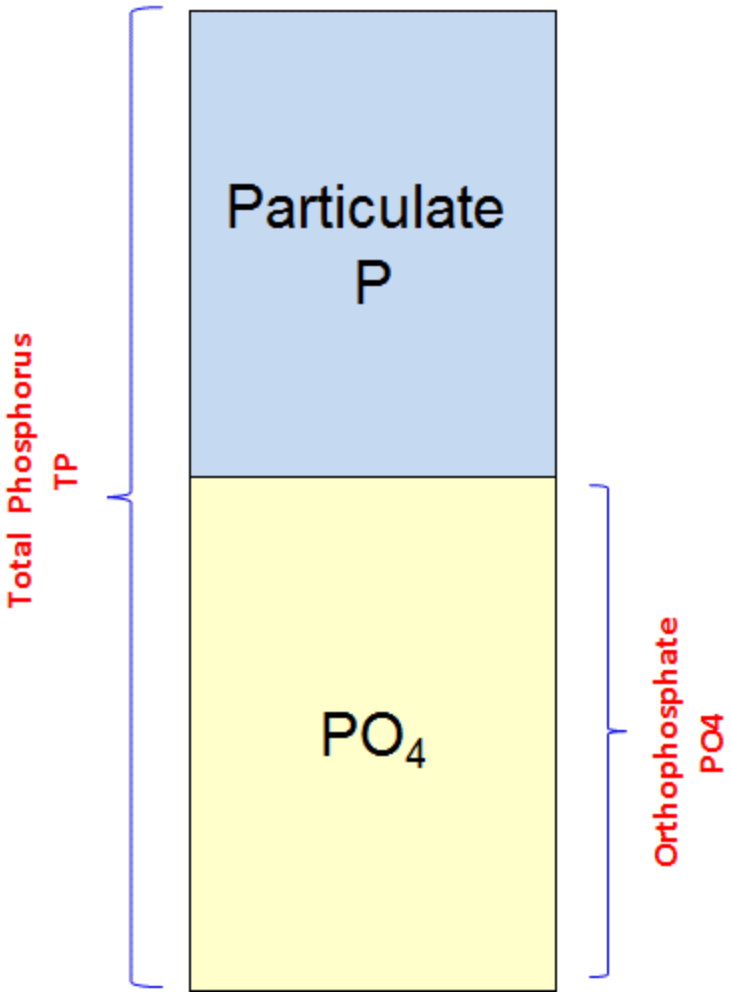
- Passes through the plant untouched.
- Estimated as approximately 1.5-2% of the Influent TKN.Typically ranges from 1 to 2 mg/l.
- Assuming that all of the soluble biodegradable organic nitrogen is degraded within the treatment process , then the effluent filtered TKN minus the effluent ammonia will equal the nbsON.

$$nbsON \approx fTKN - NH4\_N$$



PHOSPHORUS FRACTIONS

- Knowing the phosphorus fractionation is important for plants that provide biological phosphorus removal.
- Orthophosphate(PO_4) and soluble biodegradable phosphorus are taken up by PAOs in the aerobic zone.
- Orthophosphate(PO_4) typically makes up a large portion of TP in domestic wastewater(50% to 80%).
- Almost all of the effluent soluble phosphorus is orthophosphate.
- P fractions are simplified as follows:
  - TP, total phosphorus .
  - Orthophosphate (PO4) represents the two reactive fractions.

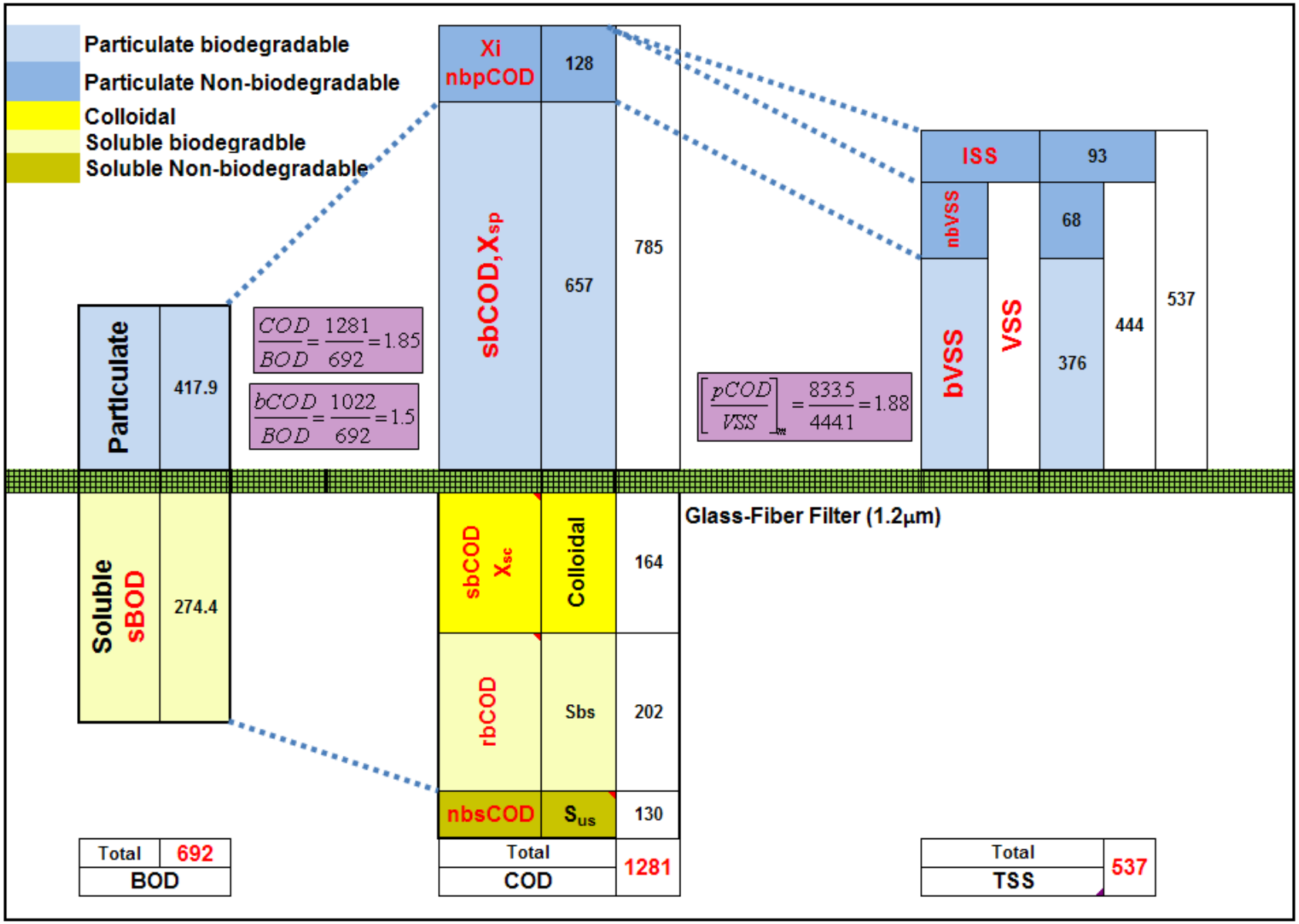


WASTEWATER CONSTITUENT RELATIONSHIPS

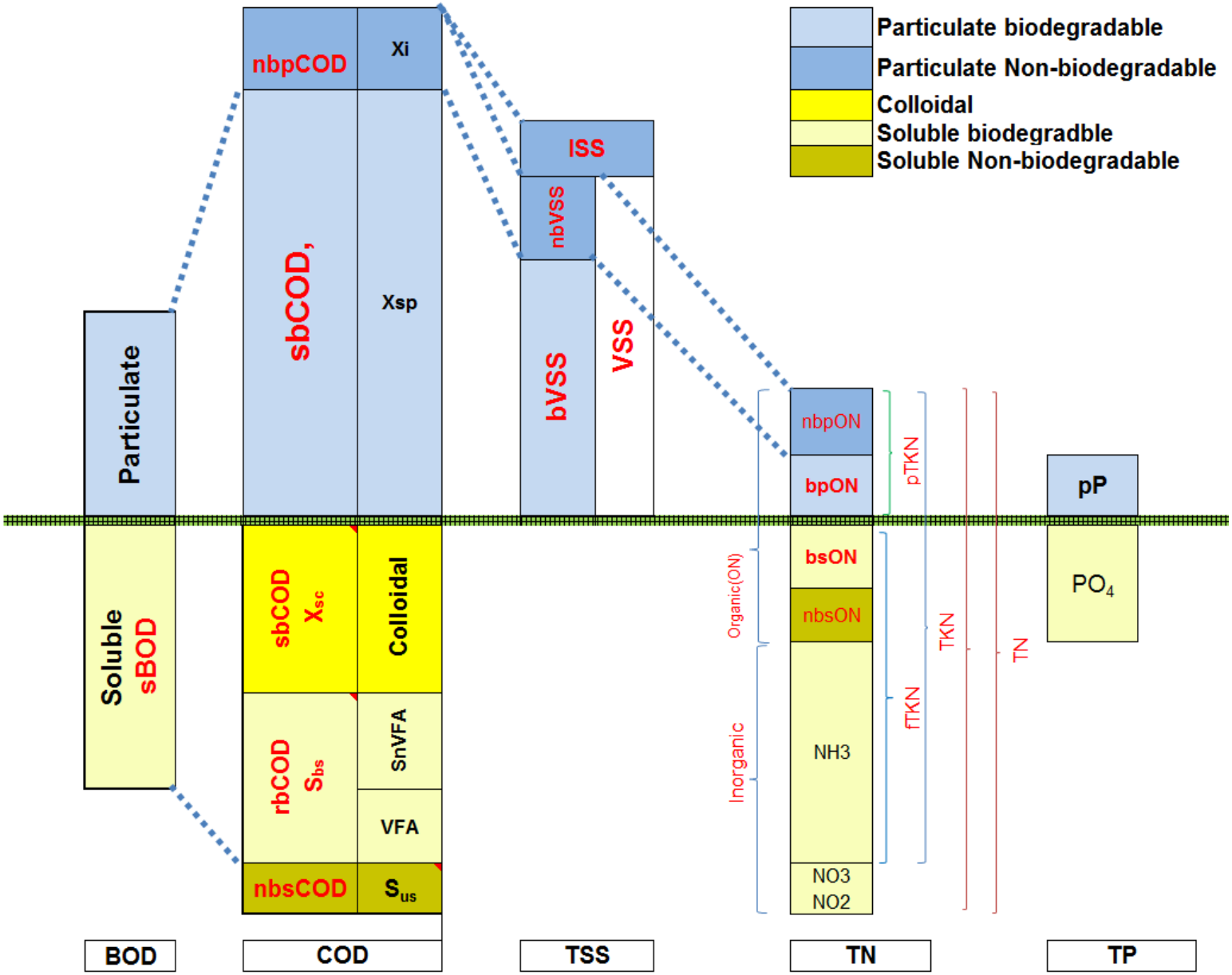
The relationships between various constituents in raw influent establish a frame of reference and are important for various process considerations. Established relationships can also be relied upon when data is non-existent. The typical wastewater constituent relationships are presented below.

Ratio	Typical Values	Meaning
COD/BOD	1.75-2.2	Indicates the component of organic matter that is biodegradable low : readily biodegradable organics high : slowly biodegradble
pCOD/VSS	1.6-1.8	Indicates the COD contenets of the VSS
TSS/BOD	0.6-1.2	Indicates the solids content of wastewater
VSS/TSS	0.7-0.9	Identifies the inert suspended solids (ISS) fraction
TKN/BOD	0.18-0.24	Indicator of the ability to denitrify, as it demonstrates how much carbon is available for nitrate reduction If this number is high, supplemental carbon is usually required to sufficiently denitrify
TP/BOD	0.015-0.025	provides one approach for estimating the influent phosphorus concentration

RELATIONSHIP BETWEEN BOD,COD AND TSS



RELATIONSHIP BETWEEN BOD,COD,TSS, TN, & TP



EXAMPLE
SAMPLING RESULTS FOR WWTP IN JORDAN

No.	Parameter	unit	Plant Influent	Plant Effluent
1	**Total COD**	mg/L	1281	316
2	**Filtered COD(1.2 um glass fiber filter)**	mg/L	448	184
3	**Flocculated & filtered COD (0.45 um filter)**	mg/L	332	
4	**BOD_5**	mg/L	692	80
5	**Filtered BOD_5(1.2 um glass fiber filter)**	mg/L	274	32
6	**TSS**	mg/L	537	102
7	**VSS**	mg/L	444	83
8	**Total Phosphurus**	mg/L	15.8	15.6
9	**Orthophosphate**	mg/L	32	37
10	**Total Kjeldhal Nitrogen(TKN)**	mg/L	137	91
11	**Filtered TKN**	mg/L	103.6	81.6
12	**Ammonium(NH_4-N)**	mg/L	99.2	76.9
13	**Nitrate**	mg/L		2
14	**Nitrite**	mg/L		2
15	**Alkalinity as CaCO3**	mg/L	619	581

EXAMPLE- ESTIMATION OF nbsCOD

No.	Parameter	unit	Plant Influent	Plant Effluent
1	**Total COD**	mg/L	1281	316
2	**Filtered COD(1.2 um glass fiber filter)**	mg/L	448	184
3	**Flocculated & filtered COD(0.45 um filter)**	mg/L	332	
4	**BOD_5**	mg/L	692	80
5	**Filtered BOD_5(1.2 um glass fiber filter)**	mg/L	274	32

nbsCOD = Effluent Solube COD(for very low soluble effluent BOD)

nbsCOD = Effluent Solube COD - Effluent biodegradable soluble COD.

$$\frac{fCOD}{fBOD} = \frac{448}{274} = 1.64$$

bCOD in the effluent

$$bCODe = fBODe \times \frac{fCOD}{fBOD} = 32 \times 1.64 = 52.5 mg/l$$

$$nbsCOD = 184 - 52.5 = 131.5 mg/l$$

Influent & Effluent non-biodegradable solubel COD = 131.5 mg/l

$$F_{us} = \frac{131.5}{1281} = 0.10$$

		COD	COD Fractions	
nbpCOD	Xi		F_{up}	
Slowly Biodegrdable COD (sbCOD)	Particulate		F_{xsp}	
	Colloidal		F_{xs}	
Readily Biodegradable COD (rbCOD)	SnVFA		F_{bs}	
	VFA			
nbsCOD	Sus	132	F_{us}	0.10
Total COD		**1281**		

EXAMPLE – ESTIMATION OF rbCOD

No.	Parameter	unit	Plant Influent	Plant Effluent
1	**Total COD**	mg/L	1281	316
2	**Filtered COD(1.2 um glass fiber filter)**	mg/L	448	184
3	**Flocculated & filtered COD**	mg/L	332	
4	**BOD_5**	mg/L	692	80
5	**Filtered BOD_5(1.2 um glass fiber filter)**	mg/L	274	32

rbCOD = ffCOD influent-nbsCOD effluent

$$nbsCOD = 184 - 52.5 = 131.5 mg/l$$

$$rbCOD = 332 - 131.5 = 200.5\_mg/l$$

$$F_{bs} = \frac{200.5}{1281} = 0.16$$

		COD	COD Fractions	
nbpCOD	Xi		F_{up}	
Slowly Biodegrdable COD (sbCOD)	Particulate		F_{xsp}	
	Colloidal		F_{xs}	
Readily Biodegradable COD (rbCOD)	SnVFA	201	F_{bs}	0.16
	VFA			
nbsCOD	Sus	132	F_{us}	0.10
Total COD		**1281**		

PARTICULATE COD/VSS RATIO(F_{cv})

No.	Parameter	unit	Plant Influent	Plant Effluent
1	**Total COD**	mg/L	1281	316
2	**Filtered COD(1.2 um glass fiber filter)**	mg/L	448	184
7	**VSS**	mg/L	444	83

$$pCOD = tCOD - fCOD = 1281 - 448 = 834$$

$$VSS = 444$$

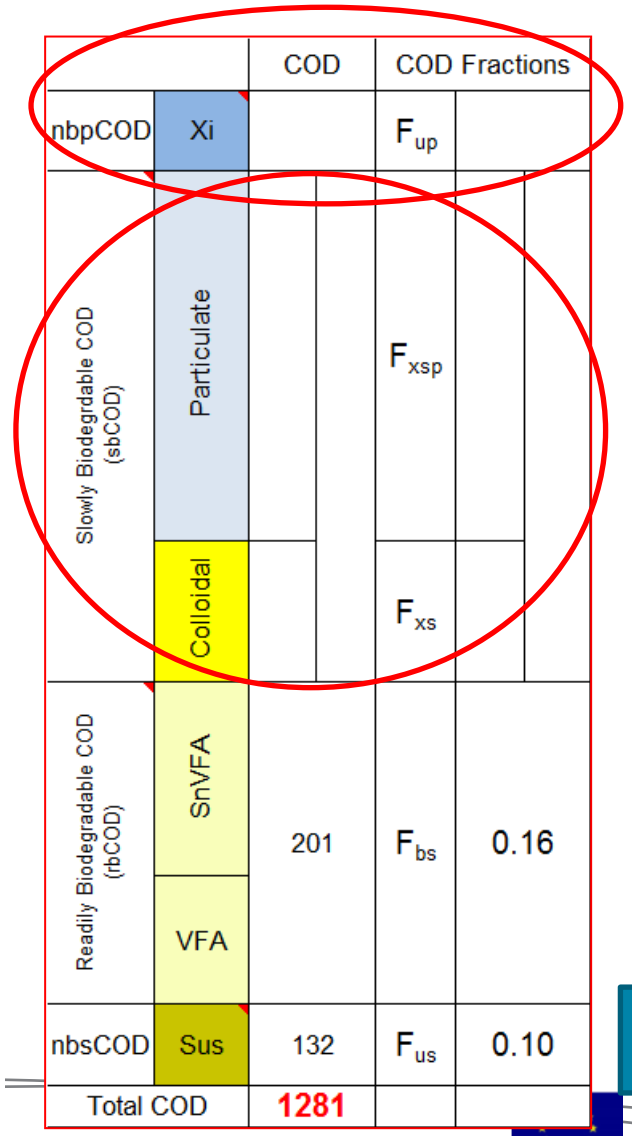
$$F_{cv} = \frac{834}{444} = 1.88$$

measured

EXAMPLE – ESTIMATION OF nbpCOD & sbCOD

Influent COD fractions	Default	Estimate	*Notes*
Fbs	0.160	0.158	*from Step 1*
Fus	0.050	0.101	*from Step 1*
Fup	0.130	0.100	*affects BOD, VSS*
Fzbh	0.000	0.000	*from separate method*
Fxs	0.660	0.641	*by difference (must be > 0!!)*
Fxsp	0.750	0.800	*affects VSS, scale: 0 to 1*

Influent values	Measured (From Step 1)	Calculated (Based on fractions above)	*Match Status*
CODt	1281		
Soluble COD (GFC)	448	496	***Acceptable***
FF COD	332	332	***Excellent***
cBOD5	692	606	***Acceptable***
fcBOD5 (GFC)	274	259	***Acceptable***
VSS	444	418	***Acceptable***
TSS	537	511	***Acceptable***
Calculated concentrations (from CODt & fractions)			
Sus	130		
Xi	128		
Sbs	202		
Xs (c+p)	821		
Zbh	0		
Xsc	164	Added to Ss for BOD calcs	
Xsp	657		



RESULTS FOR COD FRACTIONS FOR THE EXAMPLE

		COD		COD Fractions		
nbpCOD	Xi	128		F_{up}	0.10	
Slowly Biodegrdable COD (sbCOD)	Particulate	657	821	F_{xsp}	0.80	0.64
	Colloidal	164		F_{xs}	0.20	
Readily Biodegradable COD (rbCOD)	SnVFA	202		F_{bs}	0.16	
	VFA					
nbsCOD	Sus	130		F_{us}	0.10	
Total COD		1281			1.00	

EXAMPLE – ESTIMATION OF nbVSS

$$nbVSS = \left[\left(\frac{nbpCOD}{pCOD}\right)\right] \times VSS$$

$$nbVSS = \left[\left(\frac{128.1}{657 + 128}\right)\right] \times 418.2 = 68.3$$

$$nbVSS = \left[\left(\frac{128.1}{784.8}\right)\right] \times 418.2 = 68.3$$

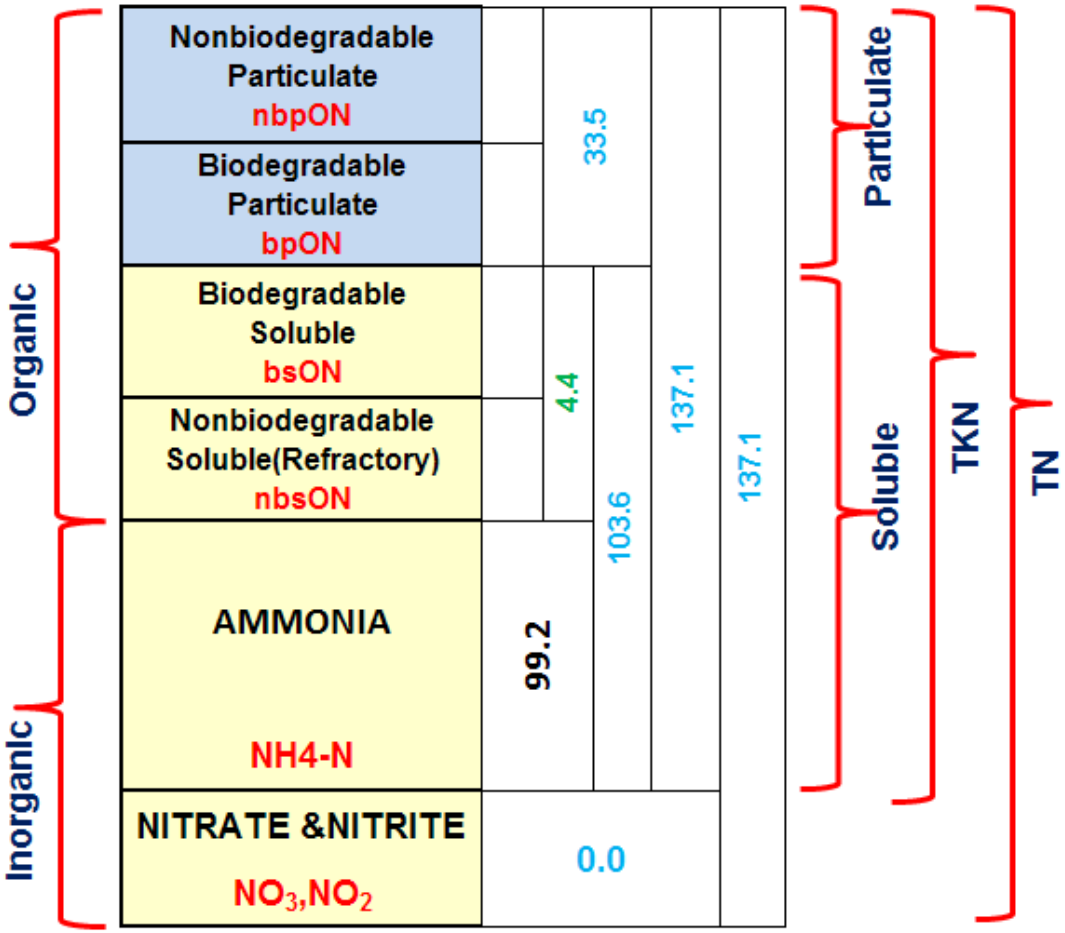
		COD		COD Fractions		
nbpCOD	Xi	128		F_{up}	0.10	
Slowly Biodegrdable COD (sbCOD)	Particulate	657	821	F_{xsp}	0.80	0.64
	Colloidal	164		F_{xs}	0.20	
Readily Biodegradable COD (rbCOD)	SnVFA	202		F_{bs}	0.16	
	VFA					
nbsCOD	Sus	130		F_{us}	0.10	
Total COD		**1281**			1.00	

EXAMPLE – ESTIMATION OF sON

No.	Parameter	unit	Plant Influent
10	**Total Kjeldhal Nitrogen (TKN)**	mg/L	137
11	**Filtered TKN**	mg/L	103.6
12	**Ammonium(NH4-N)**	mg/L	99.2
13	**Nitrate**	mg/L	
14	**Nitrite**	mg/L	

sON=fTKN-ammonia

sON = 103.6-99.2 = 4.4



EXAMPLE – ESTIMATION OF nbpON

No.	Parameter	unit	Plant Influent
7	VSS	mg/L	444
10	Total Kjeldhal Nitrogen (TKN)	mg/L	137
11	Filtered TKN	mg/L	103.6
12	Ammonium(NH4-N)	mg/L	99.2
13	Nitrate	mg/L	
14	Nitrite	mg/L	

$$pTKN = (TKN - sON - NH4\_N)$$

pTKN = 137-103.6 =33.4

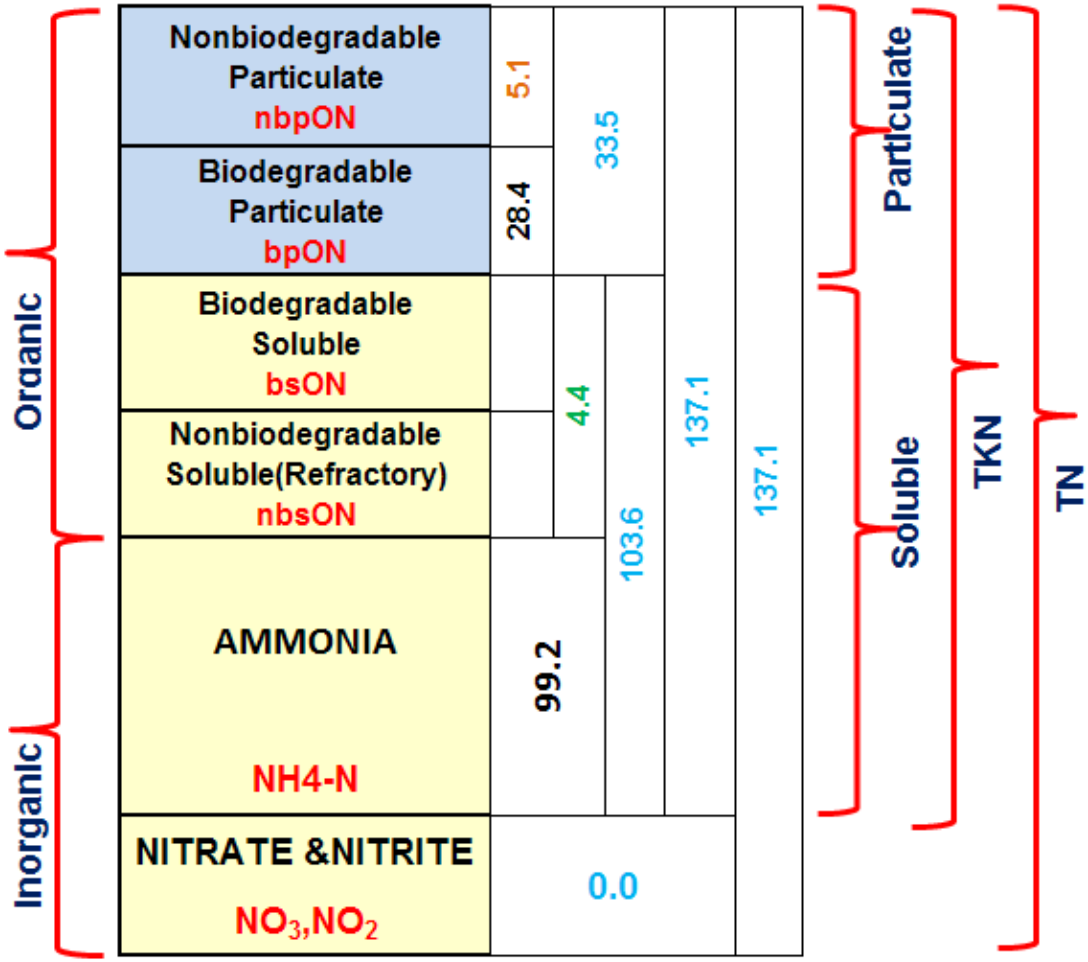
$$fN = \frac{pTKN}{VSS}$$

$$fN = \frac{33.4}{444} = 0.075$$

$$nbpON = fN \times (nbVSS)$$

nbVSS = 68.3

nbpON = 0.075x68.3 = 5.13 mg/l

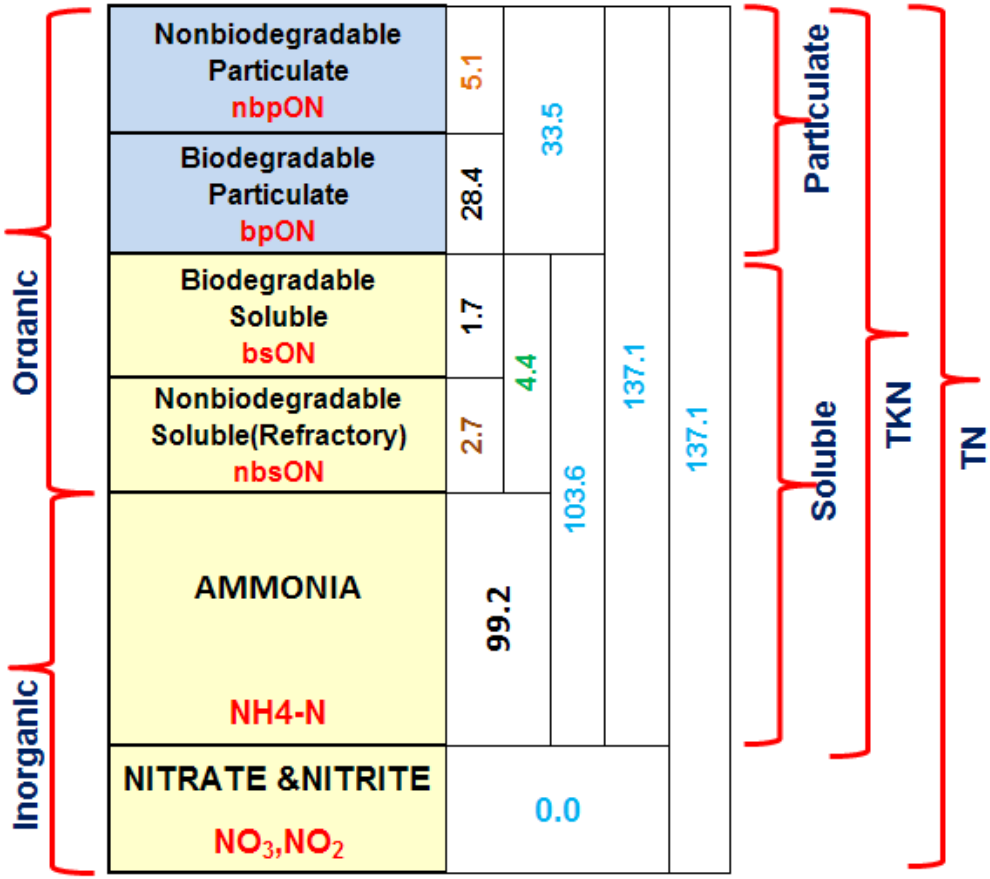


EXAMPLE – ESTIMATION OF nbsON

No.	Parameter	unit	Plant Influent	Plant Effluent
10	**Total Kjeldhal Nitrogen(TKN)**	mg/L	137	91
11	**Filtered TKN**	mg/L	103.6	81.6
12	**Ammonium(NH4-N)**	mg/L	99.2	76.9
13	**Nitrate**	mg/L		2
14	**Nitrite**	mg/L		2

$$nbsON \approx 0.02 \times TKN$$

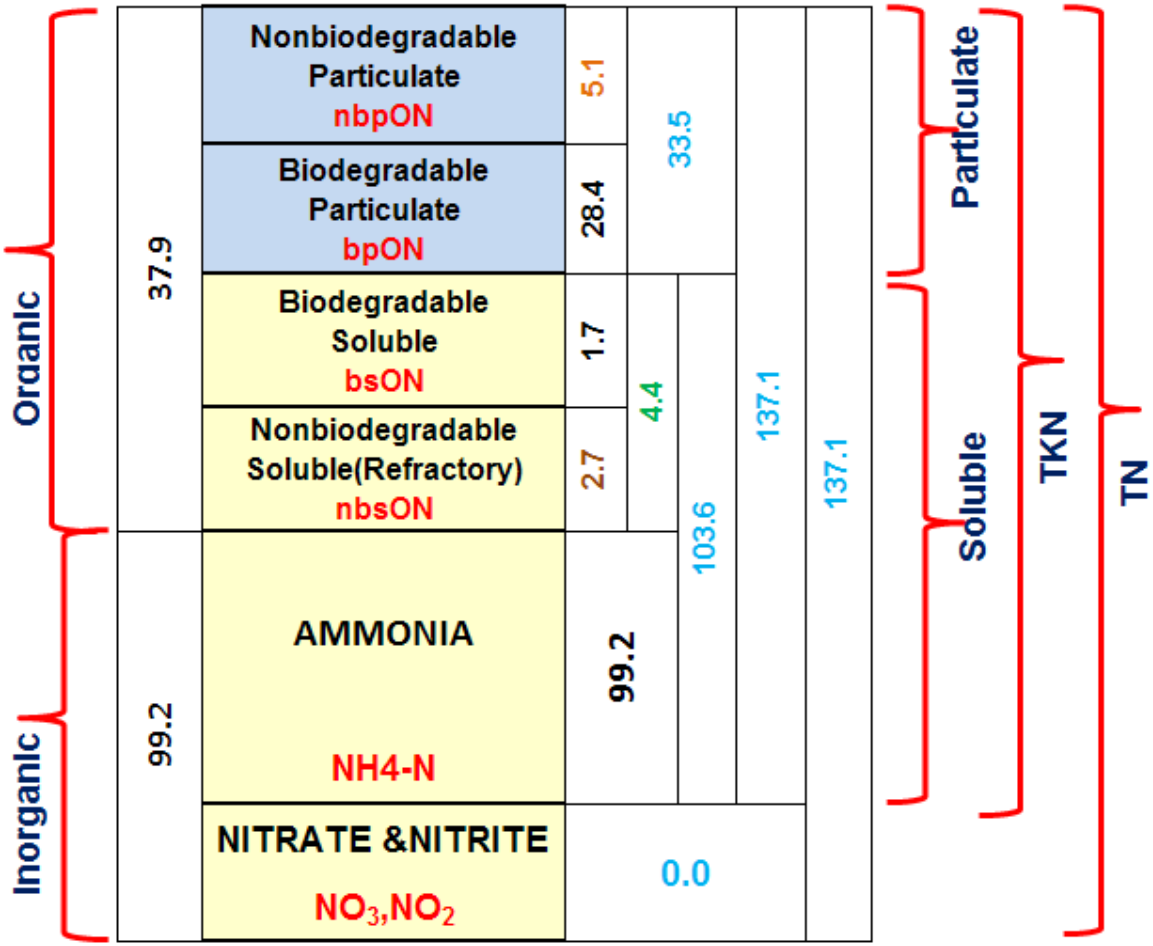
$$nbsON \approx 0.02 * 137 \approx 2.7$$



EXAMPLE – CALCULATION OF PARTICULATE ORGANIC NITROGEN FRACTION(F_{nox}) & AMMONIA FRACTION(F_{na})

$$F_{nox} = \frac{pON}{ON} = \frac{33.5}{37.9} = 0.88$$

$$F_{na} = \frac{NH_4 - N}{tTKN} = \frac{99.2}{137.1} = 0.72$$



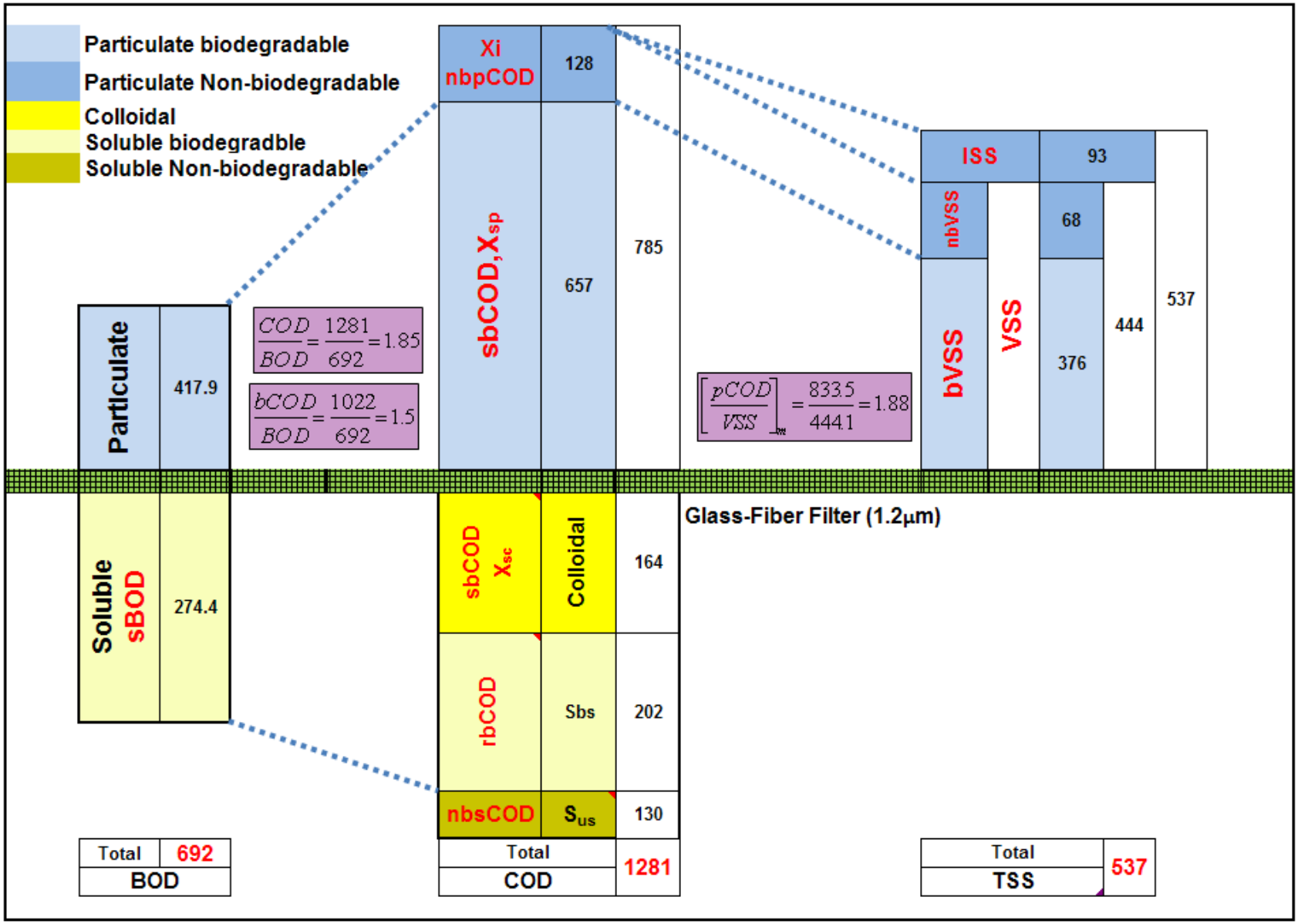
EXAMPLE – ESTIMATION OF F_{PO4}

No.	Parameter	unit	Plant Influent	Plant Effluent
8	**Total Phosphorus**	mg/L	15.8	15.6
9	**Orthophosphate (PO_4)**	mg/L	32.4	37.4
	PO_4-P	mg/L	10.5	12.1

$$F_{PO4} = \frac{PO_4 - P}{TP}$$

$$F_{PO4} = \frac{10.5}{15.8} = 0.66$$

COD,BOD & TSS RELATIONSHIP IN THE EXAMPLE



MISCONCEPTION ON NITROGEN & PHOSPHURUS LIMITS

What is the difference between?

NO_3 and NO_3-N
NH_4 and NH_4-N
NH_3 and NH_3-N
PO_4 and PO_4-N

MISCONCEPTION ON NITROGEN & PHOSPHURUS LIMITS

There is a misunderstanding in the way the Nitrogen and Phosphorus limits are expressed .

Wastewater test results and effluent quality for Nitrogen and Phosphorus given in standards are expressed in one of the following methods :

- Elemental basis (i.e. NO_3-N and NH_4-N,PO4-P).
- Molecular basis (i.e. NO_3 and NH_4,PO4).

Parameter	Ratio	Parameter	Ratio
NO_3-N / NO_3	0.226	NO_3 / NO_3-N	4.429
NH_3-N / NH_3	0.824	NH_3 / NH_3-N	1.214
NH_4-N / NH_4	0.778	NH_4 / NH_4-N	1.286
PO_4-P / PO_4	0.326	PO_4-P / PO_4	3.065

Parameter	Atomic Weight	Molecular Weight
N	14	
O	16	
H	1	
NO_3		62
NH_3		17
NH_4		18
P	31	
PO_4		95

RECOMMENDED TYPICAL FRACTIONS

Name	Fraction Description	Unit	Raw	Settled
F_{bs}	Readily biodegradable (including Acetate)	[gCOD/g of total COD]	0.16	0.27
F_{us}	Non-biodegradable soluble	[gCOD/g of total COD]	0.05	0.08
F_{xsp}	Particulate non-colloidal slowly biodegradable	[gCOD/g of slowly degradable COD]	0.75	0.50
F_{up}	Non-biodegradable particulate	[gCOD/g of total COD]	0.13	0.08
F_{na}	Ammonia	[gNH3-N/gTKN]	0.66	0.75
F_{nox}	Particulate biodegradable organic nitrogen	[gN/g Organic N]	0.50	0.25
F_{nus}	non-biodegradable solube TKN	[gN/gTKN]	0.02	0.02
F_{po4}	Phosphate	[gPO_4-P/gTP]	0.50	0.75
F_{upP}	P:COD ratio for influent non-biodegradable part. COD	[gP/gCOD]	0.011	0.011
F_{upN}	N:COD ratio fornon-biodegradable part. COD	[gN/gCOD]	0.035	0.035

HOMEWORK

Estimate COD, N and P fractions for the sampling results given below

No.	Parameter	unit	Plant Influent	Plant Effluent
1	Total COD	mg/L	2220	375
2	Filtered COD(1.2 um glass fiber filter)	mg/L	837	214
3	Filtered/flocculated COD (0.45 um filter)	mg/L	674	
4	BOD_5	mg/L	1087	108
5	Filtered BOD_5(1.2 um glass fiber filter)	mg/L	490	46
6	TSS	mg/L	925	115
7	VSS	mg/L	733	96
8	Total Phosphurus	mg/L	22	16
9	Orthophosphate	mg/L	42	17
10	Total Kjeldhal Nitrogen(TKN)	mg/L	179	127
11	Filtered TKN	mg/L	130	113
12	Ammonia	mg/L	106	102
13	Nitrate	mg/L		
14	Nitrite	mg/L		
15	Alkalinity as CaCO3	mg/L	779	904

SWIM-H2020 SM

For further information

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LDK CONSULTANTS

SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

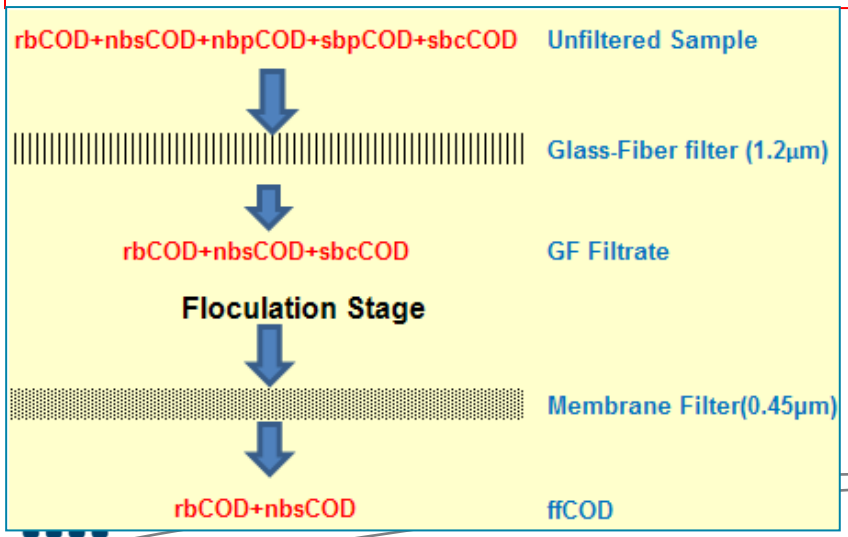
Thank you for your attention.

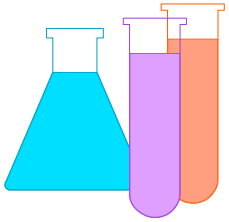
This Project is funded by the European Union

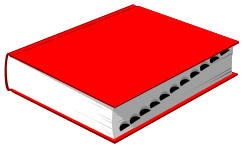
Appendix

FLOCCULATED & FILTERED COD(ffCOD) ANALYSIS

- Procedure for filtered & flocculated COD (ffCOD) test :
  - 1 mL of 100 g/L zinc sulfate solution is added to 100 mL of wastewater
  - The sample is then mixed vigorously for approximately 1 minute
  - The sample pH is adjusted to approximately 10.5 using 6 M sodium hydroxide solution(NaOH).
  - The sample then is allowed to settle, and a sample of the supernatant is withdrawn
  - The supernatant sample is filtered using a 0.45 µm membrane filter, and the filtrate COD is analyzed.







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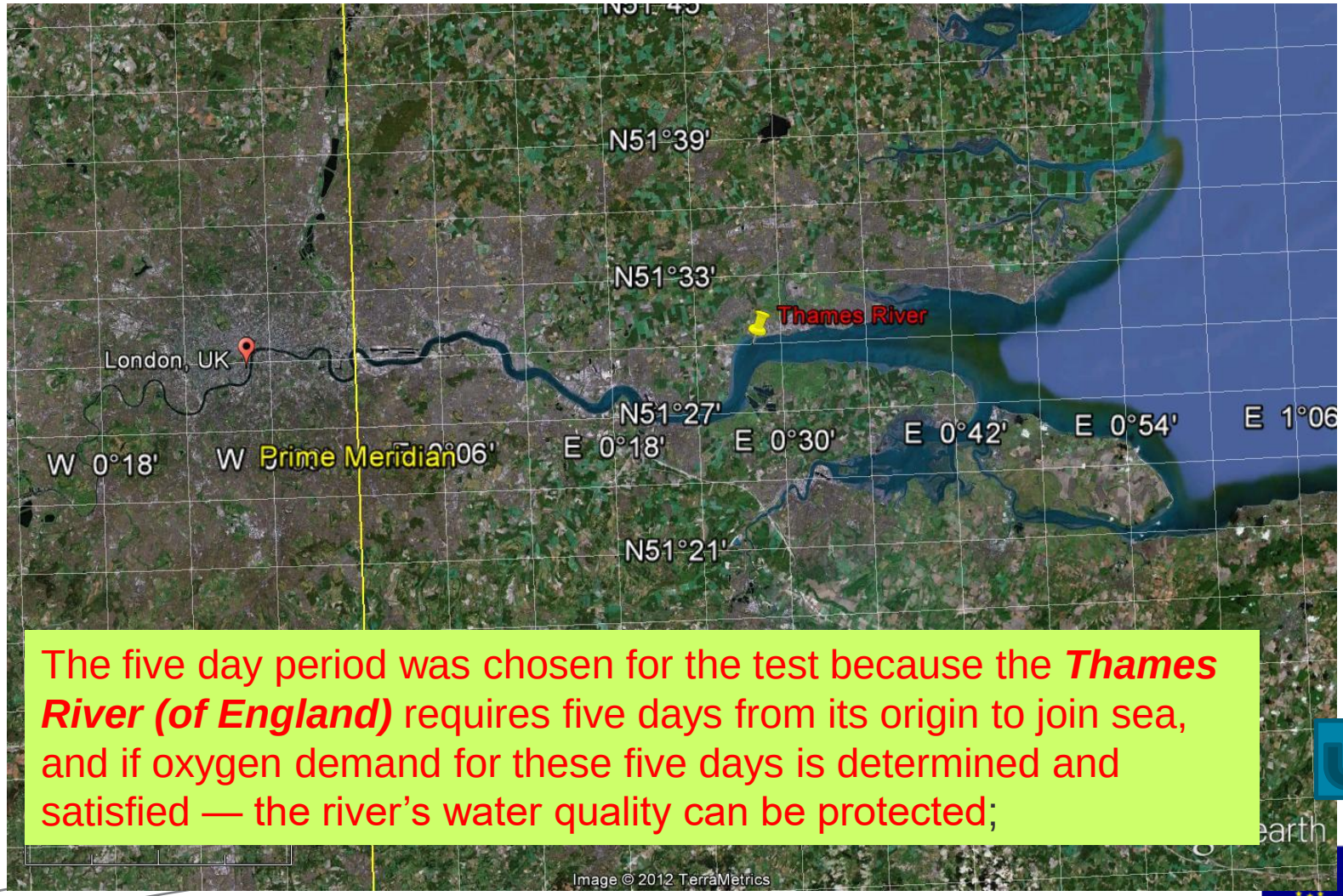
WHY 5 DAY BOD?



The five day period was chosen for the test because the ***Thames River (of England)*** requires five days from its origin to join sea, and if oxygen demand for these five days is determined and satisfied — the river's water quality can be protected;

STANDARD METHODS FOR EXAMINATION OF WATER & WASTEWATER