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Cost-effective Treatment of Wastewater in Remote Areas for Potential Reuse to Cope with Climate Change Impacts and Water Scarcity

Climate Change Adaptation in Human Settlements
Using Integrated Water Resources Management (IWRM) Tools

Hussam Hawwa

Agriculture Engineer
IWRM Specialist
Difaf Director

UNITED NATIONS
الاسكوا
ESCWA

Cost-effective DWWT & SDG’s

* SDG 11 and others
* SDG 6

→ that sets out to “ensure availability and sustainable management of water and sanitation for all”. SDG 6 expands the MDG focus on drinking water and basic sanitation to now cover the entire water cycle, including the management of water, wastewater and ecosystem resources.

→ With water at the very core of sustainable development, SDG 6 does not only have strong linkages to all of the other SDGs, but also the ability to underpin them: realising SDG 6 would in fact go a long way towards achieving much of the 2030 Agenda. (UN-WATER)

Cost-effective DWWT & SDG's

Measurable Indicators!

* Percentage of population using safely managed drinking water services
* Percentage of population using safely managed sanitation services including a hand washing facility with soap and water
* Percentage of wastewater safely treated
* Percentage of water bodies with good water quality
* Percentage change in water use efficiency over time
* Level of water stress: freshwater withdrawal in percentage of available freshwater resources
* Degree of integrated water resources management (IWRM) implementation
* Percentage of change in water-related ecosystems extent over time
* Percentage of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management

Introduction to Decentralized WWT Technology

Definition

Basic Characteristics

- are applied successfully for domestic wastewater treatment particularly where connection to main system is lacking
- in small communities, human settlements, and peri-urban villages in remote rural areas
- Answers to the “adaptive” in IWRM: modular, hybrid, temporary (or permanent), upscalable, transferable, Local Material and Knowledge
- Relatively low investment and operational costs
- Can be instrumental in protecting the environment and public health and improving livelihoods of communities in line with IWRM tools and principles

Definition

Application

Domestic wastewater
Grey water washing, bathing, cooking and cleaning. Unlike white water, gray water may contain soap particles, fat and oil from cooking, hair, and even flakes of human skin. The exact contents of gray water depend heavily on the household

Black water has come into contact with fecal matter. Fecal matter is a haven for harmful bacteria and disease-causing **pathogens.** Additionally, this waste doesn't break down and decompose in water fast or effectively enough for use in domestic irrigation without the risk of contamination.

Application

Commercial wastewater (Some suitable)

- Landfill leachate
- Sludge
- Agricultural wastewaters (livestock and cropland runoff, milk parlor and wash water)
- Storm water runoff including roofs, driveways, streets and highways

Industrial Wastewater

- Mostly not suitable, except in some cases

Application

Treatment Level	Contaminants Removed / Treated	Processes
Preliminary	Bulk solids Oil & Grease	Screening
Primary	Organic Matter Suspended Solids	Flow Equalization Flotation/Sedimentation
Secondary	Nutrients Biodegradables Suspended Solids Micro-organisms	Denitrification Aeration Biological Treatment Filtration
Tertiary	Pathogens Odor Dissolved Oxygen	Disinfection Odor Abatement Precipitation

Illustrations of Main Decentralized WWT Technology

Overview

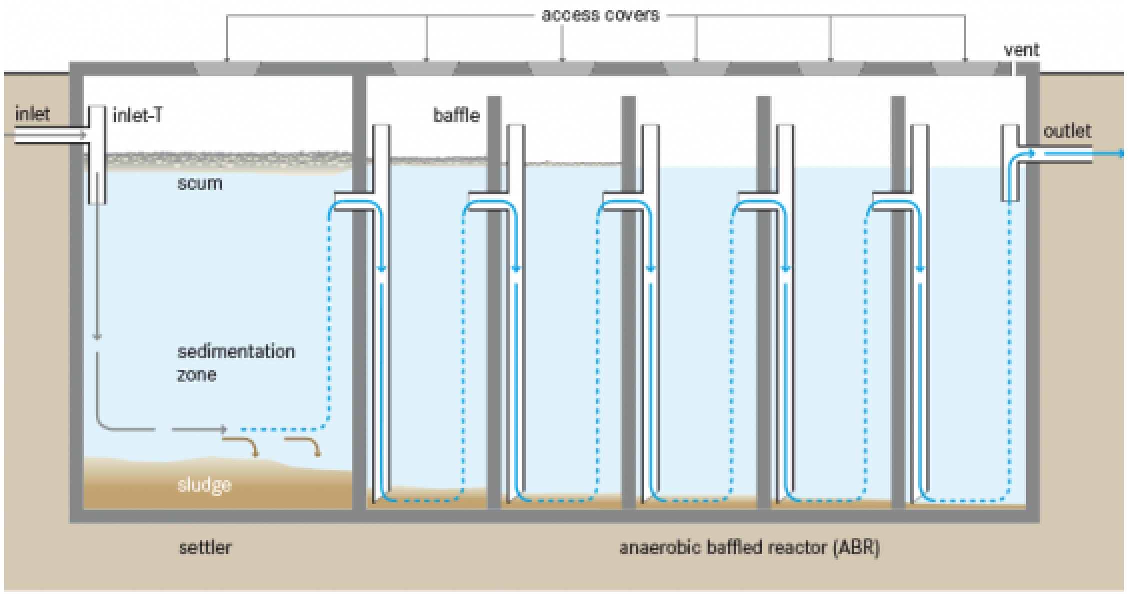
DEWATS (ABR)

Anaerobic baffled reactors (ABR) are septic tanks that have been upgraded with a series of baffles along the treatment chamber. The upflow chambers provide enhanced removal and digestion of organic matter. As septic tanks, ABRs are based on a physical treatment (settling) and a biological treatment (anaerobic digestion).

Main Principles

DEWATS (ABR)

- ABRs are a combination of the principles of septic tanks, moving bed reactors and up-flow anaerobic sludge blanket reactors.
- The difference to MBRs and UASBs lies in the fact that it is not necessary for the *sludge* blanket to float; and that *effluent* retention is not necessary since a part of the active *sludge* that is washed out from one chamber is trapped in the next (SASSE 1998). The majority of settleable solids are removed in a *sedimentation* chamber in front of the actual *ABR*.
- Typical inflows range from 2 to 200 m^3 per day. Critical design parameters include a *hydraulic retention time* (*HRT*) between 48 to 72 hours,
- Accessibility to all chambers (through access ports) is necessary for maintenance. Usually, the *biogas* produced in an *ABR* through *anaerobic digestion* is not collected because of its insufficient amount. The tank should be vented to allow for controlled release of odorous and potentially harmful gases



Advantages

DEWATS (ABR)

- Resistant to organic and hydraulic shock loads
- No electrical energy is required
- Low construction operating costs
(! construction costs for an ABR were 20% less than those for UASB reactors, and five times less than a conventional activated sludge plant for a small town)
- Long service life
- High reduction of BOD
- Low sludge production; the sludge is stabilized
- Moderate area requirement (can be built underground)
- Simple to operate

Disadvantages

DEWATS (ABR)

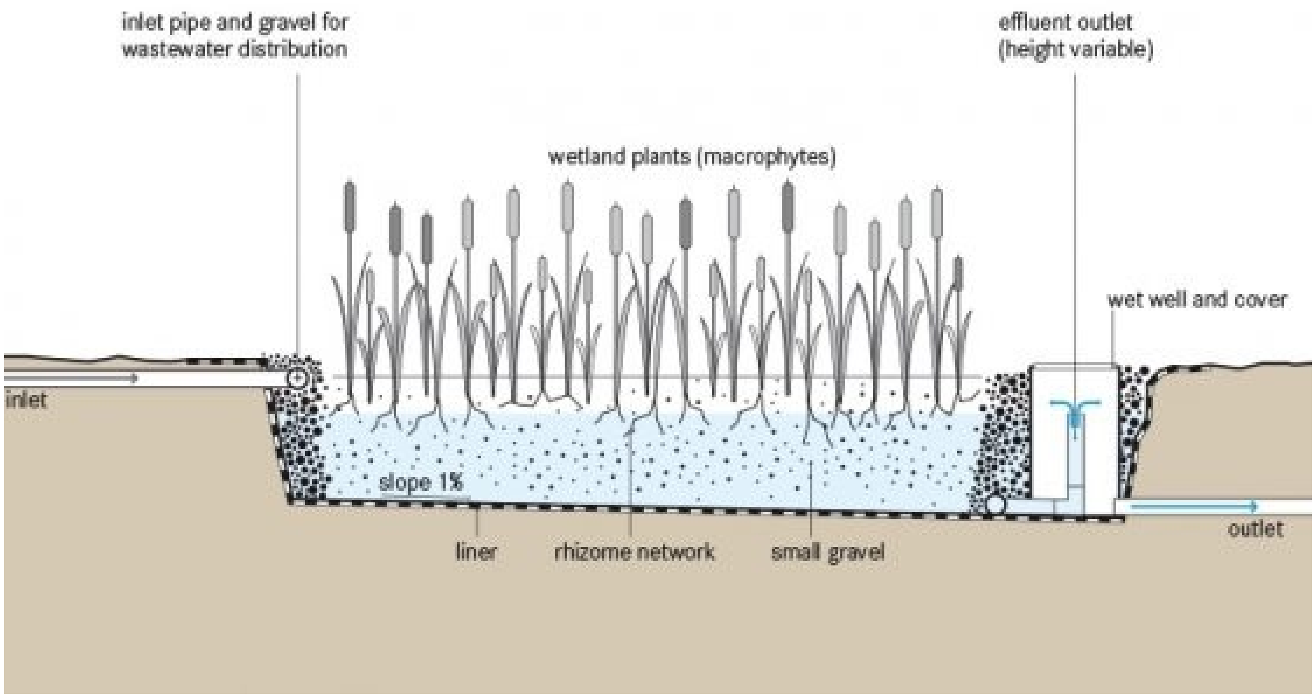
- Long start-up phase
- Requires expert design and construction
- Low reduction of pathogens and nutrients, further treatment and/or appropriate discharge
- Needs strategy for faecal sludge management (effluent quality rapidly deteriorates if sludge is not removed regularly)
- Needs water to flush

Overview

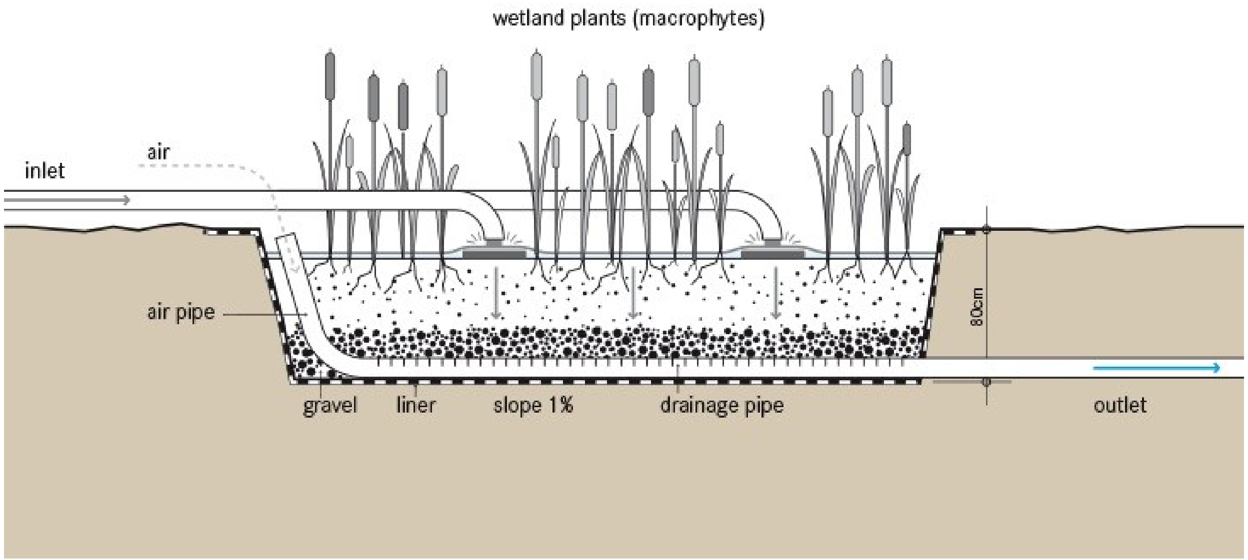
Constructed Wetlands

- *Constructed wetlands* are *secondary treatment* facilities for household (*blackwater* or *greywater*) and/or *biodegradable* municipal or *industrial wastewater*.
- *Constructed wetlands* can even be used as a *tertiary treatment* system for polishing after activated sludge or trickling filter plants (HOFFMANN et al. 2010). The plants grown in the wetland may be used for *composting* or *biogas* production
- *Effluents*, if they correspond to the *WHO* guidelines may be used for fertigation.

2- Horizontal flow constructed wetlands (HF)



3- Vertical flow constructed wetlands (VF)



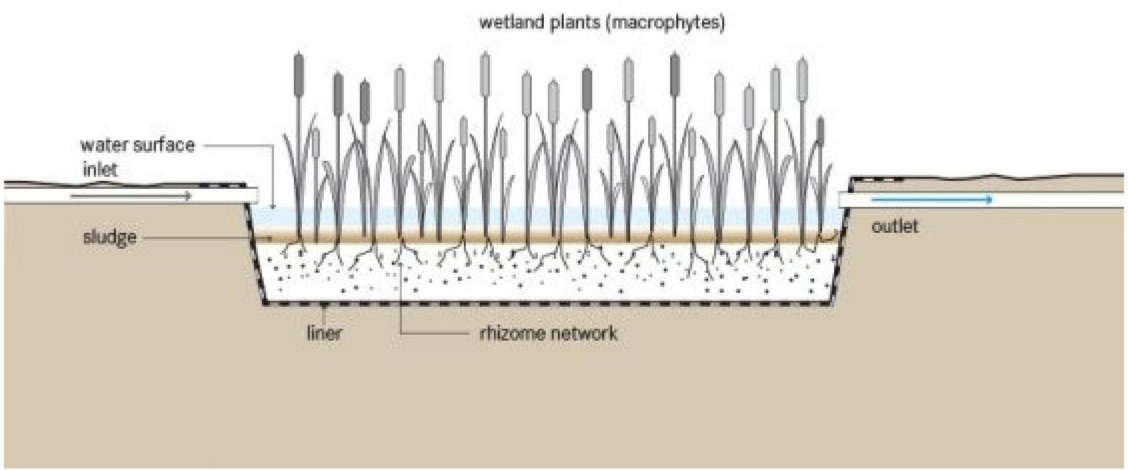
These three types of CWs may be combined with each other in hybrid constructed wetlands in order to exploit the specific advantages of the different systems.

Main Principles

Constructed Wetlands

- Pre-treated *wastewater* enters the basin via a weir or a distribution pipe. Once in the pond, the heavier sediment particles settle out, also removing *nutrients* that are attached to particles.

- Plants, and the communities of *microorganisms* that they support (on the stems and roots), take up *nutrients* like *nitrogen* and *phosphorus* (TILLEY et al. 2008).



Advantages

Constructed Wetlands

- Aesthetically pleasing and provides animal habitat
- High reduction of BOD and solids; moderate pathogen removal
- Can be built and repaired with locally available materials
- No electrical energy is required
- No real problems with odours if designed and maintained correctly
- No chemical required, process stability
- Low operating costs
- Can be combined with aquaculture and agriculture

Disadvantages

Constructed Wetlands

- May facilitate mosquito breeding
- Requires a large land area
- Long start-up time to work at full capacity
- Requires expert design and construction
- Requires supervision
- Not very tolerant to cold climates

Main Principles

AD Biogas Systems

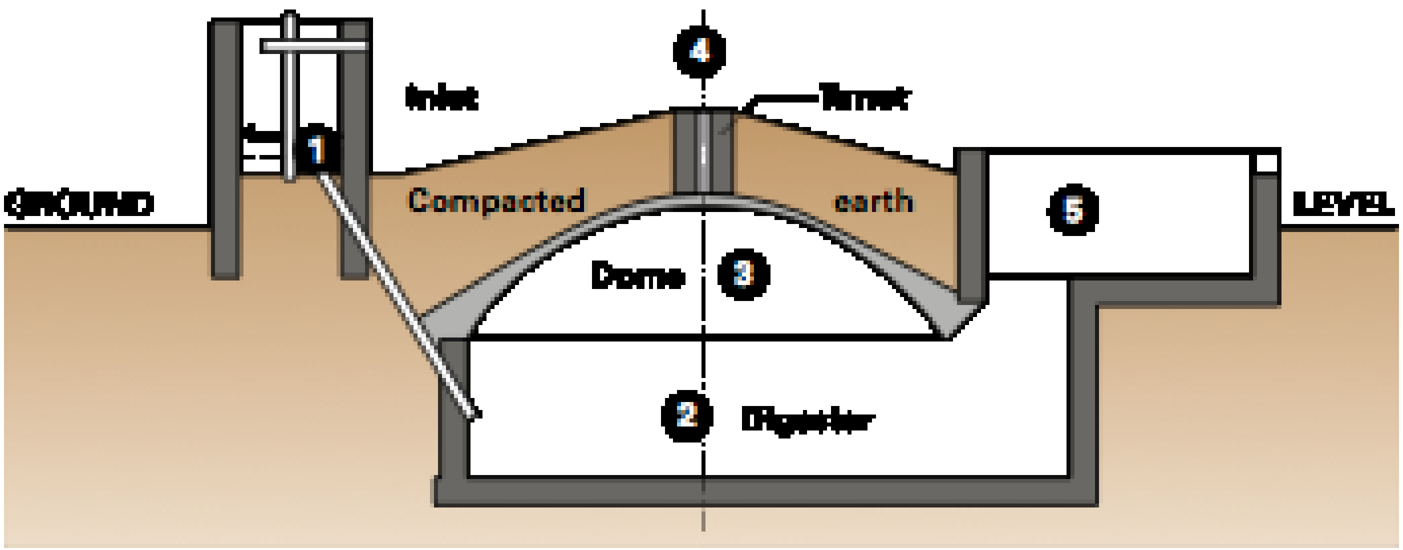
- A small-scale biogas reactor or anaerobic digester is an anaerobic treatment technology that produces (a) a digested slurry (digestate) that can be used as a fertilizer and (b) biogas that can be used for energy.

- Biogas is a mix of methane, carbon dioxide and other trace gases which can be converted to heat, electricity or light. Small-scale biogas reactors are typically designed to produce biogas at the household or community level in rural areas.

- The airtight reactors are filled with animal manure from the farm. Kitchen and garden wastes can also be added and toilets can directly be linked to the reactor for co-treatment of excreta.

Decentralized WWT Technology

AD Biogas Systems

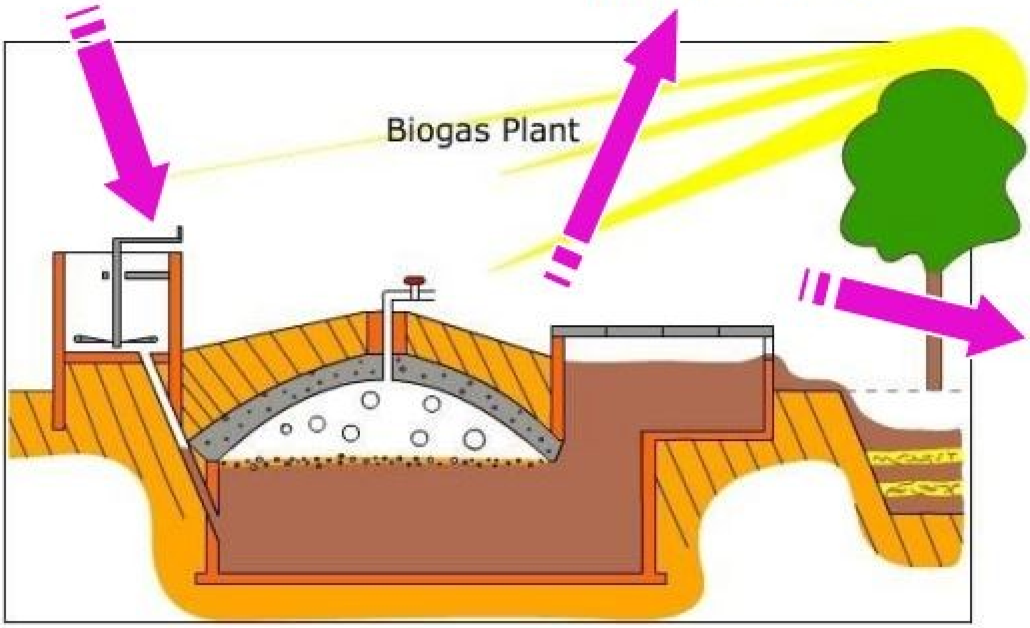


Advantages and Disadvantages

AD Biogas Systems

Biogas plants transform traditional manure management; reducing CH_4 emissions

Biogas substitutes conventional domestic energy sources, reducing reliance on fossil fuel and firewood (CO_2)



Bio-slurry can substitute chemical fertilizer, reducing N_2O emissions

Major Design Consideration

AD Biogas Systems

- They can be built as fixed dome or floating dome digesters. In the fixed dome, the volume of the *reactor* is constant.
- As gas is generated it exerts a pressure and displaces the slurry upward into an expansion chamber. When the gas is removed, the slurry flows back into the *reactor*.
- The pressure can be used to transport the *biogas* through pipes. In a floating dome *reactor*, the dome rises and falls with the production and withdrawal of gas. Alternatively, it can expand (like a balloon).
- Rubber-balloon *biogas* plants, are the most simple and cheapest ones to construct. To minimize distribution losses, the *reactors* should be installed close to where the gas can be used. For more information on the different types of biogas *reactors* read the section "Types of Biogas *Reactors*".

Major Design Consideration

AD Biogas Systems

- The *hydraulic retention time* (*HRT*) in the *reactor* should be at least 15 days in hot climates and 25 days in temperate climates. For highly pathogenic inputs, a *HRT* of 60 days should be considered.

- Normally, biogas *reactors* are operated in the *mesophilic temperature* range of 30 to 38°C. A *thermophilic temperature* of 50 to 57°C would ensure the *pathogens* destruction, but can only be achieved by heating the *reactor* (although in practice, this is only found in industrialized countries).

- If the *temperature* of the *biomass* is below 15°C, gas production will be so low that the *biogas* plant is no longer interesting from an economic point of view (ISAT/*GTZ* 1999, Vol. I).

- At higher *temperature*, not only *methane* production can be increased but also free *ammonia*, which can have an inhibitory effect on the digestion performance (ISAT/*GTZ* 1999, Vol. I).

Advantages

AD Biogas Systems

- Generation of renewable energy
- Small land area required (most of the structure can be built underground)
- Can be built and repaired with locally available materials
- No electrical energy required
- Combined treatment of animal, human and solid organic waste
- Conservation of nutrients
- Long service life
- Low to moderate capital costs; low operating costs

Disadvantages

AD Biogas Systems

- Requires expert design and skilled construction
- Substrates need to contain high amounts of organic matter for biogas production
- Incomplete pathogen removal, the digestate might require further treatment
- Limited gas production below 15°C
- Requires seeding (start-up can be long due to the low growth yield of anaerobic bacteria)

			Removal (%)										
Treatment process	Capacity	Unit	BOD	COD	TSS	TN	TKN	NH_3-N	TP	TC/FC	Country	References	Remarks
DPS	5,000	p.e.	~ 95	~ 90	–	87	–	–	43	–	Zimbabwe	Nhapi et al. (2003)	Treatment scheme includes anaerobic and maturation pond
	10,000	p.e.	–	–	–	56	–	–	11	–			
	2,000–3,000	p.e.	–	–	–	–	74–77	> 90	–	–	The Netherlands	Alaerts et al. (1996)	–
WSP	2,000	p.e.	75	70	60	51	–	–	51	–	Spain	Rodríguez (2009)	–
	30–60	m^3/d	94	–	63	–	–	72	–	–	Greece	Papadopoulos & Tsihrintzis (2011)	WSP utilizes duckweed plants
	3,000	p.e.	50.6	48.9	44.3	–	–	–	–	98.8 and 95.6	Egypt	Ghazy & El-Senousy (2008)	The scheme comprises anaerobic, facultative and maturation ponds
	5,000	m^3/d	–	6.7 (sol)	16.3	–	–	3.6	18.1	–	Israel	Avsar et al. (2008)	Scheme comprises two sedimentation tanks followed by a pond
	–	–	75	55	48	44	–	–	46	1.6 log unit FC	Brazil	Sperling & Oliveira (2009)	–
Horizontal flow constructed wetland (HFCW)	1,750	p.e.	–	98.7	93.1	94	–	91.9	92.4	–	Ireland	Dzakpasu et al. (2012)	Combined treatment of domestic sewage and mountain water river
	–	–	96	–	–	–	–	88.4	87.8	–	China	Wu et al. (2011)	Preceded by a settling tank
	< 2,000	p.e.	> 78	–	> 78	40–60	–	–	40–60	–	Spain	Vera et al. (2011)	Treatment scheme includes septic tank as pretreatment followed by HFCW and WSP as post-treatment unit
	350	p.e.	> 90	> 90	95.6	–	–	–	–	–	France	Merlin et al. (2002)	Septic tank followed by HFCW
	100	p.e.	97	94.5	99.4	–	–	–	62.5	–	Czech Republic	Vymazal (2011)	Pretreatment by septic tank and screen followed by HFCW
	20	p.e.	–	79.2	64.7	–	–	–	–	–	Italy	Pucci et al. (2000)	Imhoff tank followed by HFCW
Vertical flow constructed wetland (VFCW)	1,000	p.e.	92.3	91.7	93.2	–	80.3	87.5	61.3	99.9	France	Gikas et al. (2007)	Treatment scheme includes screening, primary sedimentation tank (PST) and sludge tank followed by VFCW
	72	p.e.	> 60	> 55	> 80	–	–	–	–	–	Tunisia	Sellami et al. (2009)	Septic tank followed by VFCW
	–	–	–	93	96	–	–	86	75	–	Nepal	Bista & Khatiwada (2004)	Septic tank followed by reed bed based vertical and horizontal wetland

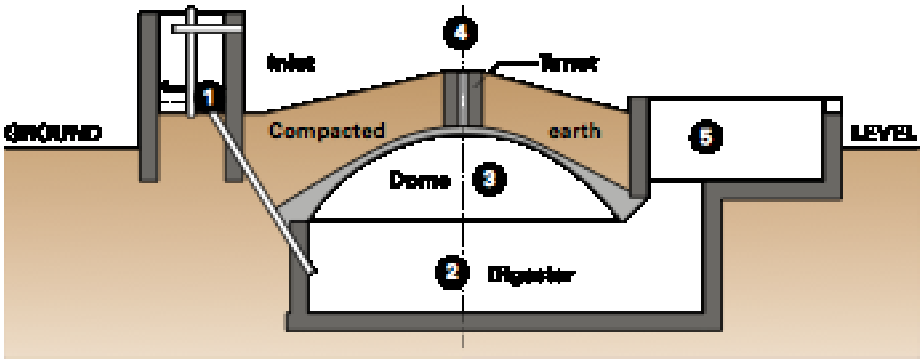
Case Studies

Various

AD Biogas Systems

Biogas Sanitation Systems in Nepalese Prisons

model: medium scale system
size: 10 m3/65 persons
substrate: 3 Kg kitchen waste, 320 L human waste
biogas yield: 6 m3/d or 20 hours cooking
cost: 7,174 USD



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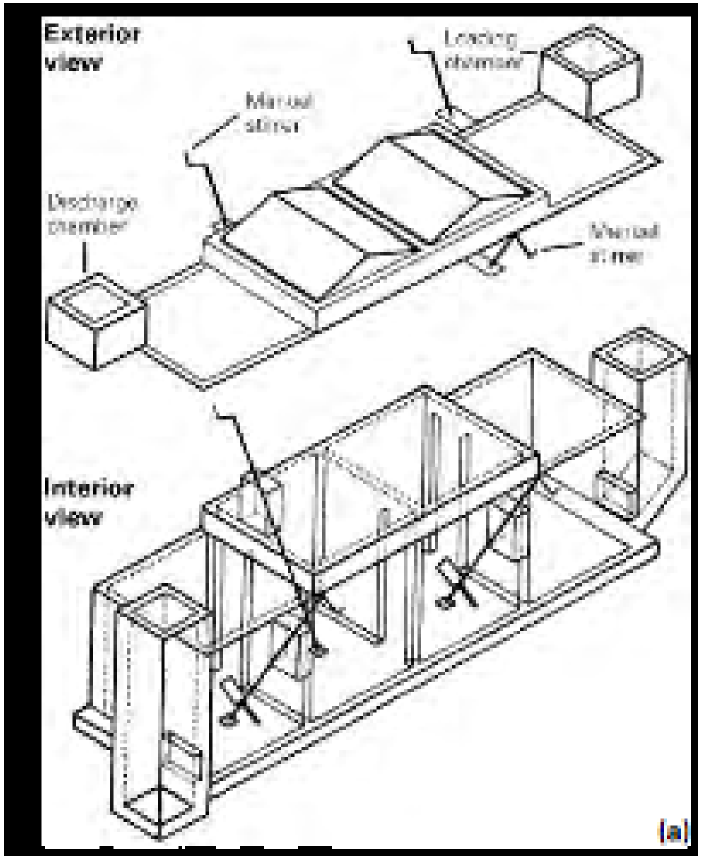
Biogas Sanitation Systems in Nepalese Prisons

saving from use of LPG from septic tank: 41%
payback period: 1,5 years

main problems:
use of effluent: not use due to barrier and local circumstances
maintenance: lack of maintenance due to low
interest

AD Decentralized Technology

Anaerobic Digestion of Agricultural and Domestic Solid Waste in Emilia, Santa Fe Province, Argentina



model: large scale system
size: 25 m3
substrate: domestic waste, canteen waste, pig and poultry manure
biogas yield: 25 m3/d compared to 15 Kg LPB
cost: 8,066 USD

AD Decentralized Technology

Anaerobic Digestion of Agricultural and Domestic Solid Waste in Emilia, Santa Fe Province, Argentina

- The daily biogas production is used to make can-dies, jams and other foods to supply the school dining hall, and is also used to heat water.
- the digester is a horizontal Plug flow design, with manual stirrers, and partially underground
- the gas is partially stored in a 2 m3 biogas holder
- organic solid waste, without prior crushing, are gravity fedd onto a loading chamber before entering the digester

Case Study: Lebanon

CW

Bcharré
Reed bed Filters : 300 – 400 PE (équivalent-habitant) vertical flow,
1200 m2, 160,000 $

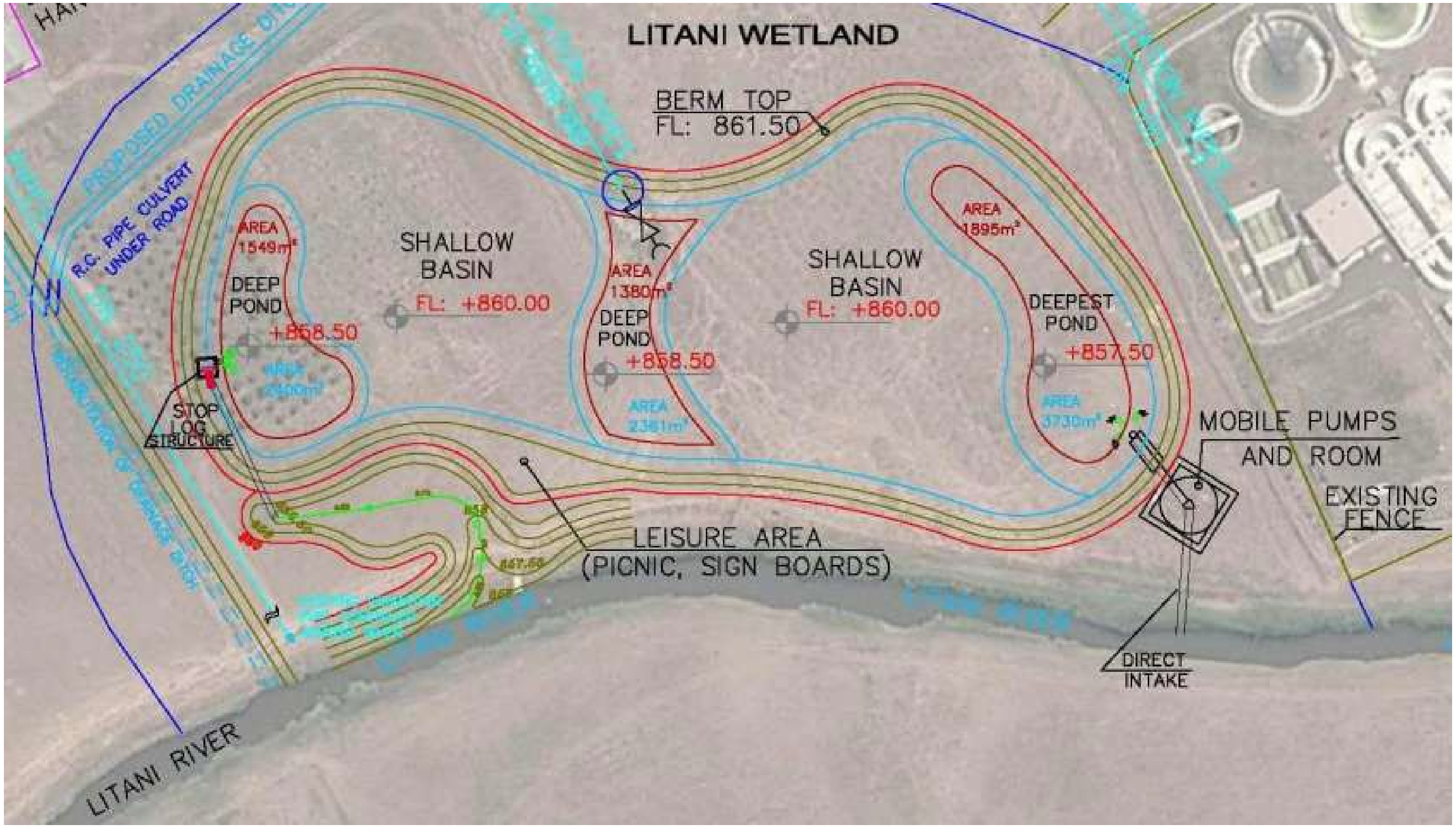
Litani CW

* At the chosen site, the Litani River suffers from the cumulative effects of the agricultural, industrial, and domestic wastewater discharges upstream.
* In addition, most wastewater treatment plants in the Bekaa (even the recently constructed ones such as the Joub Janine plant just upstream of the wetland site) are currently not or only marginally operated and untreated domestic wastewater directly enters the Litani River.
* Concentrations of nutrients such as nitrogen and phosphorus, suspended solids, biochemical oxygen demand, and pathogens are present in elevated concentrations that impair the river.

Litani CW

- The constructed wetland system has been designed to treat as much of the flow in the Litani River as possible given the project budget constraints. At approximately 2.5 ha in size, the wetland will receive 30 L per second of flow during the dry season and 60 L per second of flow during the rest of the year.
- The wetland system will remove between 30 to over 90% of the mass of pollutants entering itThe system will consist of a basin containing alternating deep (2-3 m) and shallow (30-50 cm) zones planted with vegetation adapted for each zone.
- A pump basin next to the river will provide the inflow while an adjustable weir outflow structure will maintain consistent water levels and convey wetland effluent to a discharge channel that brings the effluent back to the Litani River.

Litani CW



LITANI WETLAND
BERM TOP
FL: 861.50
SHALLOW BASIN
FL: +860.00
AREA 1549m²
DEEP POND
+858.50
AREA 1380m²
DEEP POND
+858.50
AREA 2361m²
SHALLOW BASIN
FL: +860.00
AREA 1895m²
DEEPEST POND
+857.50
AREA 3730m²
R.C. PIPE CULVERT UNDER ROAD
PROPOSED DRAINAGE DITCH
STOP LOG STRUCTURE
MOBILE PUMPS AND ROOM
EXISTING FENCE
LEISURE AREA (PICNIC, SIGN BOARDS)
DIRECT INTAKE
LITANI RIVER

N
© 2016 Google
277 m
Image © 2016 CNES / Astrium
© 2016 ORION-ME
Google earth
2003
Imagery Date: 5/15/2014 33°38'15.91" N 35°46'29.63" E elev 860 m eye alt 2.06 km

Dry Season	BOD5	TSS	NH_4-N	$NO_{2/3}$-N	TN	TP	FC**
Inflow Concentration (mg/L)	60	200	4	7	28	3	2,500,000
Inflow Mass Rate (kg/ha/d)	64	213	4	7	30	3	NA
Outflow Concentration (mg/L)	32	37	2	4	8	2	26,000
Outflow Mass Rate (kg/ha/d)	22	25	1	2	5	2	NA
Concentration Removal	47%	81%	44%	46%	72%	23%	99%
Mass Removal	66%	88%	65%	66%	82%	52%	NA
Wet Season	**BOD5**	**TSS**	**NH_4-N**	**$NO_{2/3}$-N**	**TN**	**TP**	**FC****
Inflow Concentration (mg/L)	9	200	2	9	20	1	280,000
Inflow Mass Rate (kg/ha/d)	20	427	5	19	43	3	NA
Outflow Concentration (mg/L)	7	20	2	8	15	1	29,000
Outflow Mass Rate (kg/ha/d)	13	37	3	14	27	2	NA
Concentration Removal	24%	90%	19%	10%	26%	14%	90%
Mass Removal	35%	91%	31%	23%	36%	26%	NA

Dry Season	BOD5	TSS	NH_4-N	$NO_{2/3}$-N	TN	TP	FC**
Outflow Concentration (mg/L)	32	37	2	4	8	2	26,000
Wet Season	**BOD5**	**TSS**	**NH_4-N**	**$NO_{2/3}$-N**	**TN**	**TP**	**FC****
Outflow Concentration (mg/L)	7	20	2	8	15	1	29,000
Environmental Limit Values (mg/L)	25	60	10	90	30	10	2,000

Lebanon

Greywater