Natural and Advanced Treatment Systems for Wastewater Management at Municipal Solid Waste Disposal Site in Developing Countries

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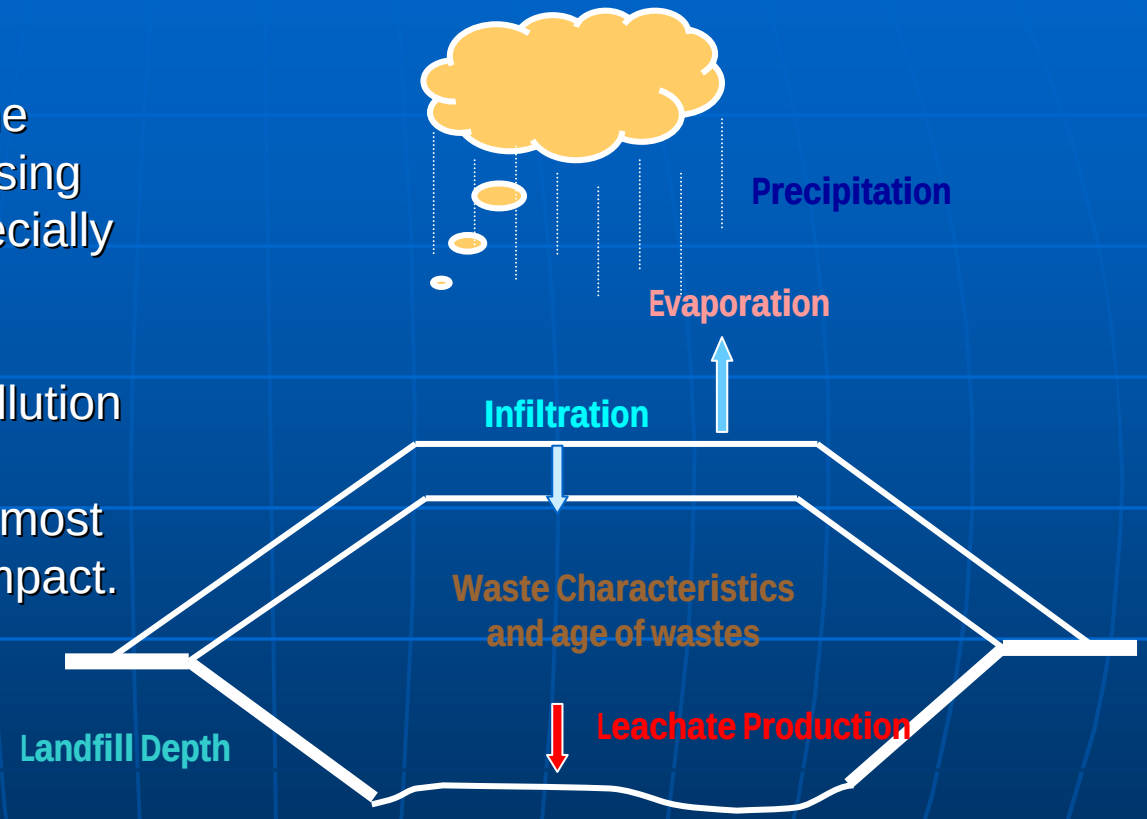
Introduction

Landfill of fresh wastes is the most common way of disposing municipal solid wastes especially in developing countries

During landfill operation, pollution arise from leachate contamination is one of the most concerned environmental impact.



Several factors affect leachate quantity and characteristics, e.g. precipitation, waste characteristics, age of landfill etc.

Variation in Leachate Characteristics: Problem encountered

Leachate characteristics varied significantly along the operation of landfill

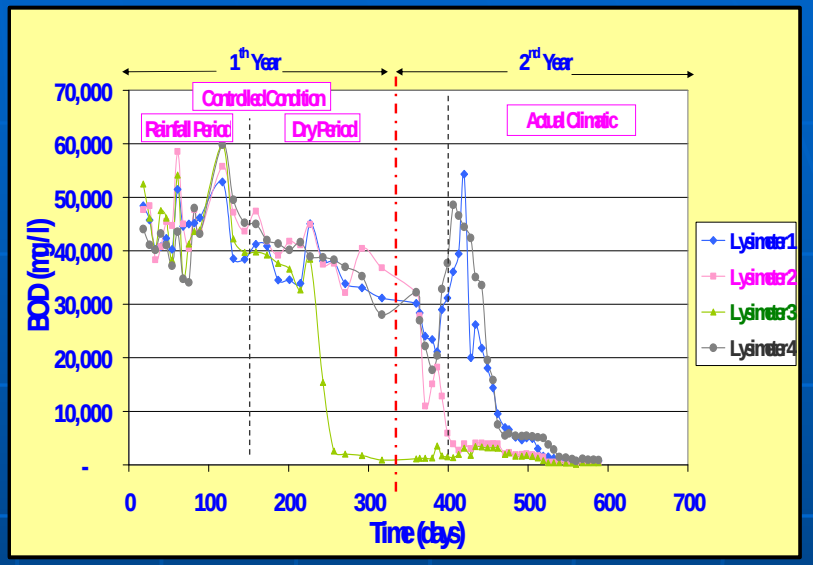
In young landfill:

- High organic (BOD, COD) concentration
- High degree of biodegradability (BOD/COD)
- Relatively low nitrogen content (high COD/N)-nutrient limit condition

As the landfill is aged:

- Low organic BOD concentration
- Low BOD/COD (Less than 0.1)-biological treatment not effective
- High nitrogen content (low COD/N) - toxic condition

Ideally, the treatment should be done by the combination of biological and physico-chemical processes but its application is limited due to high cost.



Alternatives for Leachate Management at Solid Waste Disposal Site

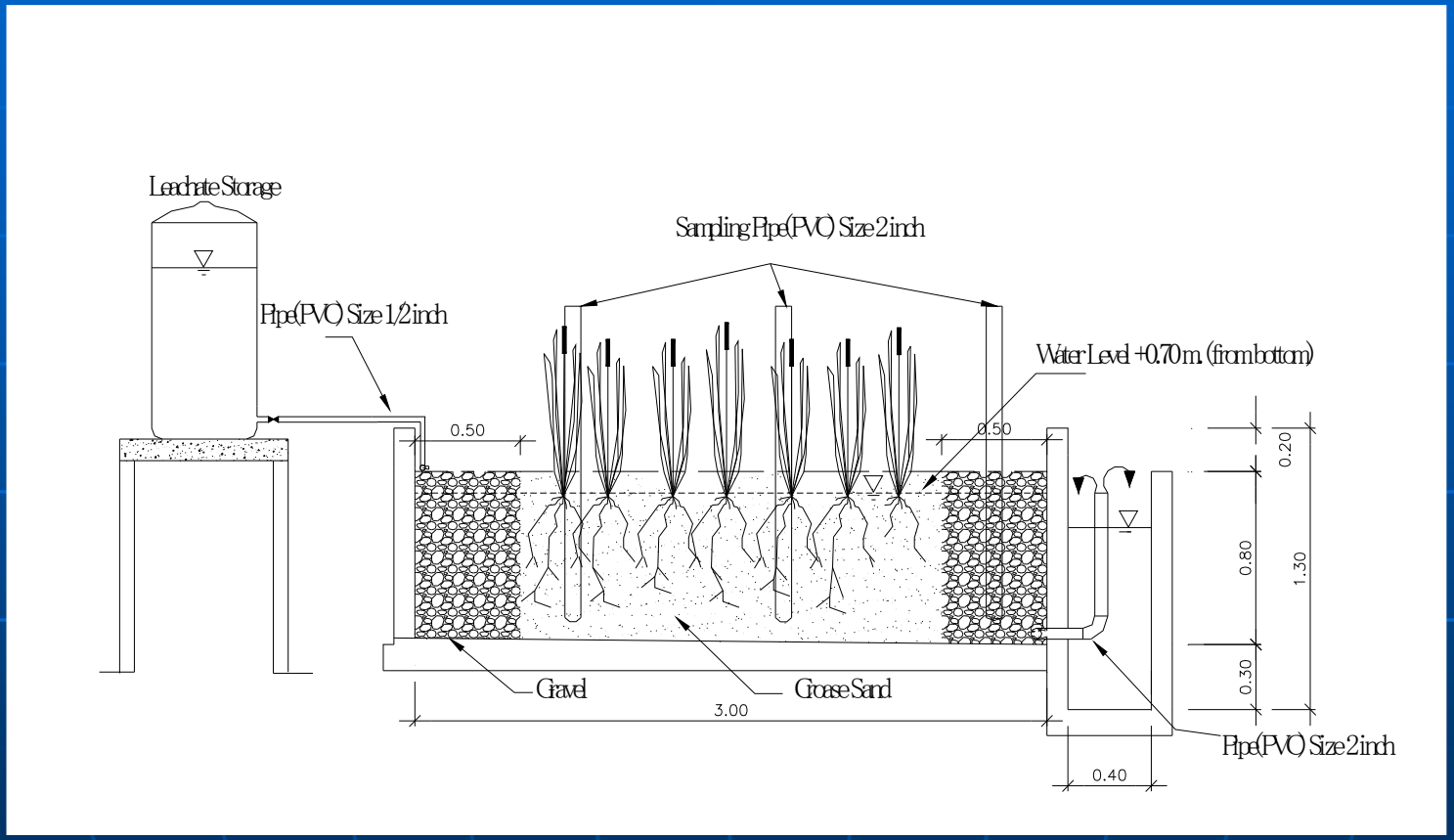
1. Leachate recirculation/ Evaporation on final cover soil
   - Cheapest solution
   - Salt accumulation- detrimental effect to vegetation
   - Not possible during rainy season
2. Stabilization ponds
   - Most popular treatment process due to low cost
   - Moderate treatment efficiencies
   - Hydraulic governed process/ Poor performance at high flow
3. Constructed wetland
   - Improved performance from stabilization pond
   - Nutrient removal possible
4. Conventional biological treatment processes (e.g. A/S, bio-film]
   - Good treatment efficiencies but ineffective for old leachate
   - High investment/ operation cost
5. Advanced treatment system (e.g. combined biological/chemical processes, MBR)
   - Improved performance from conventional processes
   - High investment/operation cost

Natural Treatment System using Constructed Wetland For the treatment of Young and Stabilized Waste Leachate

Direct application of sub-surface horizontal flow constructed wetland to young and stabilized municipal solid waste leachate.

Organic and nitrogen removal were evaluated at different hydraulic loading rates (HLR) of 10, 28 and 56 mm/d (equivalent to HRT of 28, 10 and 5 days) .

Subsurface Horizontal Flow Constructed Wetland (Cattail) size: 1 m (W) x 3 m (L) X 0.7 m (D)



Leachate characteristics

Parameter	Young leachate (Run I-III)	Stabilized leachate (Run I)	Stabilized leachate (Run II-III)
pH	4.3-6.5	8.2-8.5	7.9-9.2
BOD (mg/l)	3,150-7,400	209-278	15-68
COD (mg/l)	5,850-12,820	1,613-4,506	414-2,184
SS (mg/l)	320-825	124-223	10-158
NH_3-N (mg/l)	43-108	711-967	88-305
TKN (mg/l)	144-366	846-1,454	107-411
PO_4 (mg/l)	4.3-23.4	7.3-8.8	1.4-5.4
EC (mS/cm)	1.5-6.7	17.4-21.3	1.4-13.1

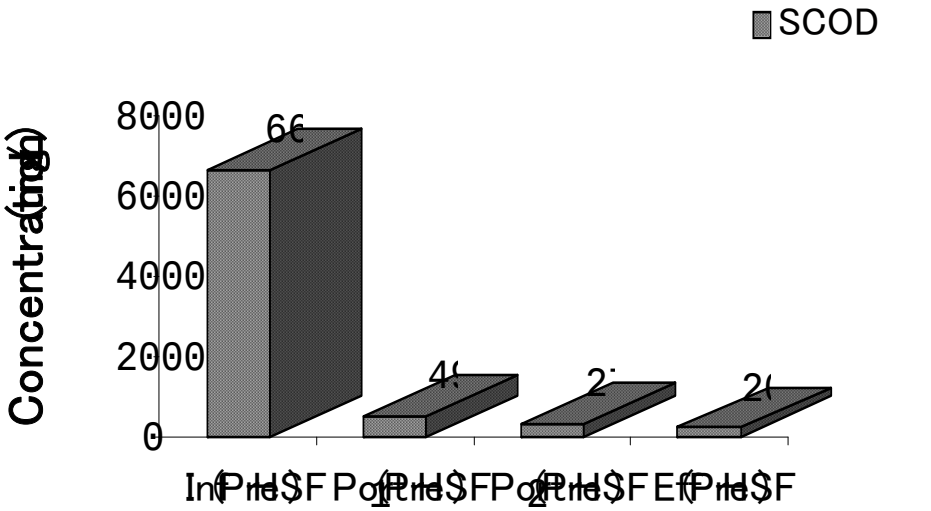
Steady state performance – young leachate

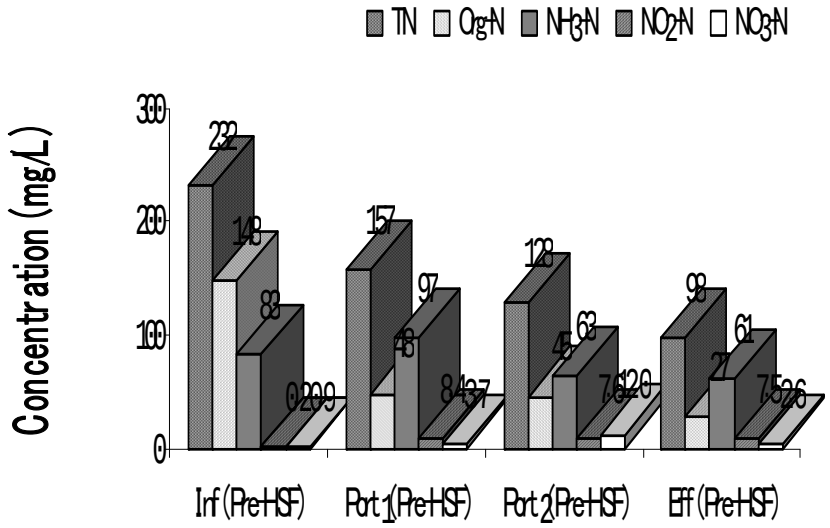
Parameter	HLR 10 mm/d	%R	HLR 28 mm/d	%R	HLR 56 mm/d	% R
pH	7.6 (0.3)		8.1 (0.1)		7.6 (0.3)	
BOD (mg/L)	136 (171)	98	32 (31)	99	115 (36)	97
COD (mg/L)	757 (692)	94	438 (294)	97	364 (169)	96
SS (mg/L)	30 (25)	88	113 (128)	71	87 (19)	88
NH_3-N (mg/L)	44 (20)		72 (40)		98 (18)	
TKN (mg/L)	86 (40)	43	114 (37)	36	182 (24)	8
NO_2-N (mg/L)	3.9 (6.6)		1.9 (2.3)		0.3 (0.1)	
NO_3-N (mg/L)	0.7 (0.2)		4.2 (4.8)		3.0 (0.3)	
PO_4 (mg/L)	0.1 (0.1)	99	0.5 (0.1)	95	0.9 (0.3)	95

Remark: average (SD) values

- High organic removal efficiencies (>90%) was achieved in HSF treating young leachate at HLR of 10-56 mm/d. Moderate TKN removal (36-43%) was obtained.

COD and nitrogen profile (HLR = 10 mm/d)





- Most of COD were removed within the first 1 m distance from the inlet
- Nitrogen transformation gradually took place along the treatment path.
- There was no significant level of oxidized nitrogen found in the system at steady state.
- DO in plant root zone was found in range between 0.9-1.4 mg/L @ HLR of 10 mm/d to 0.1-0.2 mg/L @HLR of 56 mm/d

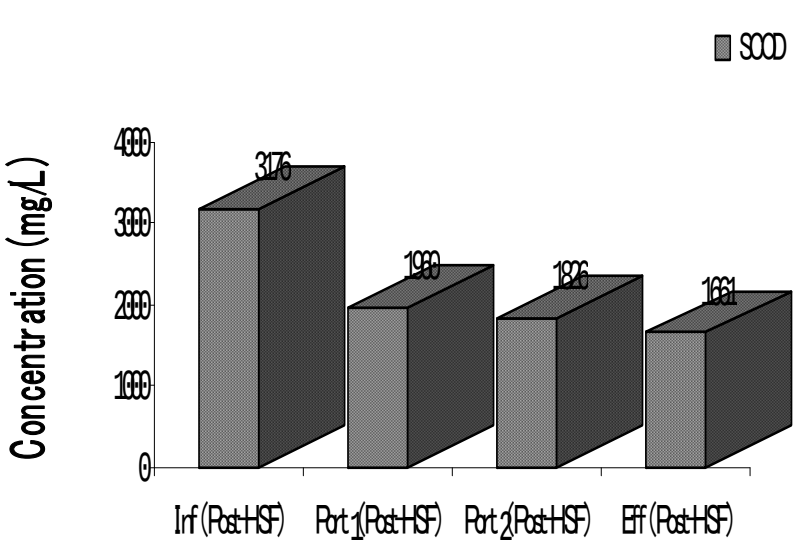
Steady state performance – stabilized leachate

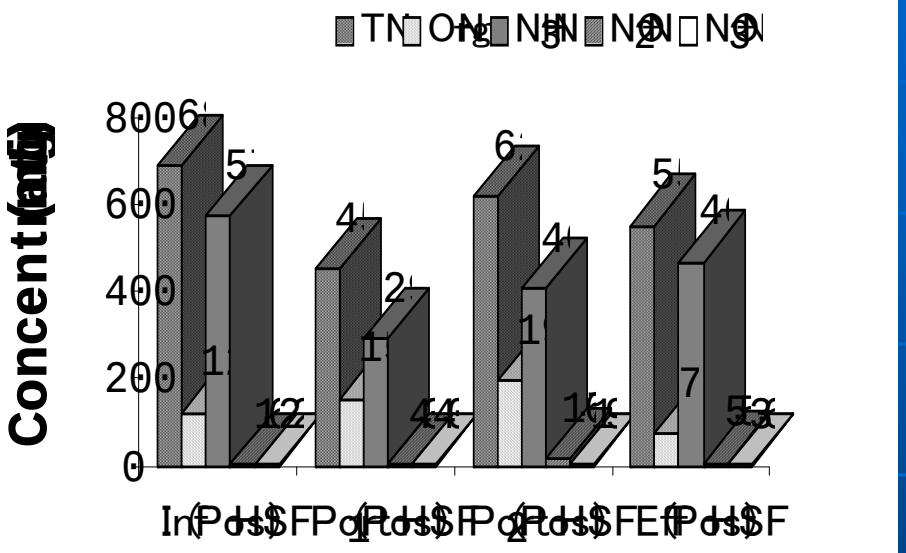
Parameter	HLR 10 mm/d	%R	HLR 28 mm/d	%R	HLR 56 mm/d	% R
pH	8.4 (0.3)		8.6 (0.1)		7.9 (0.1)	
BOD (mg/L)	47 (31)	71	27 (10)	55	11 (10)	44
COD (mg/L)	1,489 (529)	58	1,037(175)	42	185 (115)	63
SS (mg/L)	40 (15)	56	51 (10)	66	28 (4)	66
NH_3-N (mg/L)	281 (191)		133 (62)		55 (6)	
TKN (mg/L)	358 (191)	46	224 (50)	41	154 (14)	20
NO_2-N (mg/L)	54 (47)		4.9 (3.4)		17.1 (3.1)	
NO_3-N (mg/L)	4.2 (5.7)		1.6 (1.2)		6.8 (1.3)	
PO_4 (mg/L)	2.2 (2.1)	21	2.1 (0.7)	48	1.2 (0.7)	25

Remark: average (SD) values

Lower organic removal (41-77% BOD) was observed when the system was applied to the treatment of old leachate with BOD/COD <0.1. Nevertheless, moderated TKN removal (41%) was still achieved at HLR of 28 mm/d when influent TKN was controlled at 100-300 mg/l.

COD and nitrogen profile – stabilized leachate

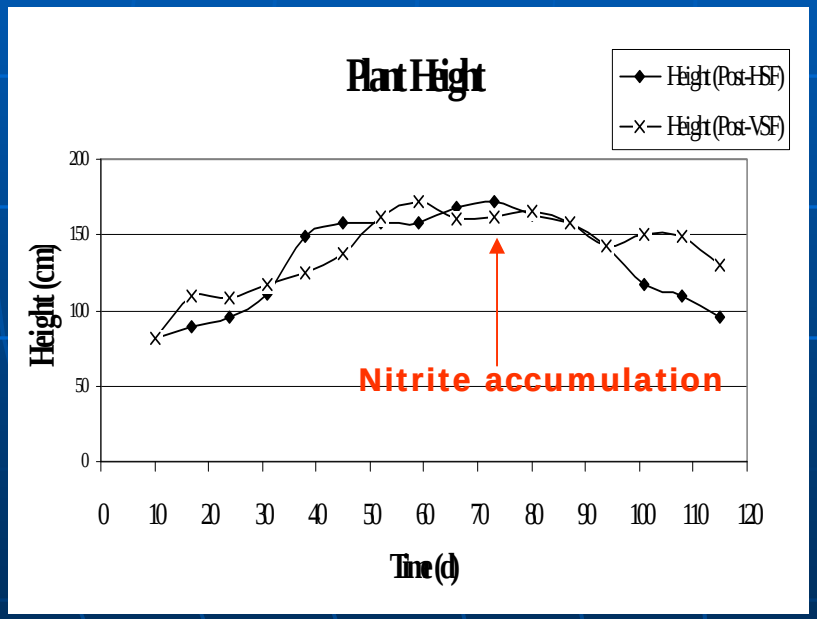


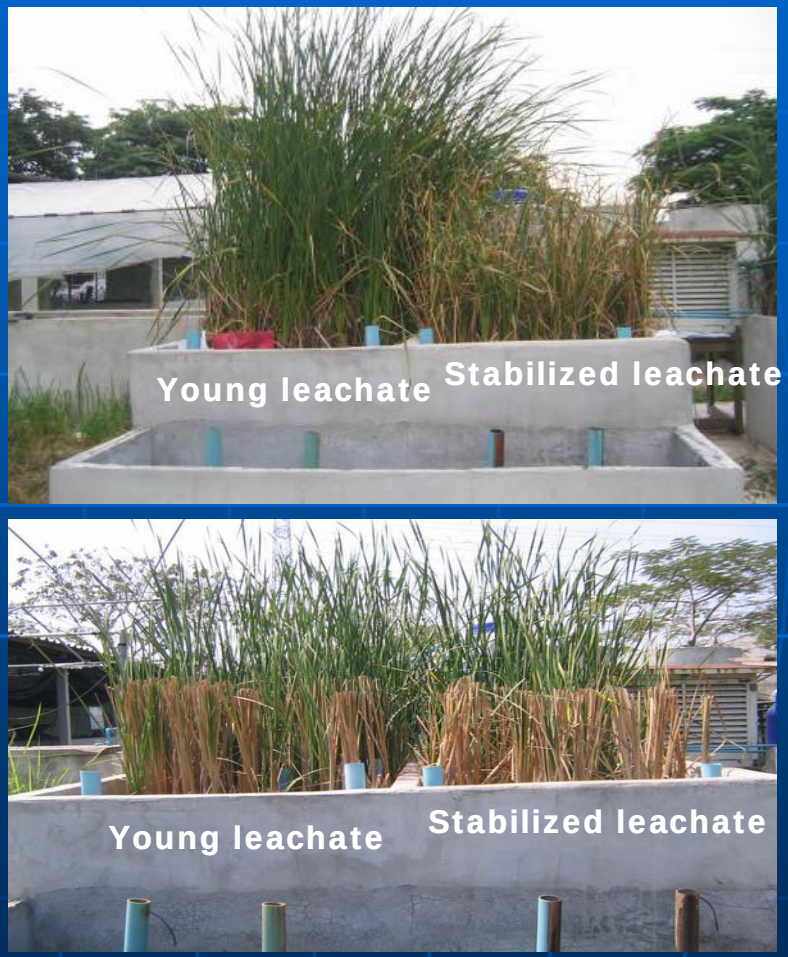


- COD were gradually removed along the treatment pathway.
- Nitrogen transformation were low. Majority of nitrogen was in ammonium form
- Similar TKN removal efficiency was obtained at HLR of 28 mm/d when compared HLR of 10 mm/d at the same N loading rate .
- Increase of HLR to 56 mm/d reduced TKN removal to 20%. Nitrite accumulation was observed in this case.

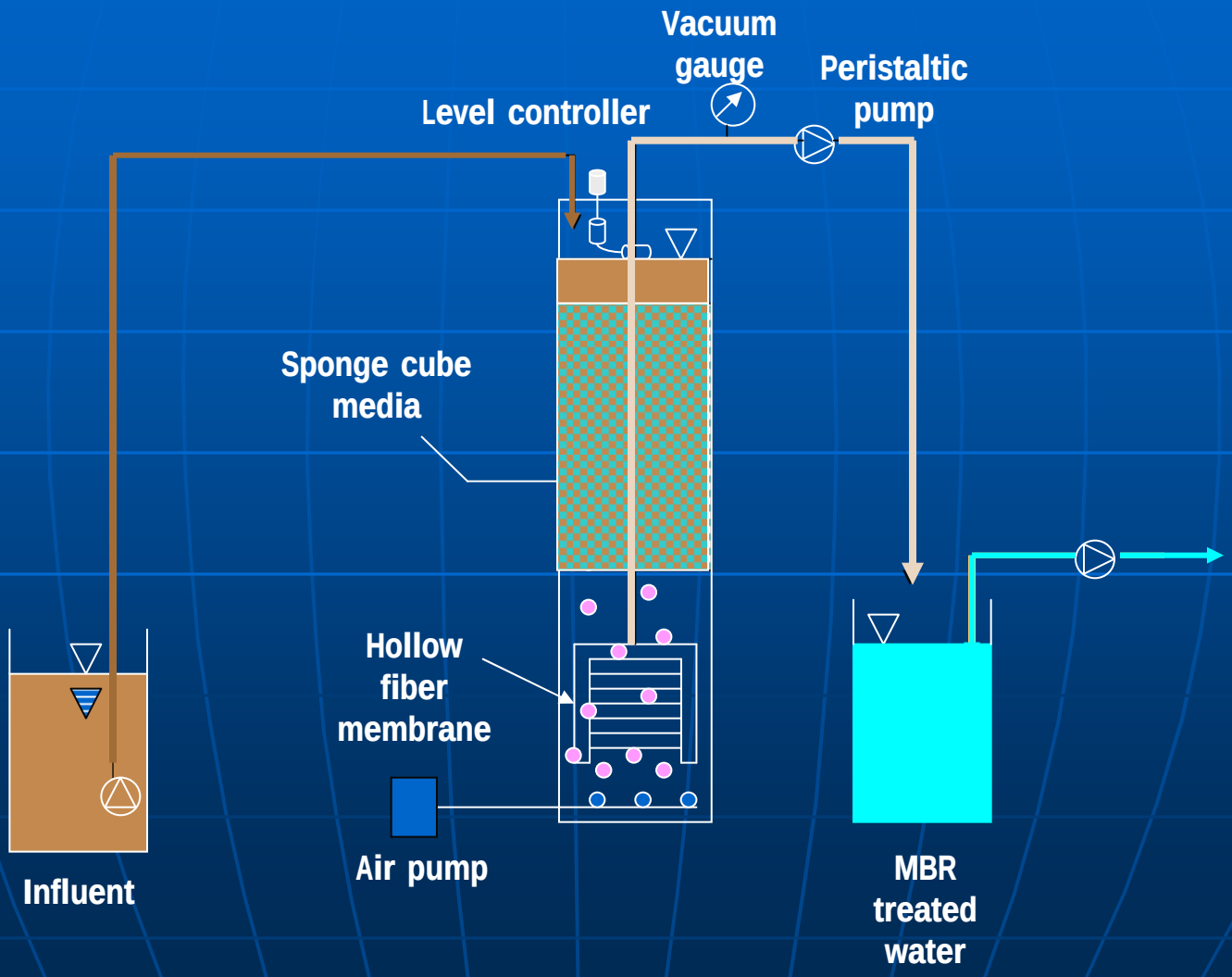
Effect of leachate on plant growth

- Higher plant growth was observed in unit fed with young leachate
- For stabilized leachate, negative effect of localized NO_2 accumulation on plant growth was observed.

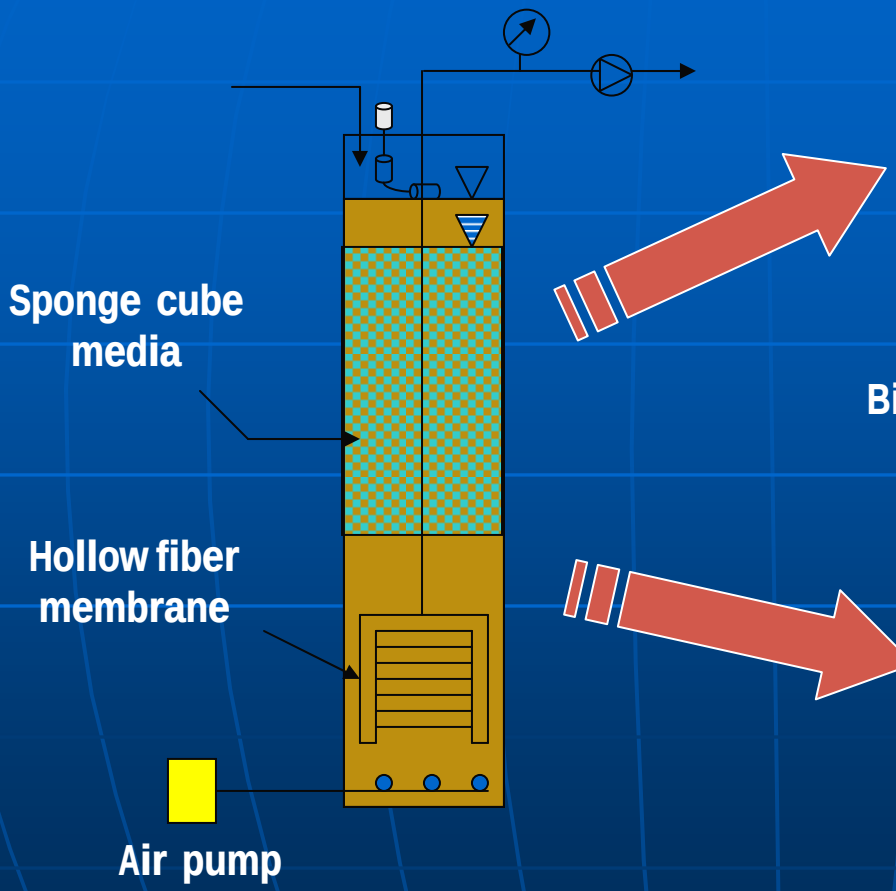




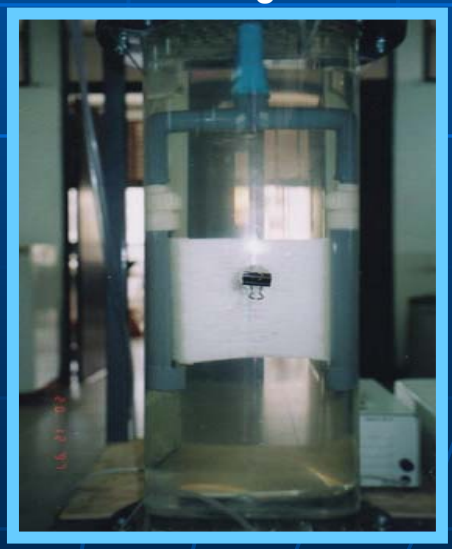
Advanced Treatment System using Bio-film membrane bioreactor



Biofilm membrane bioreactor:
Floating Media Bed/Hollow fiber Microfiltration Membrane



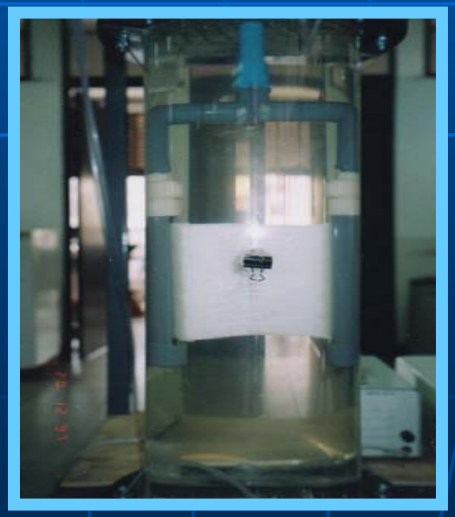
Biological activity on attached growth floating media



Solid liquid separation by microfiltration membrane

MBR experimental system & Operation

Reactor volume: 68 liters



Sponge cube 2*2*2 cm size

Porosity: 46% (external)

Bed depth: 60 cm.

Hollow fiber membrane:

Pore size: 0.4 micron.

Surface area: 0.2 m^2

HRT = 48 hours

Aeration mode:

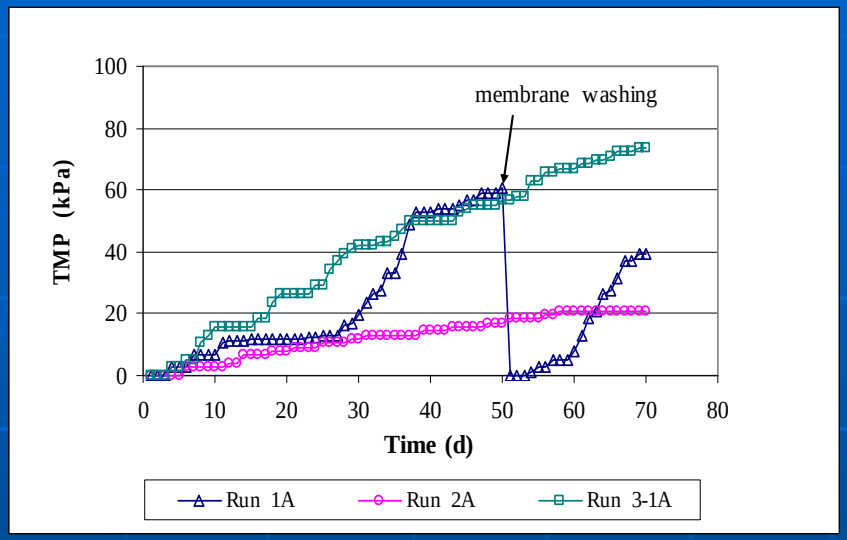
Continuous aeration

Intermittent aeration

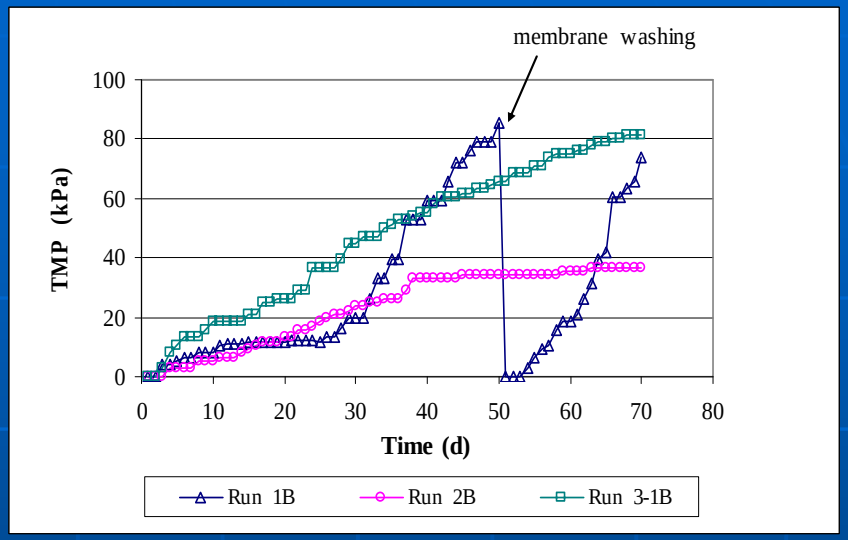
Leachate Characteristics

Parameter	New wastes	Stabilized wastes	Mixed leachate
pH	4.2-6.0	7.8-9.0	6.0-8.6
BOD (mg/l)	750-1400	370-900	500-1190
COD (mg/l)	600-1900	1300-1730	1160-1750
BOD/COD	0.7-0.9	0.3-0.7	0.4-0.7
SS (mg/l)	20-80	90-140	100-200
NH_3-N (mg/l)	20-40	1200-1700	100-180
Org-N (mg/l)	10-30	40-100	3-70
COD/N	20-30	1	10
TP (mg/l)	2-5	5-10	5-8

TMP Development in Biofilm MBR: Effect of Aeration



a) Continuous aeration

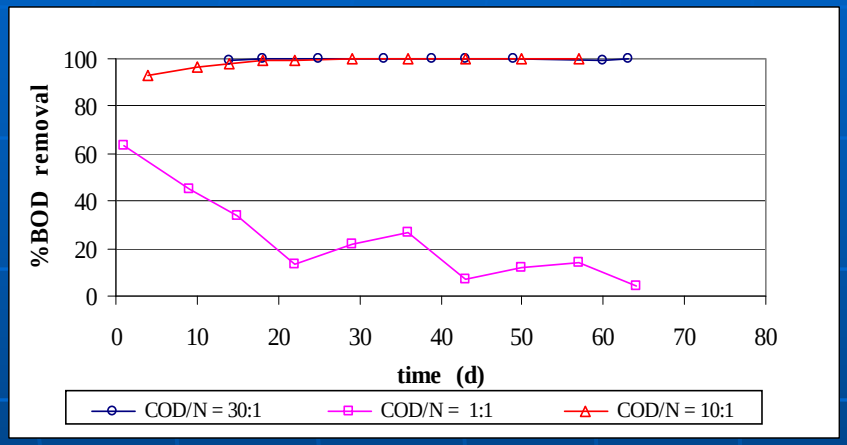


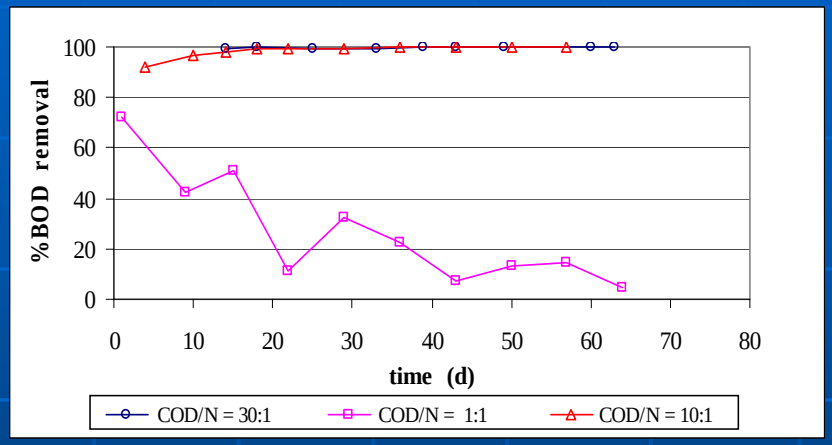
b) Intermittent aeration

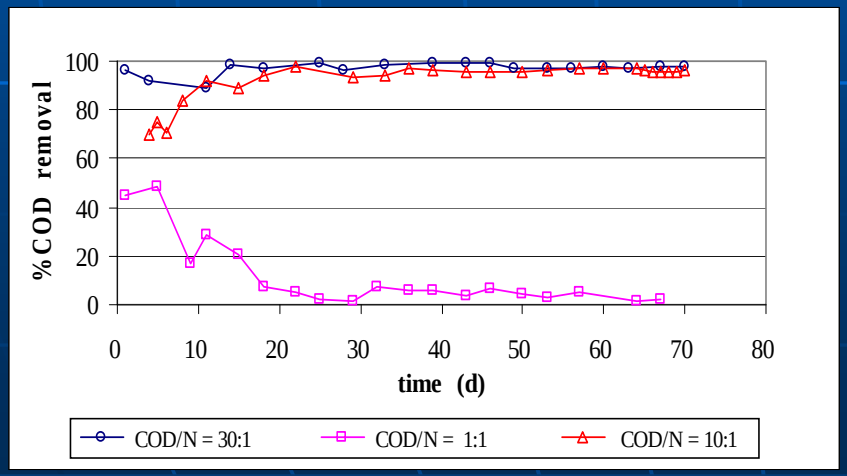
- MLSS in MBR was between 1330-1980 mg/l, higher under continuous aeration mode
- TMP increasing rate was affected by MLSS concentration.
- However, aeration mode had greater effect on TMP development (20-40% higher under intermittent aeration mode)
- The permeate flux could be kept constant at 0.17 m^3/m^2d.

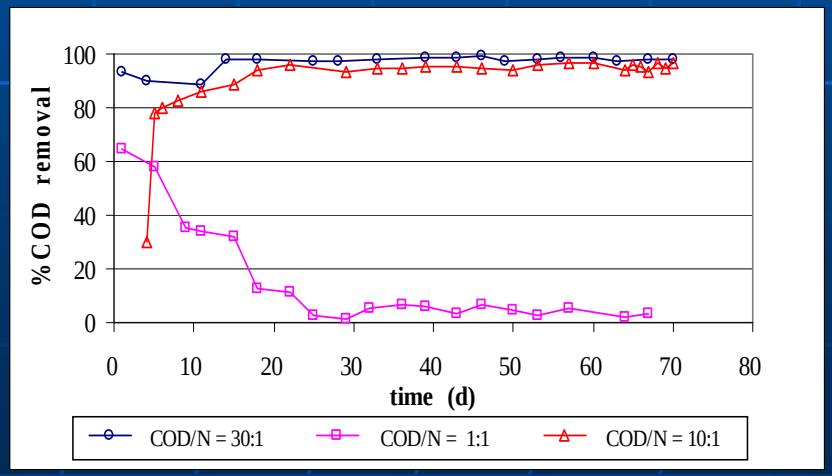
Organic Removal in Biofilm MBR: Effect of COD/N

- BOD/COD removal was high when leachate with COD/N between 10 and 30 was fed.
- Organic removal was severely deteriorated when leachate with COD/N of 1 was applied.







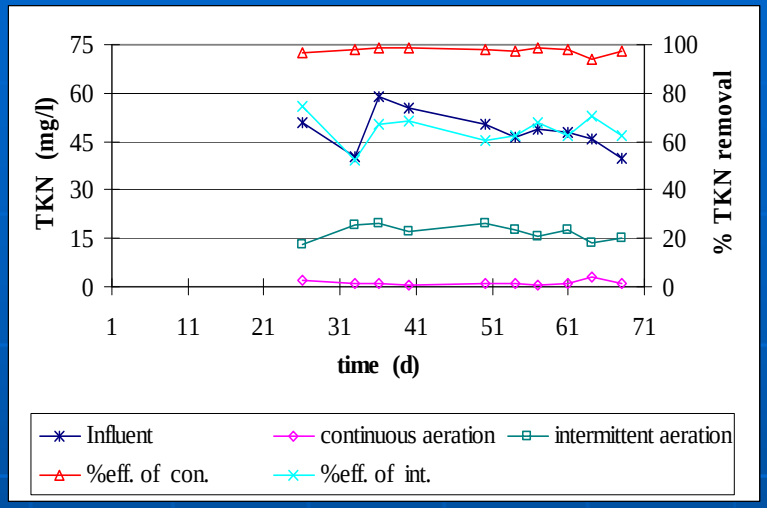


a) Continuous aeration

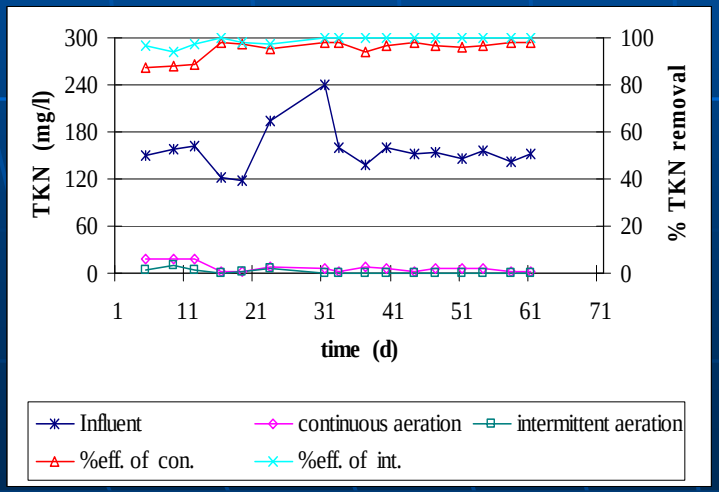
b) Intermittent aeration

Nitrogen Removal in Biofilm MBR: Effect of COD/N and aeration

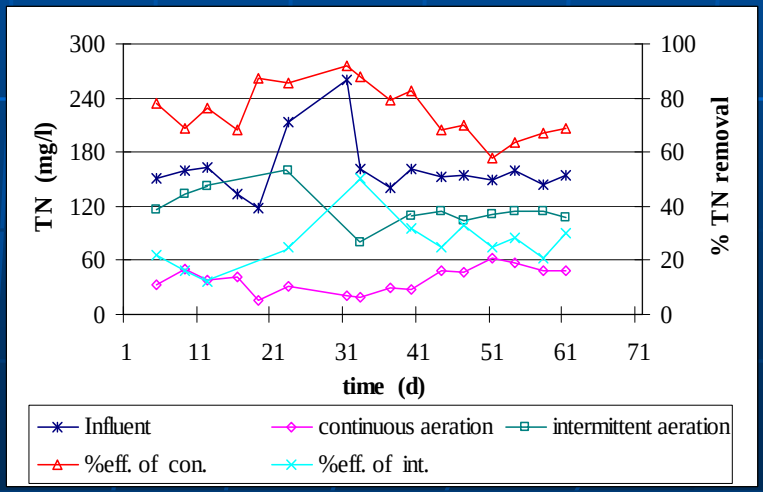
- At COD/N of 30, TKN removal was 93-98% under continuous aeration. Application of intermittent aeration reduced TKN removal to 60-70% (N uptake for cell synthesis)
- At COD/N of 10, high TKN removal of >90% was achieved regardless of aeration mode. (Nitrification-denitrification)
- At COD/N of 1, biological activity diminished. (Ammonia volatilization)



a) COD/N of 30



b) COD/N of 10



c) COD/N of 1

Improvement of Stabilized Leachate Treatment by Chemical Precipitation

- To improve the treatment of leachate from stabilized landfill with low COD/N, chemical precipitation using $MgCl_2$ + Na_2HPO_4 was employed for ammonia removal.

$$MgCl_2.6H_2O + Na_2HPO_4.12H_2O + NH_4^+ \rightarrow MgNH_4PO_4.6H_2O + 2NaCl$$

- From standard jar test, the required dose of $MgCl_2$ and Na_2HPO_4 for adjusting COD/N of stabilized leachate to 10 was 6.5-7.6 g/l and 5.4-6.3 g/l respectively.

- After chemical pre-treatment, the pre-treated leachate can be successfully treated in MBR with COD and NH_3 removal efficiencies of 97% and 98%. The effluent from MBR contains COD and NH_3-N of 40 and 2 mg/l respectively.

Summary of MBR performance

- Integrated membrane system consisting of floating filter media - microfiltration membrane could be successfully applied for the treatment of leachate with different degree of stabilization.
- Hollow fiber microfiltration membrane in Biofilm MBR could be operated at constant permeate flux of 0.17 m/d under intermittent suction of 15 min. on and off. Aeration in MBR helped reducing the accumulation of biomass on the membrane surface and retarding TMP development.
- High degree of organic and nitrogen removal of more than 90% could be achieved in the system when COD/N was between 10-30. However, inhibition of biological activities was observed when stabilized landfill was fed.
- Optimum aeration pattern in MBR was 2 hour of non-aeration period followed by 1 hours of aeration period.

Comparison of natural and advanced treatment system For leachate management in developing countries

- Natural treatment system using constructed wetland are sufficiently effective for the treatment of fresh leachate containing high biodegradable organics provided that the organic loading to the system is properly controlled. Moderate removal of nutrient (N) is also attainable.

- Advanced treatment system using biofilm MBR are very effective for fresh and mixed leachate both in terms of organic and nitrogen. For highly stabilized lechate, its combination with physico-chemical treatment is recommended. Shortened HRT made the system compacted.

- The selection of appropriate treatment will depend on land area available, effluent quality requirement and affordable investment & operation cost

Thank you