TRICKLING- FILTER- BASED SOLUTIONS FOR URBAN WASTEWATER TREATMENT AND REUSE IN INDIA

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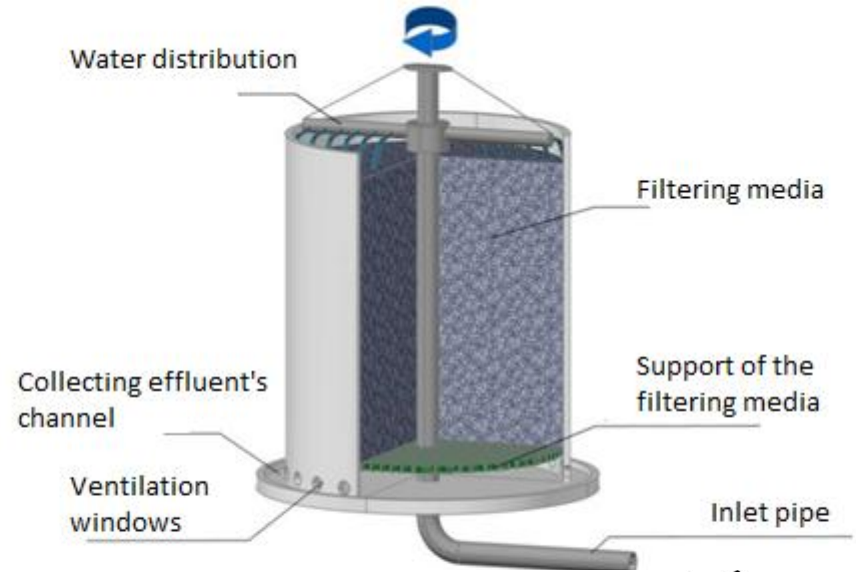
FUNDACIÓN CENTRO DE LAS NUEVAS TECNOLOGÍAS DEL AGUA
Universität für Bodenkultur Wien

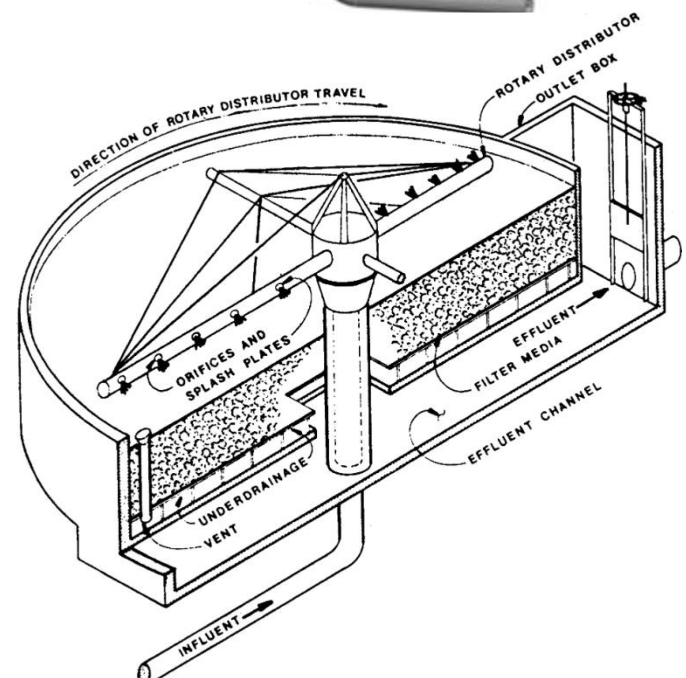
Content

1. Trickling filters (TF): some basic ideas
2. TF *versus* Activated sludge systems
3. Successful TF case studies in Spain
4. Why TF in SARASWATI project?
5. Q&A

1. Trickling filters (TF): some basic ideas

- Trickling filters, also known as percolating filters, are the most traditional method of biofilm process.
- It is an **aerobic process**, where the wastewater, after receiving prior treatment (pre-treatment and primary treatment), percolates by gravity through a filling material, which constitutes the medium on which microorganisms develop and grow, forming a biofilm of variable thickness. The filling material is fixed, inside the reactor, and provides a high specific surface area.
- Global Water Research Coalition [GWRC] (2011) note that biological filters (TFs) are regarded as **the lowest energy usage** of any secondary processes in hierarchy of wastewater treatment processes (potential energy efficiency).





1. Trickling filters (TF): some basic ideas

Source: NILSA (Navarra, Spain)

1. Trickling filters (TF): some basic ideas

- Original TF used rocks as the support media; currently, engineered plastic packing with high surface area/volume ratios with high void volumes, to avoid blockages and to achieve high loading rates.

Media	Nominal size (cm)	Specific surface area (m^2/m^3)	Void space %
Rock (granite)	2.5 - 10	43 - 69	35 - 50
Redwood (slats) stacked	19 x 19 x 0.8	46	76
Random media, polypropylene	20 cm diameter	90 – 280	
(nitrification 130)	90 - 95 %	48 - 95 kg/m3	
Plastic moulded blocks (cross flow) PVC	24 x 24 x 48 to 60 x 60 x 120	75 - 115	94 - 97
Plastic tubular		217	

- Air flows upwards, through the voids in the packing, created by the chimney effect of the filter vessel. Circulation of air can be enhanced by forced ventilation (WEF, 2007).

1. Trickling filters (TF): some basic ideas

Trickling Filter Operating Modes (EPA 2000, Wang et al 2006, WEF 2007)

Filter type	Loading	BOD removal performance (%)	Comments
Low rate	BOD < 0.40 kg / m^3.d Wetting > 0.4 L/m^2.s (plastic), [0.001 – 0.002 m3/m^2.d], down to 0.1 L/m^2.s for rock	80 – 95 Achieves nitrification	Fewer issues with flies, odours, plugging
Intermediate	BOD 0.4 - 0.64 kg / m^3.d	60 – 90	Filter to be recirculated. Solids not as well digested
High rate	BOD 0.64 – 1.6 kg / m^3.d Hydraulic 0.003 – 0.013 m^3/m^2.d	65 - 90	Likely to be for second stage process (combined process more typical)
Roughing	BOD 1.6 – 4.8 kg / m^3.d	50 - 65	Allow significant soluble BOD to bleed through to next stage

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2. TF versus Activated sludge systems

Factor	Activated Sludge	Trickling Filter
Capital Cost	Lower	Higher (10 – 25 %)
Operating Cost (power)	High	Lower (40 – 60 %)
Land Area	Low	Higher (5 – 10 %)
Process Control	Complex	Simple
Climatic Problems	Problems during dry months	Best at high ambient temperatures
Ability to Treat Industrial Wastewater	Prone to failure (largely due to variability)	Good
Operational aspects	Better flexibility	Better reliability
Effluent Quality	Better (5 – 15 %)	Good (prone to high suspended solids)
Fly / Odour Nuisance	Generally little	Can be high
Head Loss	Low (0.3 m)	High (2 – 5 m)
Mechanical Equipment Requirement	High (aeration system, return & waste sludge pumps)	Low (delivery / recirculation pumps, distributor arm)
Sludge Handling Requirement	High	Lower (20 – 40 % less volume)
Ability to nitrify / denitrify	Yes	Generally nitrifies only
Ability to Handle:		
High Hydraulic Loads	Poor	Good
High Organic Loads	Poor	Good

Comparison of activated sludge and trickling filter processes (Bliss 1983, Ch. 4-5; Metcalf & Eddy 1991; Amenu 2014; Moodie 1979; EPA 2008)

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3. Successful case studies in Spain

NILSA

seguimiento trimestral instalaciones

TUDELA

DATOS DE LA EDAR

Trimestre: Cuarto **Año:** 2015

Localidades atendidas (censo): Cascante (3.999), Murchante (3.753), Tudela (35.268)

Censo total atendido: 43.020 habitantes

Fecha de puesta en operación: 31/10/2002

AUTORIZACIÓN DE VERTIDO

Fecha de la última autorización: 26/04/2013 **Referencia en docuware:** 1143/13

Fecha de la próxima autorización: 26/04/2018 **Titular de la autorización:** NILSA

2012S0241

	mg/l	m^3
SS / Sólidos suspendidos	35	
DQO / Demanda Química de Oxigeno	125	
DBO / Demanda Bioquímica de Oxígeno	25	
N-NH3 / Nitrógeno Amoniacal	10	
Volumen anual máximo:		7.560 miles de m^3
Volumen diario:		22150 m^3

RESULTADOS

Volumen de vertido diario: 19610 m^3/dia

Parámetros	Entrada mg/l	Salida mg/l	Rendimiento	Conforme
SS / Sólidos suspendidos	256	19	93	SI
DQO / Demanda Química de Oxigeno	648	67	90	SI
DBO / Demanda Bioquímica de Oxígeno	317	16	95	SI
N-NH3 / Nitrógeno Amoniacal	21,7	3,1	85	SI

LODOS

Nº de Tm. MS: 659,67 **Grado de sequedad:** 29,20 **Destino:** SLIR, S.L.

3. Successful case studies in Spain

NILSA

seguimiento trimestral instalaciones

BAJO EGA

DATOS DE LA EDAR

Trimestre: Cuarto **Año:** 2015

Localidades atendidas (censo): Andosilla (3.039), Cárcar (1.180), San Adrián (6.293)

Censo total atendido: 10.512 habitantes

Fecha de puesta en operación: 16/05/2002

AUTORIZACIÓN DE VERTIDO

Fecha de la última autorización: 15/07/2009 **Referencia en docuware:** 2036/09

Fecha de la próxima autorización: 15/07/2014 **Titular de la autorización:** MANCOMUNIDAD DE MONTEJURRA

2014S0687

	mg/l	m^3
SS / Sólidos suspendidos	35	
DQO / Demanda Química de Oxigeno	125	
DBO / Demanda Bioquímica de Oxigeno	25	
N-NH3 / Nitrógeno Amoniacal	9	
Volumen anual máximo:		2.300 miles de m^3
Volumen diario:		6300 m^3

RESULTADOS

Volumen de vertido diario: 1704533

Parámetros	Entrada mg/l	Salida mg/l	Rendimiento	Conforme
SS / Sólidos suspendidos	342	15	96	SI
DQO / Demanda Química de Oxigeno	1052	76	93	SI
DBO / Demanda Bioquímica de Oxigeno	653	24	96	SI
N-NH3 / Nitrógeno Amoniacal	21,1	5,9	72	SI

LODOS

Nº de Tm. MS: 30,04 **Grado de sequedad:** 5,38 **Destino:** CABANILLAS

Nº de Tm. MS: 126,93 **Grado de sequedad:** 4,32 **Destino:** TUDELA

3. Successful case studies in Spain

NILSA

seguimiento trimestral instalaciones

ARBIZU-LAKUNTZA

DATOS DE LA EDAR

Trimestre: Cuarto **Año:** 2015

Localidades atendidas (censo): Arbizu (1.082), Lakuntza (1.219)

Censo total atendido: 2.301 habitantes

Fecha de puesta en operación: 20/11/2007

AUTORIZACIÓN DE VERTIDO

Fecha de la última autorización: 04/02/2014 **Referencia en docuware:** 1165/14

Fecha de la próxima autorización: 04/02/2019 **Titular de la autorización:** NILSA

2012S0831

	mg/l	m^3
SS / Sólidos suspendidos	35	
DQO / Demanda Química de Oxigeno	125	
DBO / Demanda Bioquímica de Oxigeno	25	
N-NH3 / Nitrógeno Amoniacal	15	
Volumen anual máximo:		500 miles de m^3
Volumen diario:		1350 m^3

RESULTADOS

Volumen de vertido diario: 864

Parámetros	Entrada mg/l	Salida mg/l	Rendimiento	Conforme
SS / Sólidos suspendidos	125	4	96	SI
DQO / Demanda Química de Oxigeno	234	21	91	SI
DBO / Demanda Bioquímica de Oxigeno	110	6	95	SI
N-NH3 / Nitrógeno Amoniacal	12,1	0,4	97	SI

LODOS

Nº de Tm. MS: 4,60 **Grado de sequedad:** 2,92 **Destino:** ARAZURI

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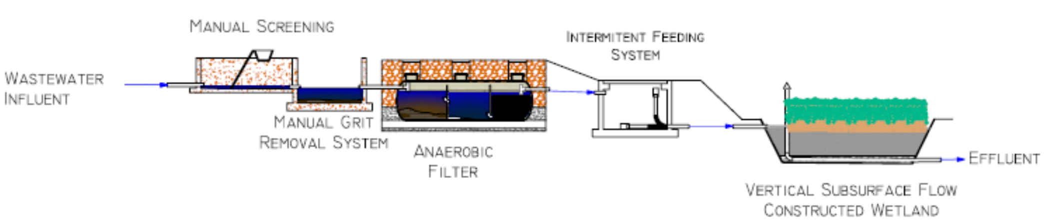
1. Initial data

Pilot 1: Raisen

- Lead implementer: CENTA (EU) CEMDS (India). OP: BOKU, IIT-Roorke
- Lead supporting stakeholder: Wateraid / UN Habit

Initially foreseen

- Natural treatments (green technologies)
- Target population: 6000 inhab (2700 pe)



The estimated surface required for the implementation of this option reached 2,800 m^2 of planted surface which implies the construction of 5 units of VFCW of 567 m^2 each one.

1. Initial data

Pilot 1: Raisen (new situation-end 2014)

- **Population growth (sewerage plan)**:

Area	No of Houses in 2014	No of Houses in 2044	No of person in House based on Survey	Total No of person in Year 2014	Total No of person in Year 2044
Zone 1	842	1694	7	5894	11858
Zone 2	323	645	7	2261	4515
Total	**1165**	**2339**	**7**	**8155**	**16373**

Wastewater generation

- Water supply rate= 135 LPCD
- Infiltration flow = 2000 lit/km/day
- Wastewater generation % of Water supply restricted 111 LPCD including filtration flow.

1. Initial data

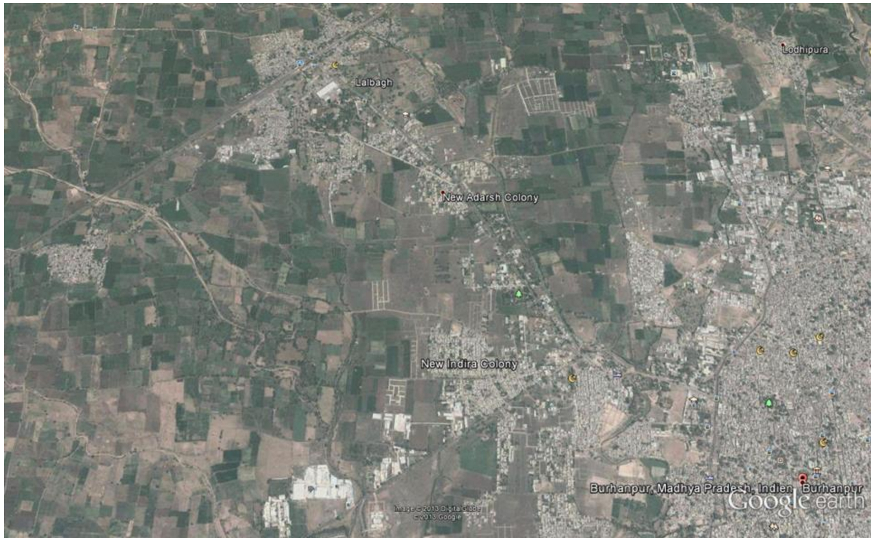
Pilot 1A: Burhanpur

- **Population growth (new data on January 2015)**:

	2015	2025	2035	2045
INDRA COLONY	8264	11212	12346	14160
LALBAGH	29923	40596	44700	51268
SINDI BASTHI	10632	14430	-	18227
Total	**48819**	**66238**	**-**	**83655**

Wastewater generation

- Water supply rate= 135 LPCD
- Wastewater generation 80 % of Water supply.

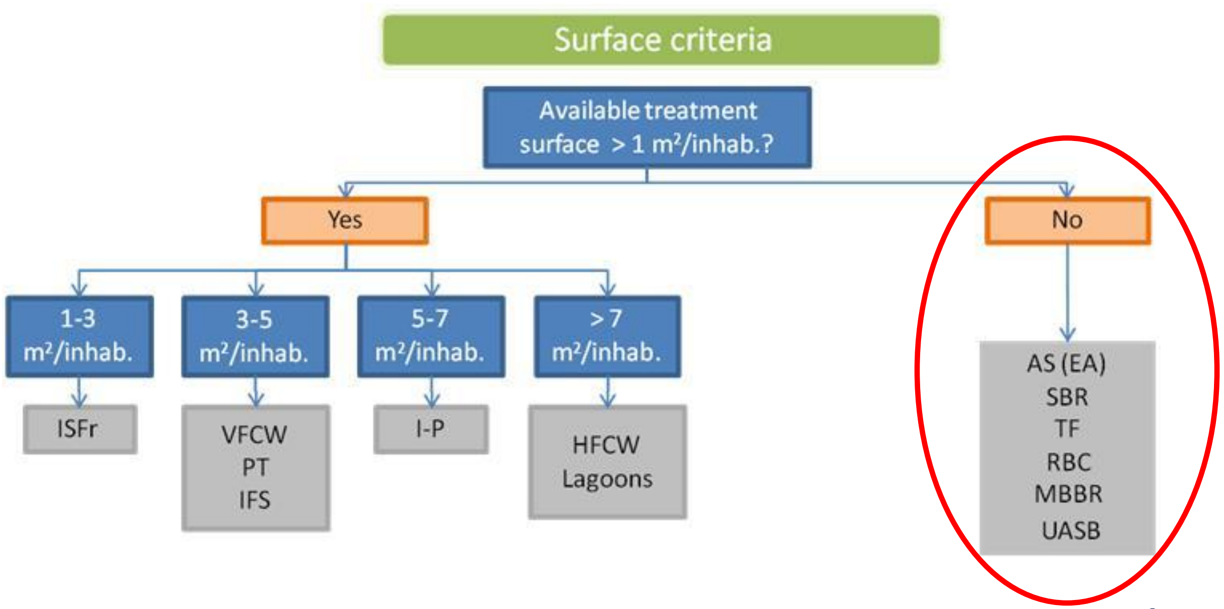


2. Selection of the most appropiate WWT system

- **Three key factors**:
  1. Size of the population to be served: horizon population in 2045
     - **Raisen:** 16373 inhab
     - **Burhanpur:** 83655 inhab

According to EU experiences, conventional technologies are recommended

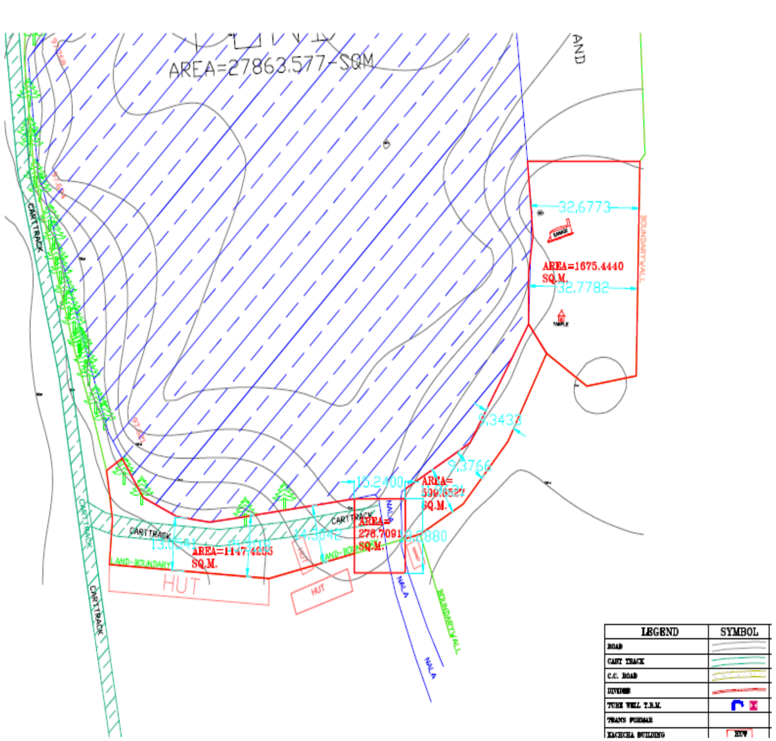
  2. Available Surface for the implementation of the WWTP



- **Raisen:** 2026 m^2 (+ 1675 m^2 Temple enclosure)
- **Burhanpur:** 11000 m^2

conventional technologies are recommended

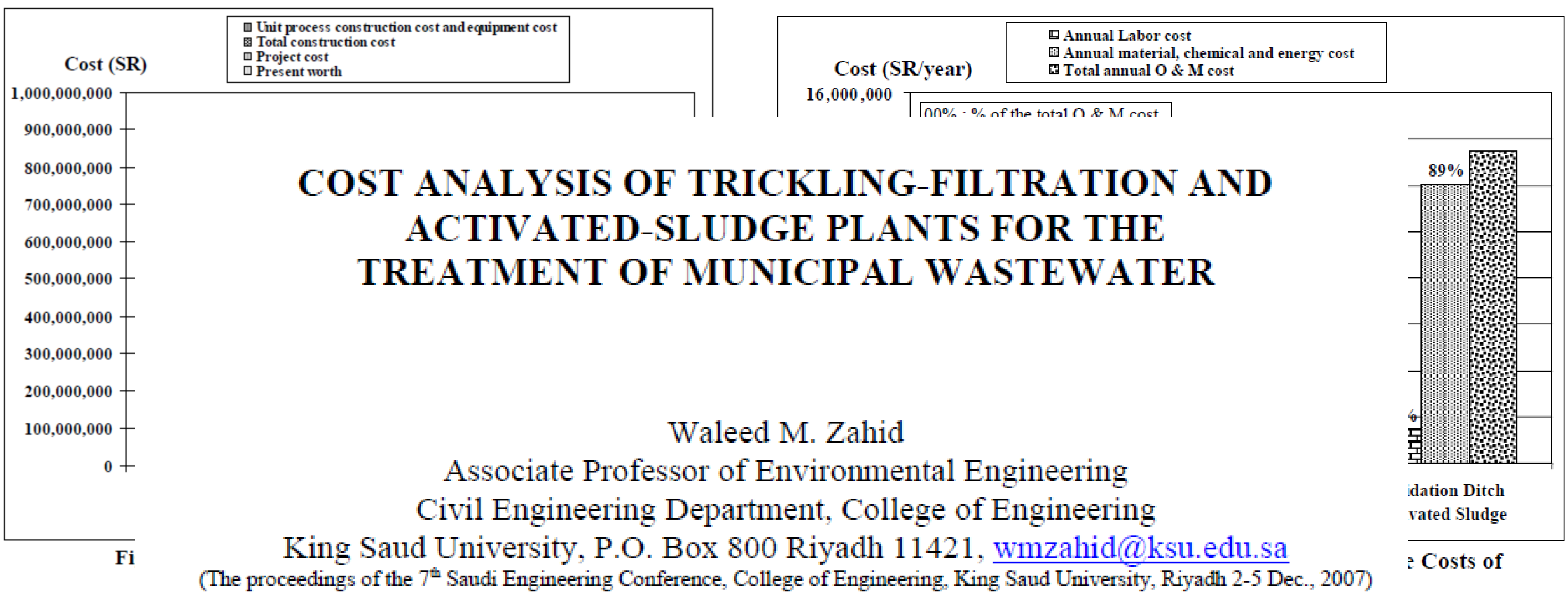
2. Selection of the most appropiate WWT system



- **Raisen:** 2026 m^2 (+ 1675 m^2 Temple enclosure)
- **Burhanpur:** 11000 m^2

2. Selection of the most appropiate WWT system

- **Three key factors**:
  3. O&M complexity and costs: low O&M cost technologies are endorsed.
     - Extensive technologies (such as wetlands, ponds, filtering systems) present lower running costs than conventional ones.
     - Focusing on conventional technologies, trickling filters are considered cheaper options in terms of O&M than the aerated activated sludge.



COST ANALYSIS OF TRICKLING-FILTRATION AND ACTIVATED-SLUDGE PLANTS FOR THE TREATMENT OF MUNICIPAL WASTEWATER

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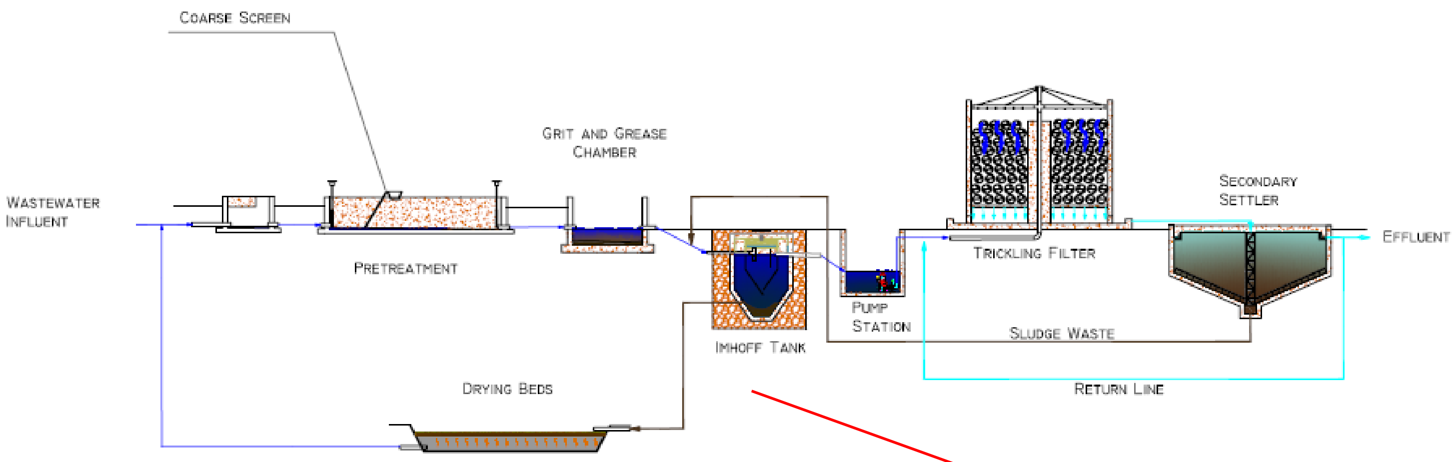
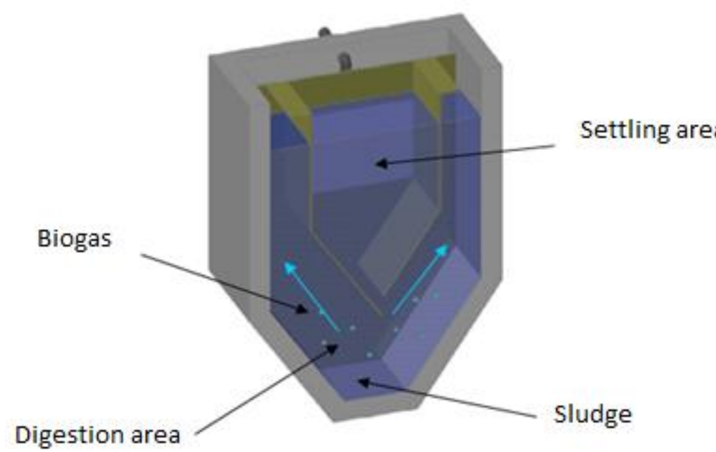
(The proceedings of the 7th Saudi Engineering Conference, College of Engineering, King Saud University, Riyadh 2-5 Dec., 2007)

2. Selection of the most appropiate WWT system

All in all, it is concluded that a **conventional technology** should be implemented according to the size population and surface availability and, among the different existing technologies, the **Trickling Filter** seems the best option due to its **lower O&M costs**. However, in the selection of complementary units such as the primary treatment or the sludge dewatering unit, low cost and easy- operational processes have been considered.

3. Proposed flow-sheet: seeking simplicity





4. Design and dimensions: Raisen

- **Designing data**

Date (Year)	2044
Population (inhab)	17353
Hydraulic load (l/inhab·d)	111
Organic load (gBOD/inhab·d)	27
Population equivalent(p.e.)	7809
Wastewater flow (m^3/d)	1926.2
Average flow (m^3/h)	80.3
Peak flow (m^3/h)	120.4
BOD inlet (mg/l)	243

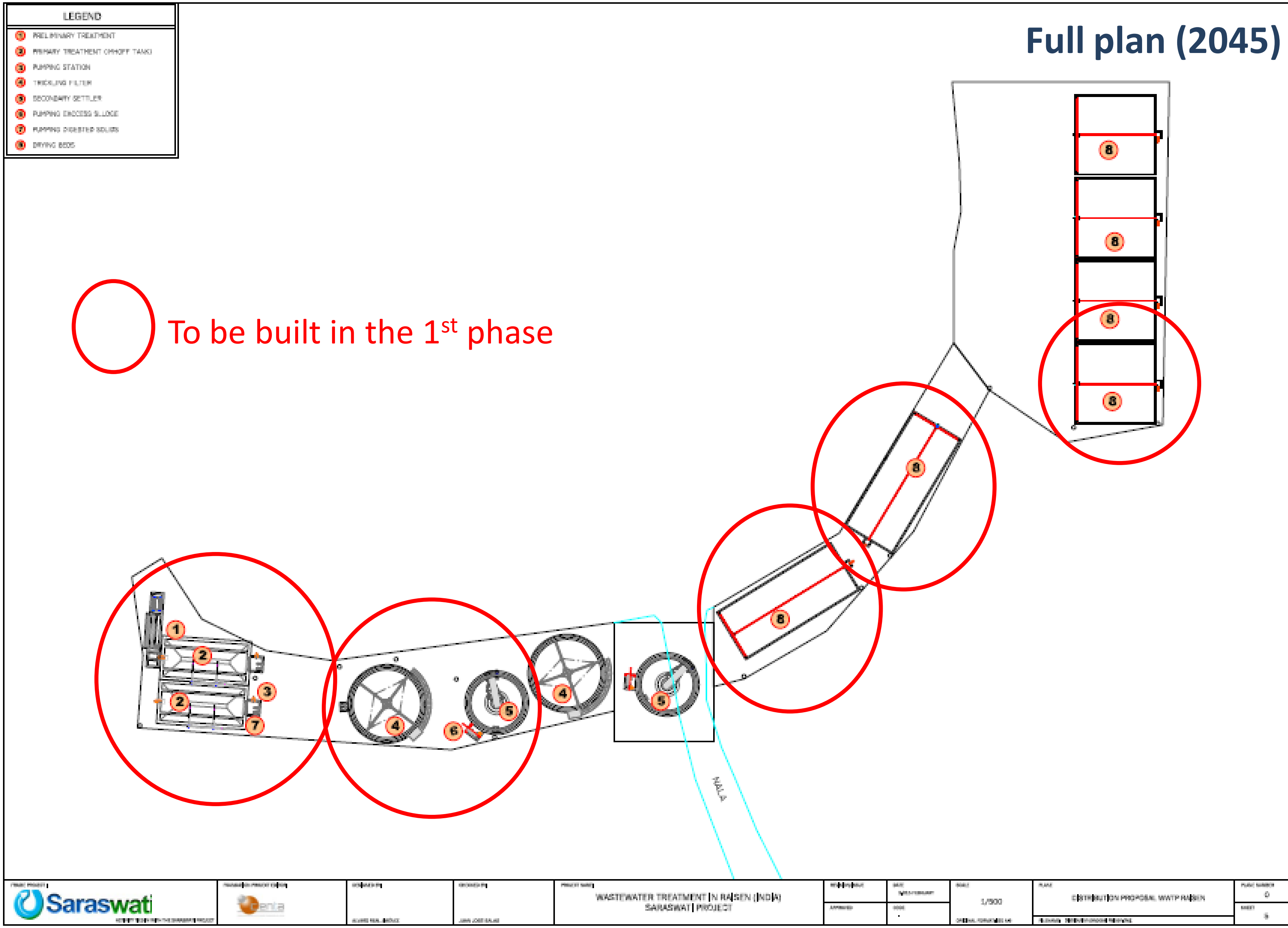
Construction in **two phases**: 1st phase will cover a population equivalent up to 4000 p.e. (around 9000 inhab.)- 1 MLD, meanwhile the 2nd phase will double the capacity up to 8000 p.e (around 18000 inhab.)-2MLD.

1st phase will consist in the construction of the following units:

- Pretreatment (half capacity, 4000 p.e.)
- 1 Imhoff tank (half capacity, 4000 p.e.)
- 1 Trickling filter (half capacity, 4000 p.e.)
- 3 drying beds

- DPR sanctioned by the authority in August 2015. Tendering in process

4. Design and dimensions: Raisen



4. Design and dimensions: Burhanpur

- **Designing data**

Construction in **two phases**: phase one will cover a population equivalent up to 19000 p.e. (around 42000 inhab.), meanwhile the second phase will double the capacity up to 38000 p.e (around 84000 inhab.)- 9 MLD. First phase will consist in the construction of the following units:

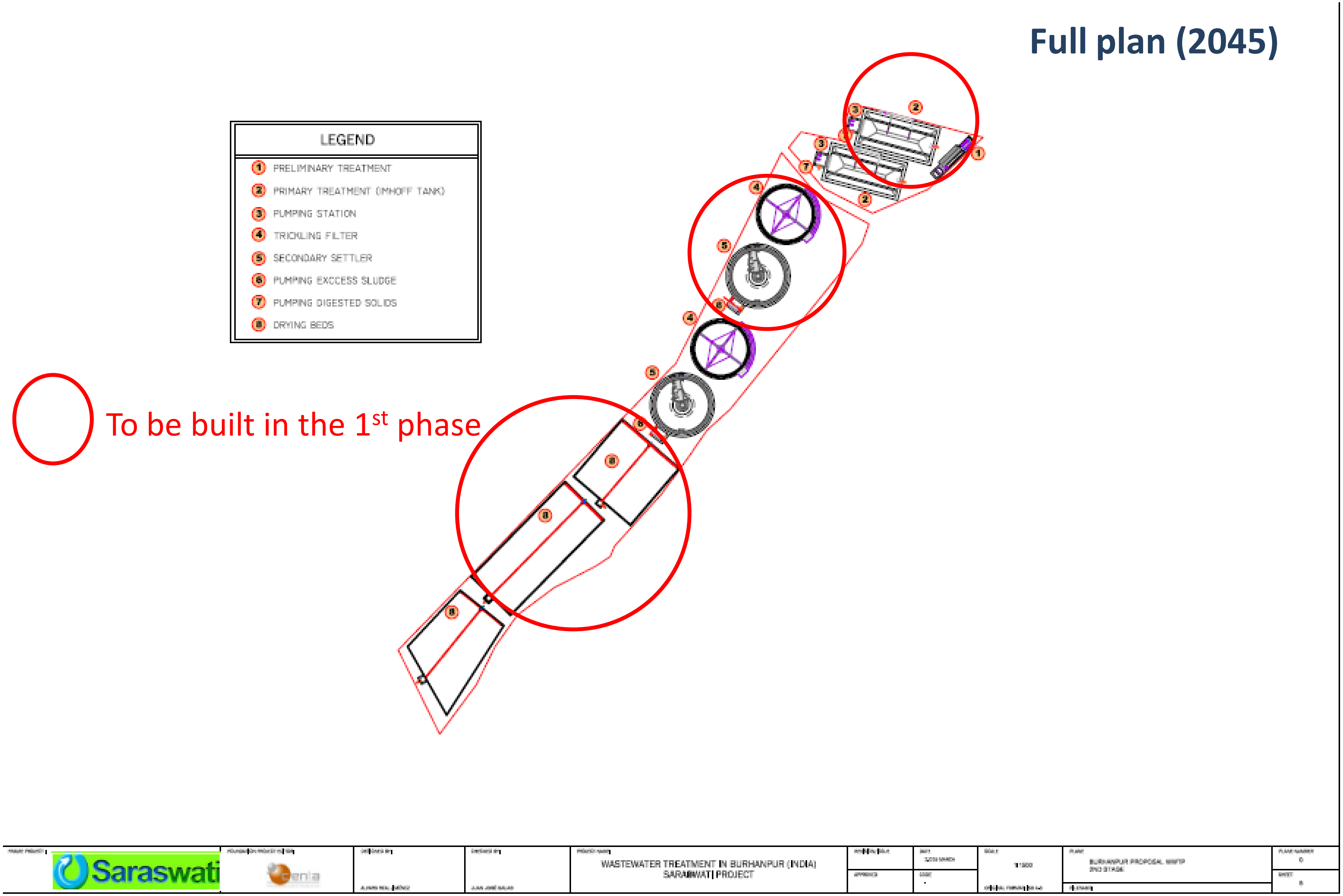
- Pretreatment (half capacity, 19000 p.e.)
- 1 Imhoff tank (half capacity, 19000 p.e.)
- 1 Trickling filter (half capacity, 19000 p.e.)
- 2 drying beds

In the second phase, the remaining units will be constructed reaching full capacity.

- DPR submitted on March 2015 to the State Government and sanctioned by the authority in August 2015. Tendering in process.

4. Design and dimensions: Burhanpur

Full plan (2045)



5. New challenges

- Both Raisen &Burhanpur STP were designed according to The **Environmental Protection Rules**, launched in 1986 and still in force (at least when DPRs were sanctioned).

Parameters	Unit	Inland surface water
pH		5.5-9.0
Total suspended solids, max	mg/l	100
BOD,max	mg/l	30
COD,max	mg/l	250
Ammonical nitrogen (as N), max	mg/l	50

- Current designs aims at COD removal and partial nitrification.

5. New challenges

Sl. No.	Parameters	Standards for New STPs (Design after notification date)*
1.	pH	6.5-9.0
2.	BOD	10
3.	COD	50
4.	TSS	20
5.	NH4-N	5
6.	N-total	10
7.	Fecal Coliform (MPN/100ml)	<100
Note: (i) All values in mg/l except for pH and Coliform. (ii)These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Fecal Coliform may not be applied for use of treated sewage in industrial purposes. *Achievements of Standards for existing STPs within 05 years from date of notification.		

- **Current status:** looking improvements in flow-sheet to meet the new requirements in 5 years time but trying not to extremely increase CAPEX and OPEX.

5. New challenges

Sample details									
Parameters	Pandol nala Buranpur	Sindhi Basti upstream	Sindhi Basti outlet sewer	Indira Colony Outlet	Raisen main drain (1)	Raisen lake Inlet	Raisen main drain (2)	Average composition _Burhanpur	Average composition _Raisen
pH	8,72	8,52	8,57	8,56	8,2	7,98	7,88	8,6	8,0
Turbidity (NTU)	35,8	98,4	49	55	25,7	5,46	8,31	52,0	17,0
BOD (Total) (mg/L)	100	158	96	112	70	27	41	104,0	55,5
COD (Total)(mg/L)	190	324	173	169	125	50	73	171,0	99,0
TSS (mg/L)	182	378	224	140	156	28	38	182,0	97,0
VSS (mg/L)	130	268	161	104	107	20	30	132,5	68,5
TDS (mg/L)	1183	1692	1440	1156	938	838	758	1298,0	848,0
Sulphate (mg/L)	60	182	177	84	72	64	57	130,5	64,5
Sulphide (mg/L)	0,8	2	0	2	0	0	0	1,0	0,0
TKN(mg/L)	36,9	26,5	45,5	42,6	54,8	26,06	11,07	44,1	32,9
NH_4-N(mg/L)	33,3	20,4	42,2	39,4	52,4	23,7	9,7	40,8	31,1
NO_3-N(mg/L)	3,4	6,9	5,3	3	4,4	6,2	8,1	4,2	6,3
NT*	40,3	33,4	50,8	45,6	59,2	32,26	19,17	48,2	39,2
Ortho PO_4-P (mg/L)	4	1,1	2,4	3,2	2,2	1,8	1,2	2,8	1,7
Total, PO_4-P (mg/L)	6	1,8	3,6	4,8	3,2	2,7	1,9	4,2	2,6

* TN has been estimated from the TKN and NO_3

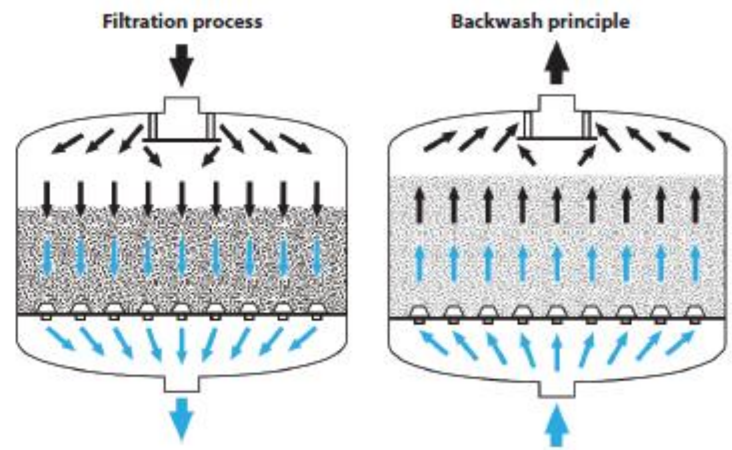
5. New challenges

	Removal efficiency (%)		Expected effluent's quality	
Parameter	Imhoff tank	Trickling filter	WWTP Burhanpur	WWTP Raisen
TSS (mg/l)	50 – 60	85 – 95	9	5
BOD_5 (mg/l)	20 – 30	85 – 95	5	3
COD (mg/l)	20 – 30	80 – 90	17	10
$N\text{-}NH_4^+$ (mg/l)	-	60 – 80	8	6.2
TN (mg/l)	-	20 – 35	30	25.5
TP (mg/l)	-	10 – 35	2.5	1.7

- Sulphates and sulphides concentration in the raw wastewater and final effluent, respectively, would not represent any problem for the proper operation of the WWTP or the latter discharge/reuse of the treated water.
- Removal of *E. coli* (*faecal coliforms)* would reach 1-2 u Log.

5. New challenges

- Depending on the final fate of the treated water (discharge or reuse) further treatment would be required.
- Proposed complementary treatment: *Sand filtration and chlorination (NaOCl).*



- Increase of both capital (around 10%) and running costs → to be assessed.

5. New challenges

- Trickling filters are an **aerobic process**, and are **highly effective at organic removal and ammonia nitrification**, but by themselves they are **unable to deliver low Total Nitrogen or Phosphorous outcomes** (influent TN loads by 10–30 percent and TP loads by 8–12 percent, Metcalf and Eddy 1991).
- However, when trickling filters are complemented by separate anoxic processes, such as anoxic bioreactors or surface flow wetlands, they are able to achieve very low nitrogen results. In many smaller (decentralized) attached growth systems, relatively high levels of nitrogen removal can be typically achieved by recirculating nitrified effluent back to an anoxic reactor (e.g., septic tank).
- P removal through chemical precipitation.

Author	Year	Location	TN	TP	Improvements
Dai et al.	2013	Australia	60%		Return nitrate-rich stream from secondary clarifiers back to primaries
Dorias and Baumann	1994	Germany	15 mg/l		Denitrification in trickling filter plants by covering filters for anoxic operation
Kardohely and McClintock	2001	Penn State			Added BNR plant to blend effluent prior to disposal or land application
Morgan et al.	1999	Australia			Conversion to MLE-type BNR by adding secondary reactors

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