Nitrification of faecal sludge liquor using pilot scale intermittent sand filters in Dakar, Senegal

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Definition of faecal sludge concepts

- **Faecal sludge (or Septage)**:
Sludges of variable consistency collected from so-called on-site sanitation systems i.e. septic tanks, latrines, non-sewered public toilets, and aqua privies;

- **Faecal sludge liquor** :
Effluent of FS settling tank (or any solid-liquid separation process applied with FS);

- **Intermittent Sand filter**:
aerobic process consisting of passing intermittently decanted wastewater through a sand bed ;

- **Nitrification** : Biochemical process of oxidizing ammonia nitrogen to nitrite and nitrate

Context of the research

Background- FS Management 1

- WHO estimated in 2004 that 1.8 million of people die each year from waterborne diseases (e.g. diarrhoea)

- 88% of the death are related to unsafe water supply, sanitation and hygiene (WHO, 2004). That justifies a bit the MDGs (Target 10 and 11).

- Requirement to shift “End-pipe solution” to “adequate sanitation systems”

- Adequate sanitation : decentralised sanitation and ecological systems) for physical environment improvement

Background- FS Management 2

- In Senegal 92% of the population are serviced by on-site sanitation;
- In Dakar at least 60% of the population are serviced by on-site
- Increasing production of FS

- FS is "only" a problem of developing countries;
- Faecal sludge is seen as temporary and will "go away" with sewer (assumption is flawed).

Problem statement

- Lack of adequate and affordable treatment options in developing countries
- Faecal sludge liquor : belongs on category of high-strength
- High COD, COD, NH_3-N, SS contents
- Little knowledge on how best to treat the faecal sludge liquor to remove specially ammonia
- Challenges is to find adequate treatment option for nitrification of faecal sludge liquor (before further processing, discharge or reuse)

Research goal and objectives

- **Goal**

  To contribute to enhance knowledge, in tropical countries, on the feasibility of intermittent sand filters for the treatment of faecal sludge liquor.

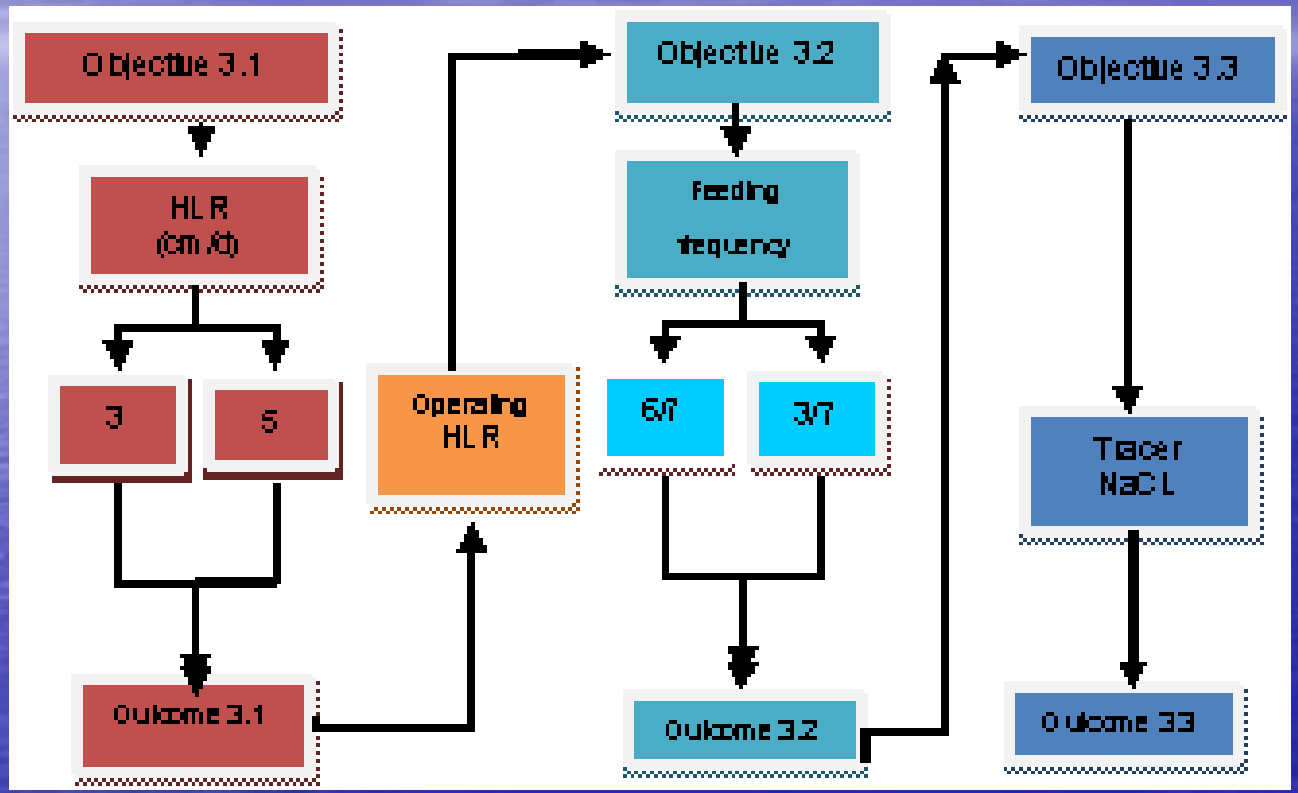
- **Objectives**

  1. To analyse the FS production in Dakar, Senegal;

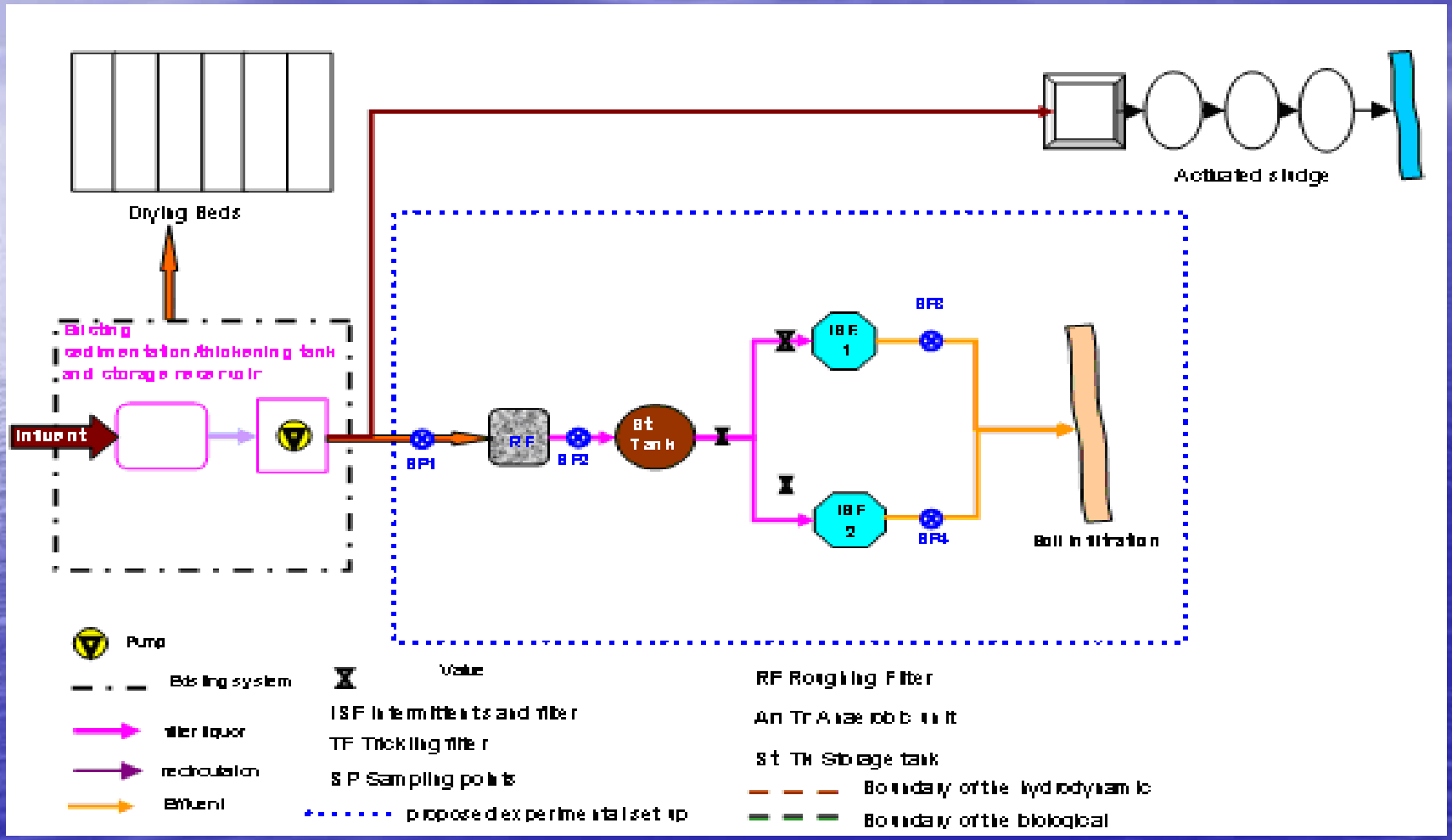
  2. To characterize the FS liquor from the settling tank;

  3. To evaluate the intermittent sand filters performances for treating the FS

Methodology: Approach

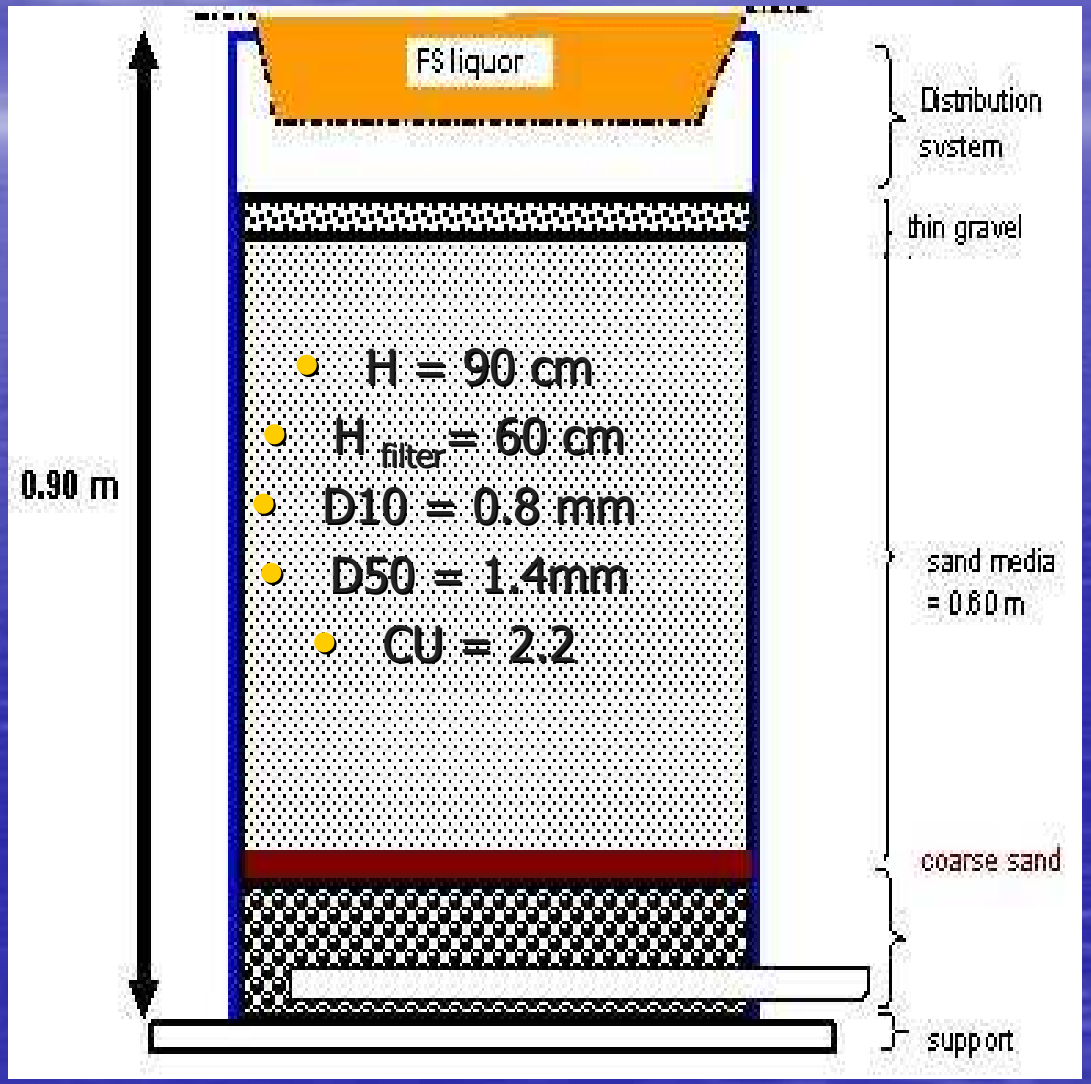


Methodology: Overview of the Pilot scale plant

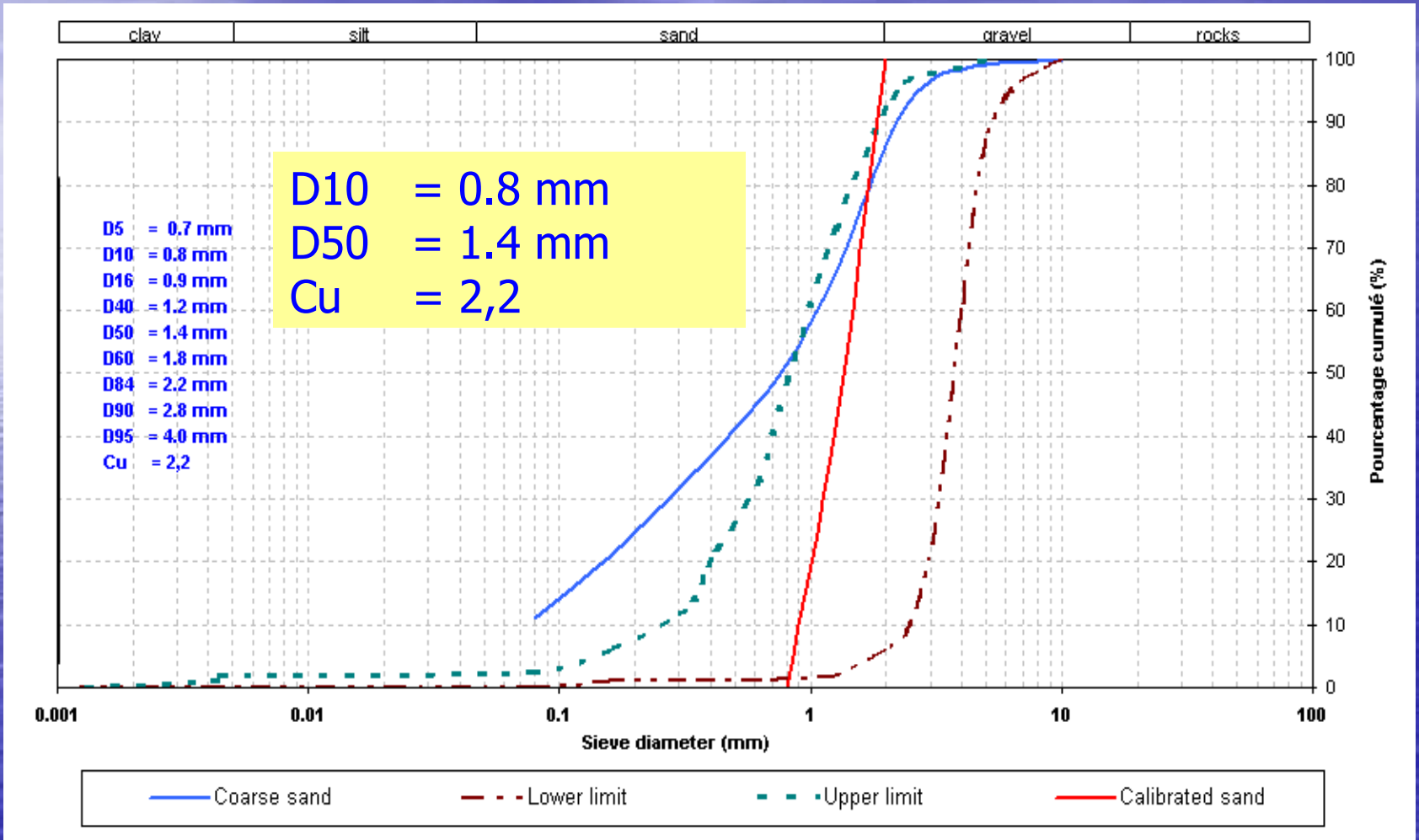


Methodology: Details of the Pilot scale plant

Methodology: Details of the ISF



Methodology: Sand calibration



Methodology: Operating HLR

Parameter	Phase1		Phase2	
	R1	R2	R1	R2
Hydraulic load (L/day)	10	17	17	17
Feeding frequency	3/7	3/7	6/7	6/7
Hydraulic loading rate ($cm/m^2/day$)	11	19	38	19
Maximum hydraulic load (cm/day)	5.1	8.7	8.7	8.7

Methodology: Organics and Ammonia Loading rate

Parameter	Phase1		Phase2	
	R1	R2	R1	R2
COD_{Total} (mg/L)	12500	12500	12500	12500
COD dissolved (mg/L)	3000	3000	3000	3000
COD_{Total} loading rate ($kg/m^2/day$)	0.8	1.3	0.6	1.0
$COD_{dissolved}$ loading rate ($kg/m^2/day$)	0.2	0.3	0.3	0.3
NH_3-N (mg/L)	270	270	270	270
NH_3-N loading rate ($kg/m^2/day$)	0.013	0.022	0.015	0.026

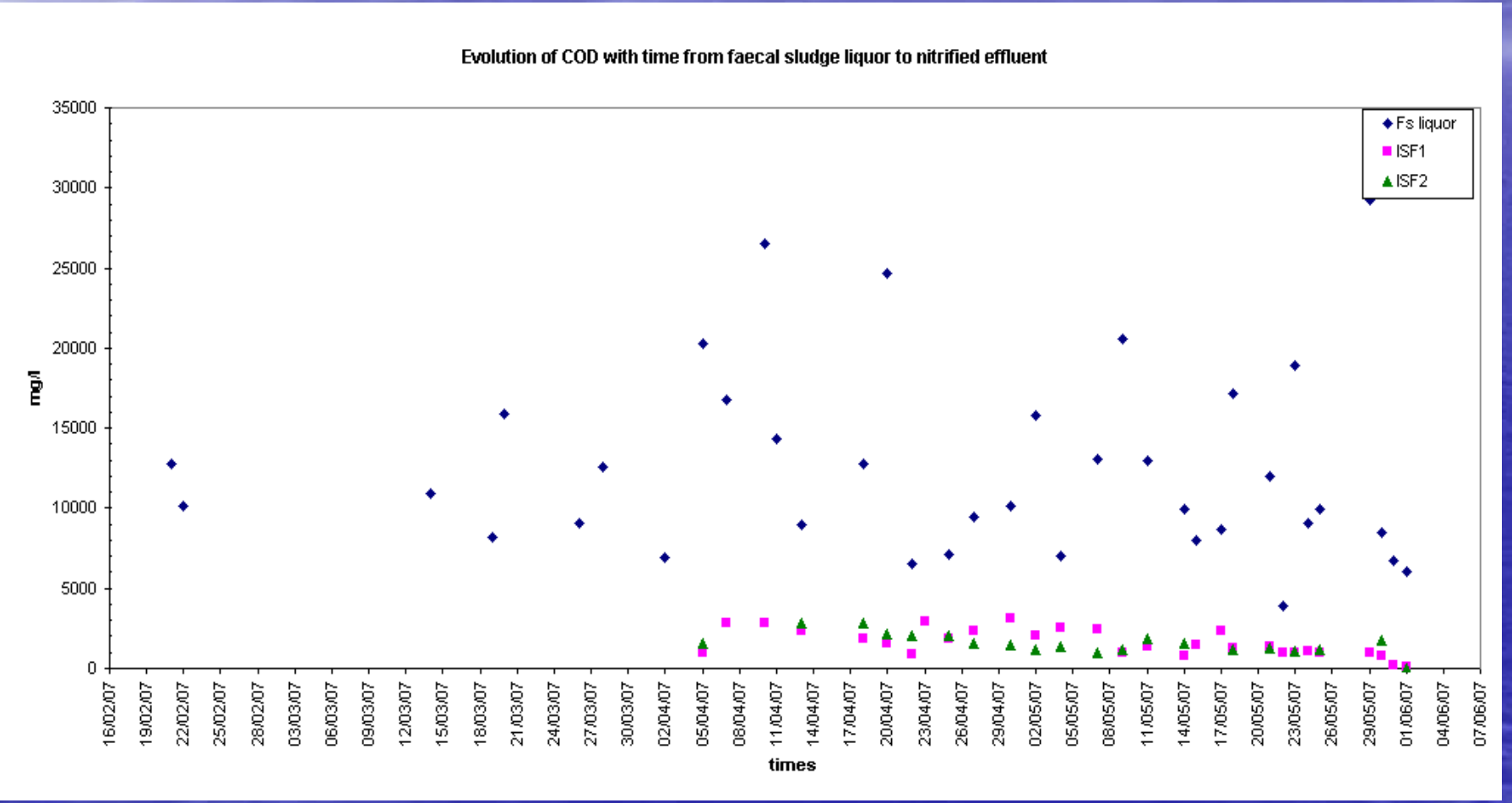
Faecal sludge Vs Municipal WW

	SS	COD unfiltered	COD Filtered	BOD	COD/BOD	NH3-N	TKN	TP
	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l
Raw faecal sludge	4250	7100		2100	3.4	200	730	5
FS liquor	2000	12500	3150	950	3.3	270	440	45
Municipal wastewater	1230	800		350	2.3	45	70	

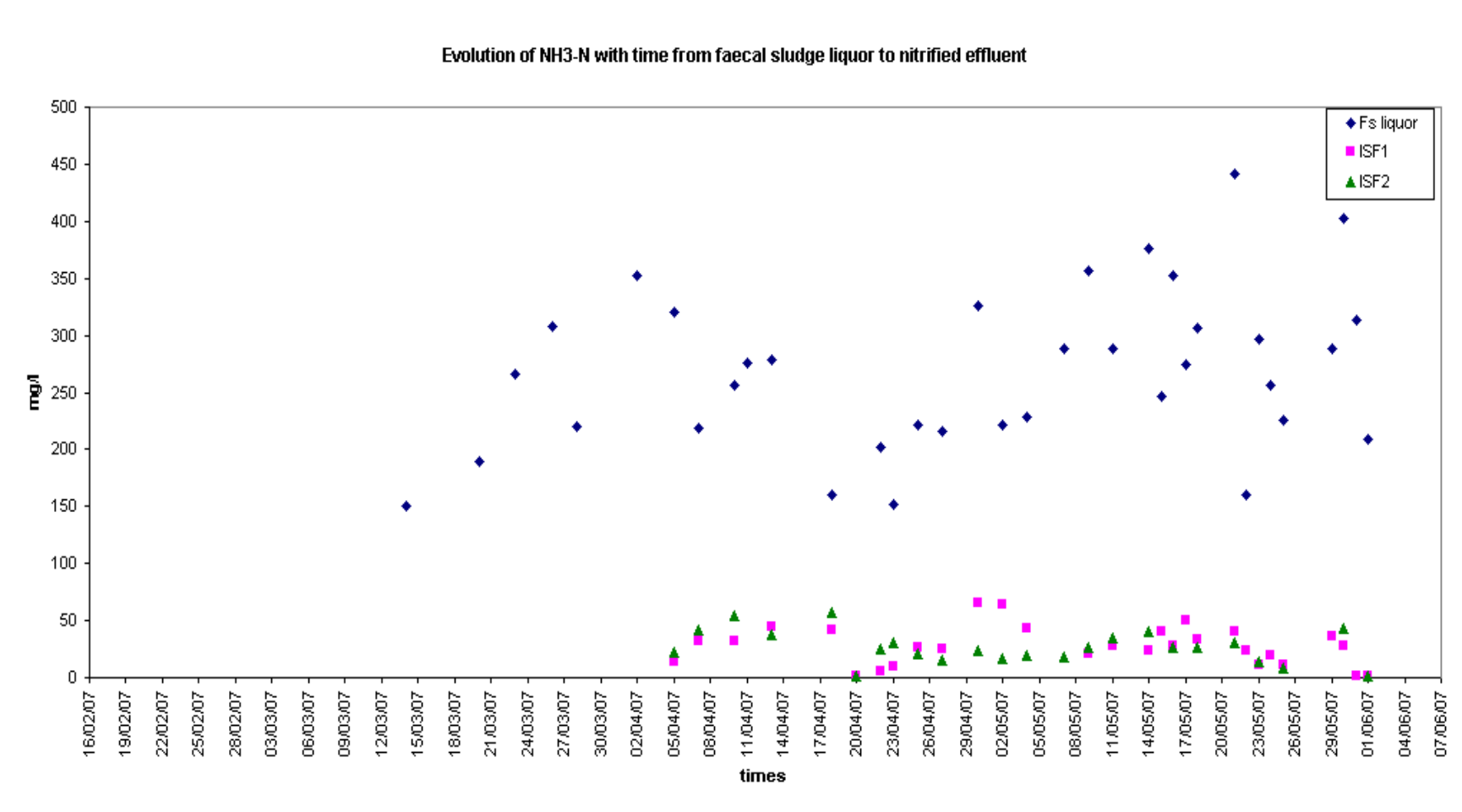
FS liquor characterization

- COD (mg/L) = 12500
- BOD (mg/L) = 950
- NH3-N (mg/L) = 300
- TKN (mg/L) = 450

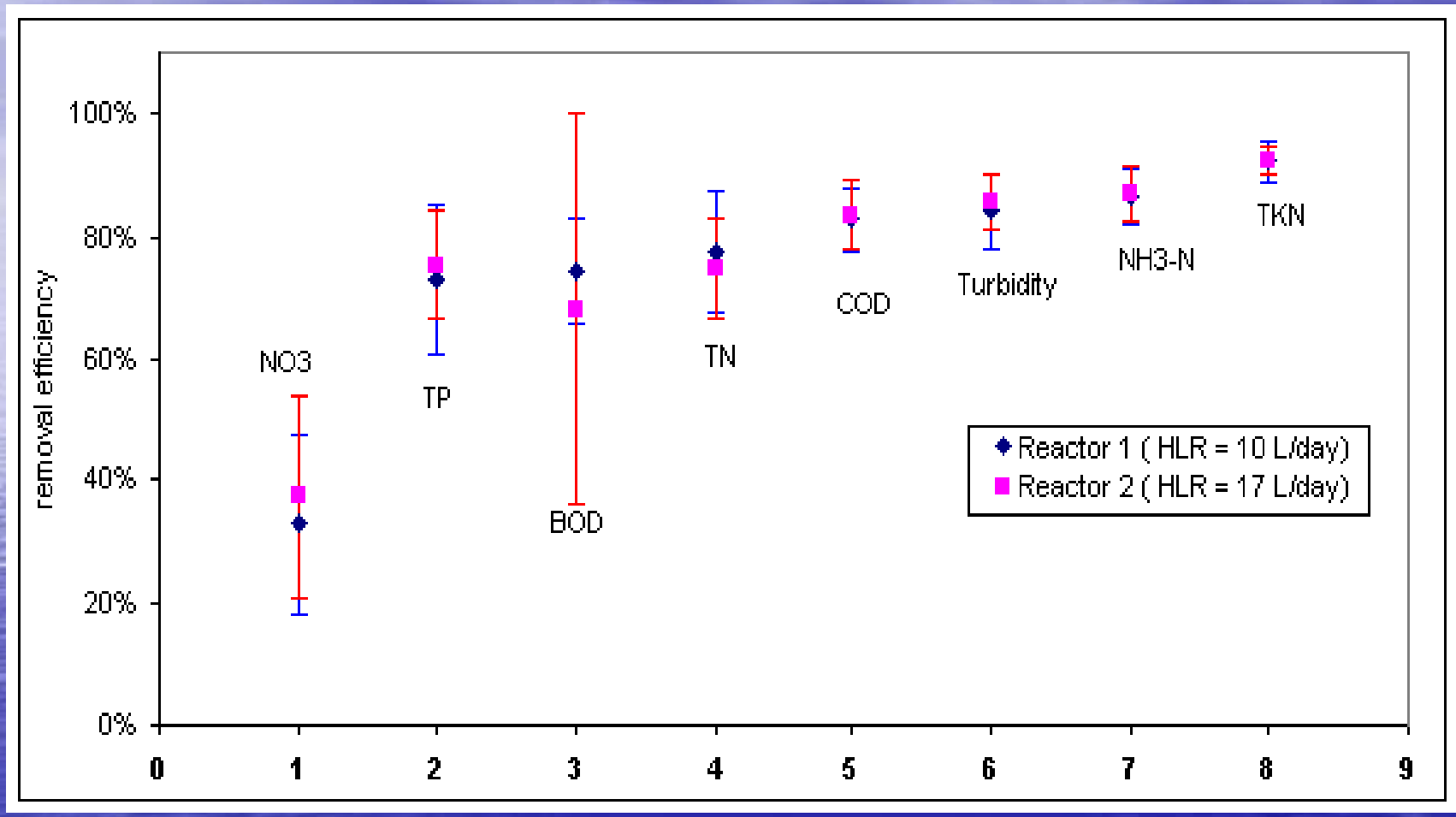
ISF COD removal Performances



Performances of ISF (NH_3-N)

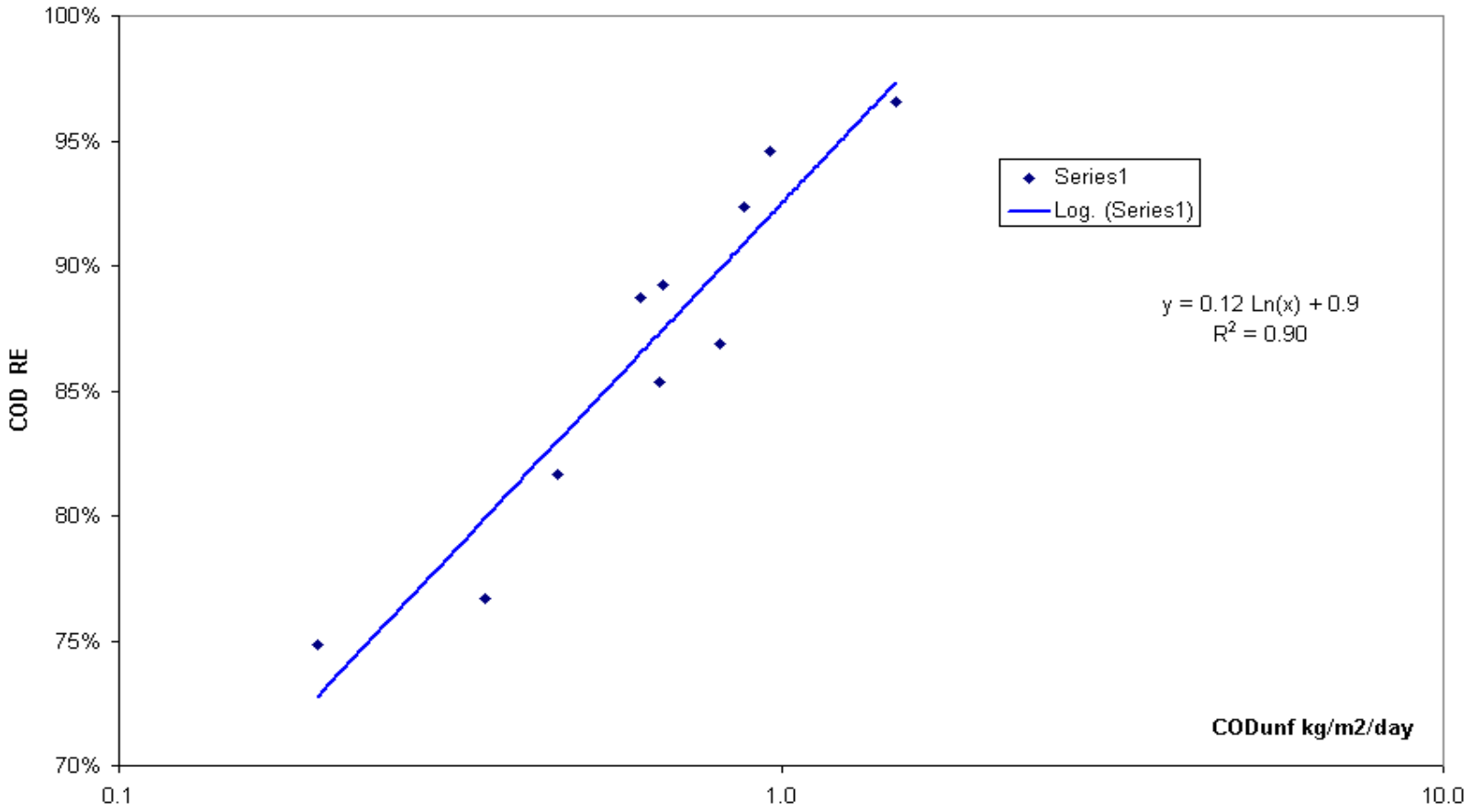


Comparison of two loading rate

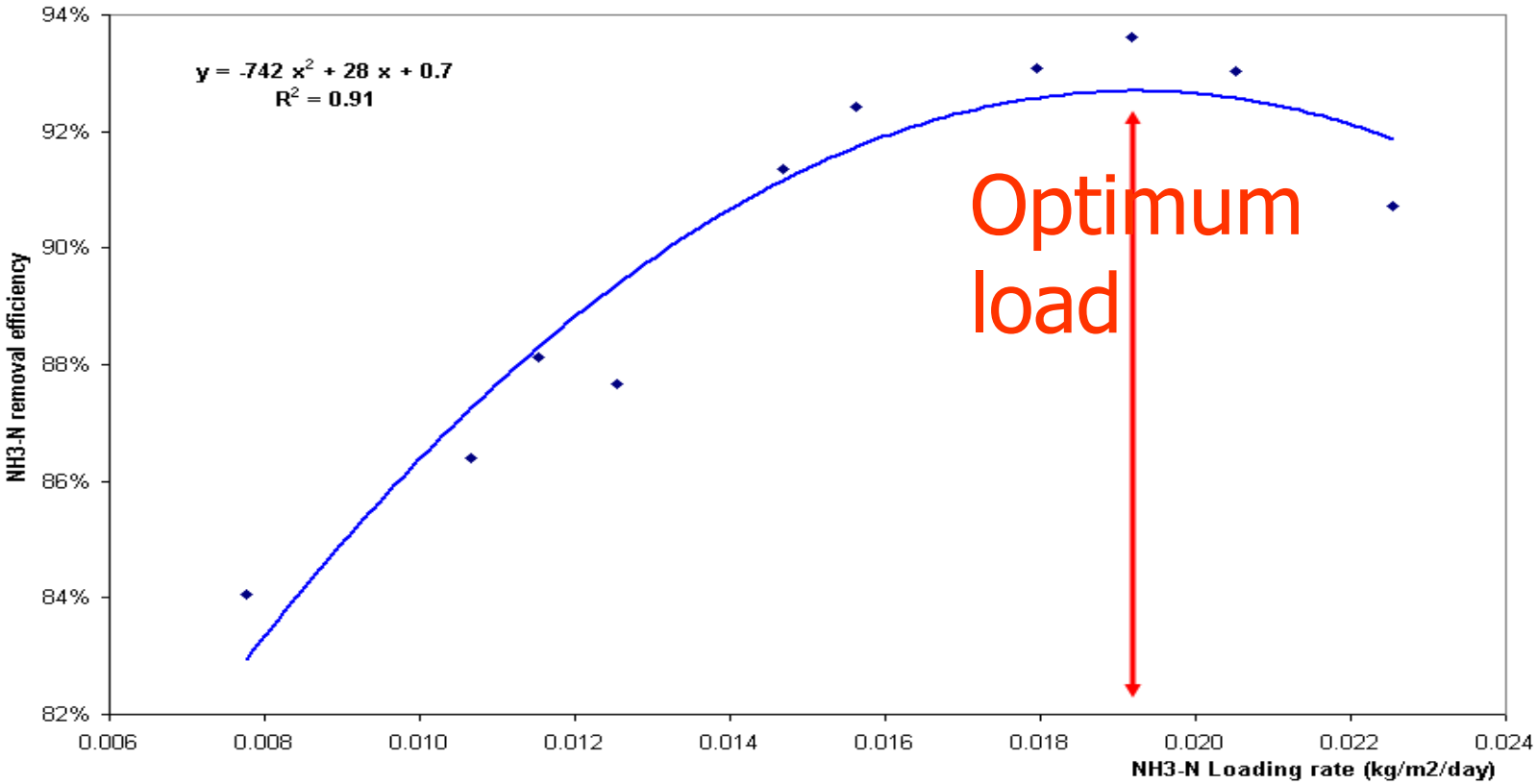


- No significant difference

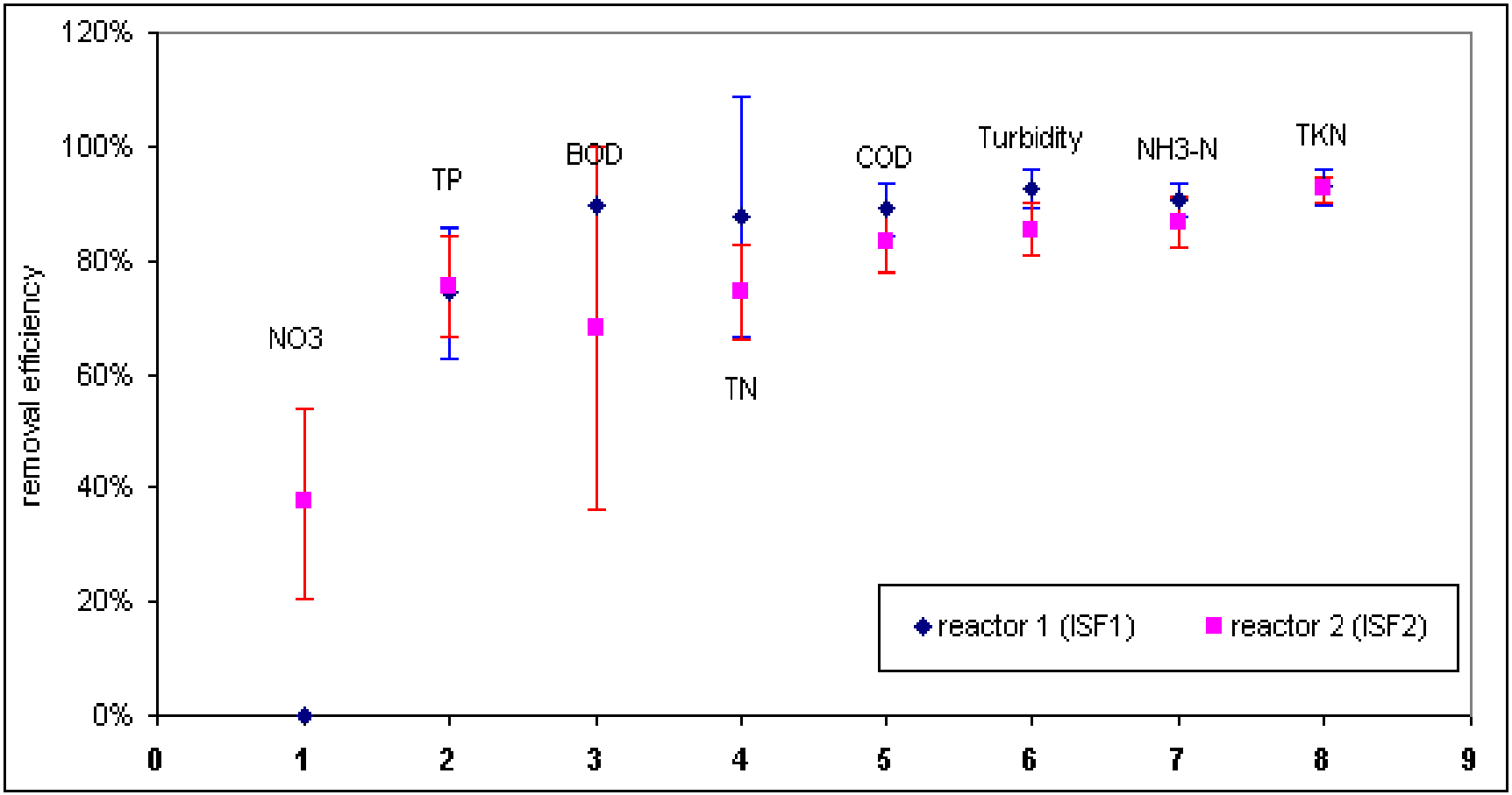
COD removal efficiency with Organic Loading rate



NH_3-N removal efficiency with N Load

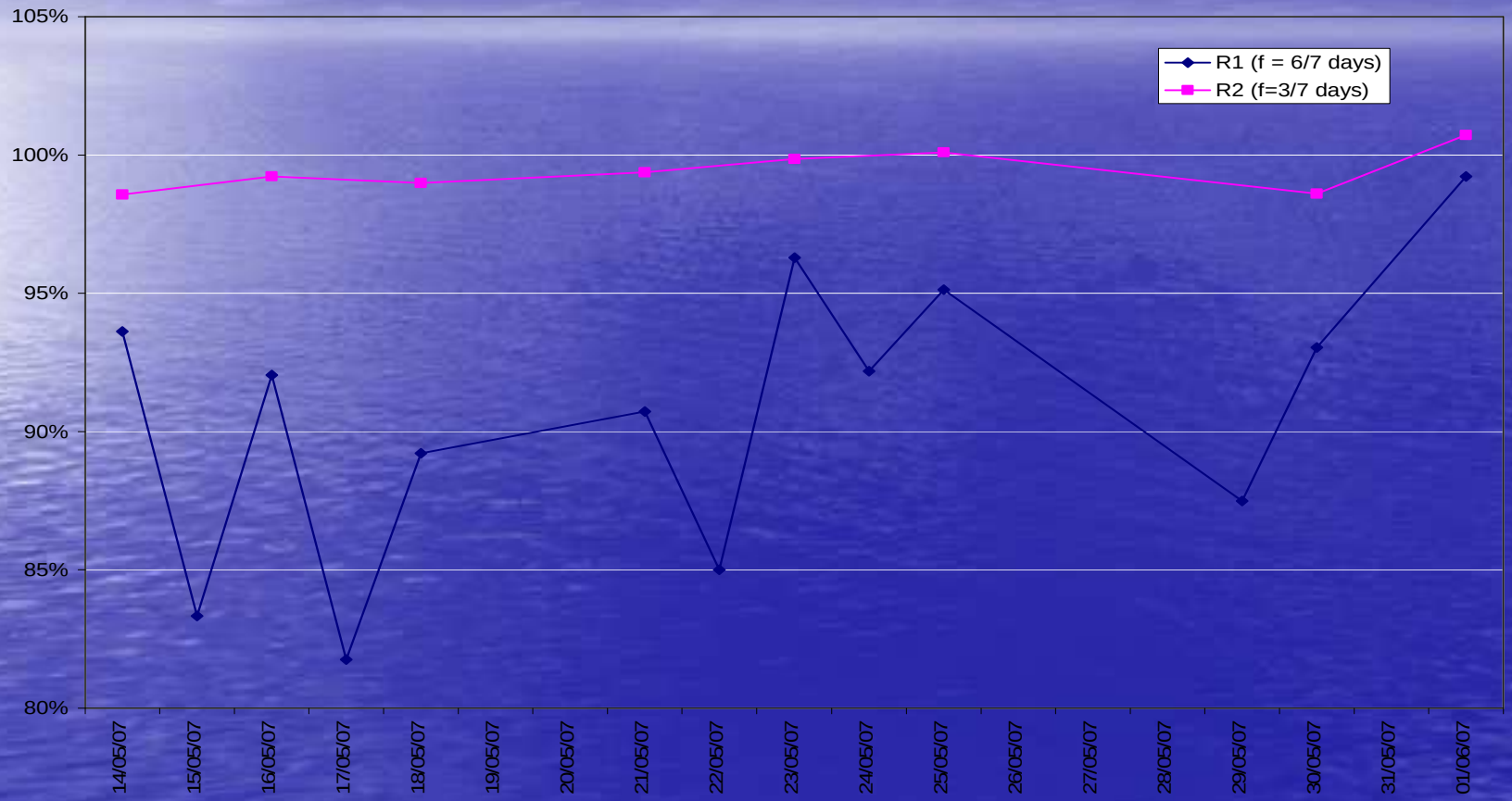


Comparison of two feeding frequencies



- Higher feeding frequency performed better

Comparative NH3-N removal efficiency in the two reactors with respective feeding frequency of 6/7 and 3/7 days



Results: ISF versus RSF and SSF

Sand Filter Type	Slow sand filtration	Rapid sand filtration	Intermittent sand filtration	ISF applied in this thesis
Infiltration rate (m/h)	0.1-0.5	5-15	0.2-3	0.5-1.5
Effective diameter d_{10} (mm)	0.2-0.5	0.5-2	0.3-2.5	0.8
Uniformity coefficient	<2	<3	<4	2.2
Turbidity (NTU)	<0.1 (25 mg/L)	<0.3 (75 mg/L)	- (< 800mg/L)	<1000 FAU (2000 mg/L)
Depth (m)	0.6-1	0.6-1	0.60-2	0.60
Run days (days)	20-100	1-3	-	>120
Cleaning	skimming	Backwash + air	-	Slight scrapping
Mechanisms	Physical, Biological	Physical, chemical	Physical, Biological	Physical, Biological
Oxidation	NH_3	Fe, Mn, NH_3	COD, NH_3	COD, NH_3

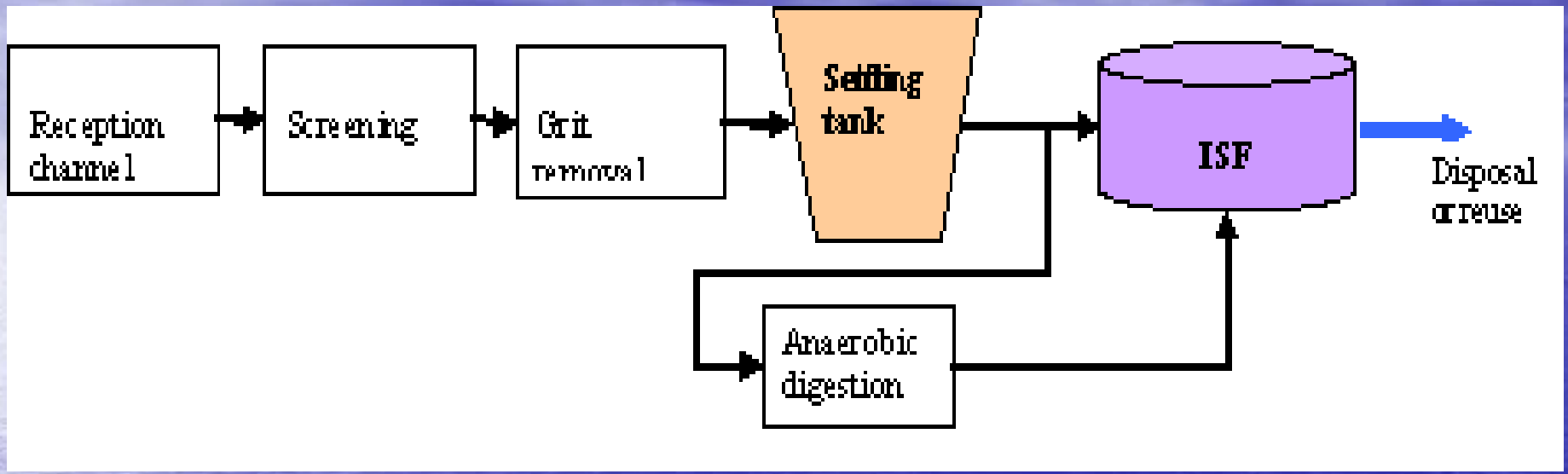
Conclusion

- ISF look like to be successfully applicable treating FS liquor despite of a high SS content and natural oxygenation;
- FS in Dakar is classified as low strength FS: SS (2-3); NH3-N (6); COD (15)
- FS characteristics depends on the performances of the settling tank (or solid-liquid separation process)
- FS liquor in Dakar consist mainly of NH3-N
- Removal efficiency of the pilot scale plant: Turbidity (93%), COD (89%), NH3-N (91%), TKN (93%), Nitrification 40%
- Statistically there was no significant effect of the increased HLR because of their slight difference of the HLR
- Higher feeding frequency (of 6/7 days seems to provide better removal efficiency) but High organic load may lead to limitation of oxygen restoration in the filter while small feedin frequency required more land for the FSTP.
- Main process for COD removal is the filtration.

Recommendations

- FS characterization: check reliability sampling methods; try COD fractioning, Inert material evaluation for a better characterisation (apply STOWA);
- Investigate nitrogen mass balance further and evaluate how much denitrification is occurring;
- Investigate further the oxygenation process in the ISF;
- Limiting factor: check maximum operating SS and relation to clogging risk;
- Effect of daily load fractioning and higher HLR
- Residence distribution is ISF with a more stable tracer;
- Microbial and helminths removal on ISF.

Sketch of possible design of ISF



Design for nitrification:

- NH_3-N load = 0.020 kg/m^2/day
- COD load = 1500 kg/m^2/day
- Cost estimation = 0.45 euro / EH

PARTNERS

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THANK YOU