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Sandec
Water and Sanitation in Developing Countries

Evaluation of biogas sanitation systems in Nepalese prisons

Summary Presentation of Evaluation Results
August 09

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January 2007

Agreement between ICRC and local expert partner BSP-N to implement 5 biogas systems in 3 Nepalese prisons

International Committee of the Red Cross

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Biogas Sector Partnership Nepal

BSP

May 2008

End of construction -> start of operation

April-June 2009

External evaluation by Eawag/Sandec

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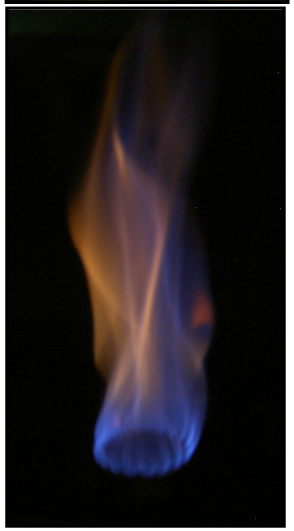
Objectives of biogas installations

- Improvement of human excreta disposal and management (reduction of health risks)
- Provision of renewable energy source as alternative to wood and kerosene
- Improvement of kitchen environment (reduction of health risks)
- Use of slurry as fertilizer
- Promote the construction of biogas plants on institutional level



Location of evaluated district jails

Source: commons.wikimedia.org (modified)

Biogas digesters

- Kaski : 10m3 and 20m3
- Chitwan : 10m3 and 35m3
- Kanchanpur : 10m3

- Measurements/analyses on-site
  - Gas production & composition
  - pH, Temp., Redox, EC
  - COD, NH4-N, N total, P total
  - VFA, alkalinity, A/TIC-ratio
  - E.Coli

- Analyses in lab
  - TS (Total Solids), VS (Volatile solids) -> KU lab
  - Helminth eggs -> Swiss Tropical Institute

- Observations and Interviews
  - Gas tightness of dome & piping
  - Fuel savings, living conditions before/after biogas plant
  - Construction, operation, maintenance and problems

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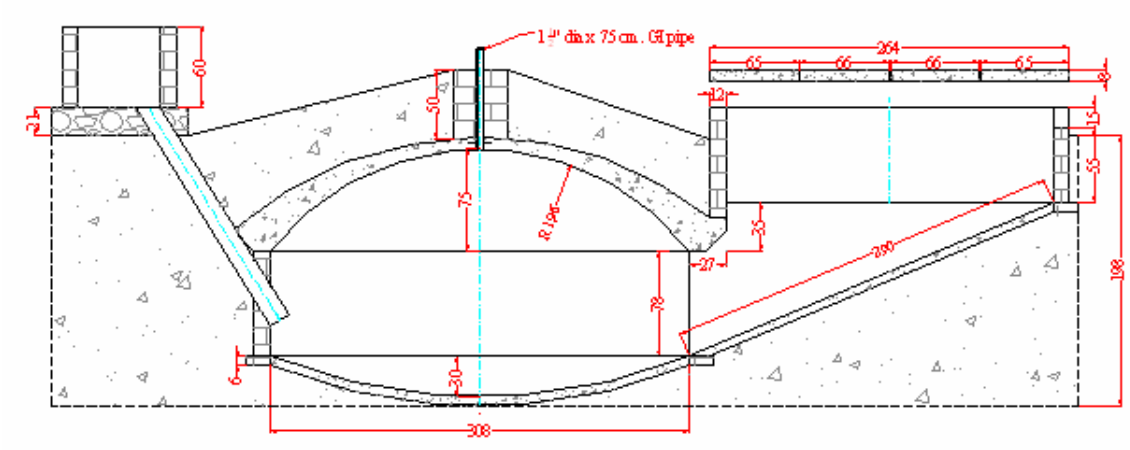
Digester design

> Nepalese GGC2049-model



Kaski, Chitwan and Kanchanpur District Jails

1. Introduction
2. Monitoring
3. Evaluation
4. Discussion

Kaski District Jail:
Altitude: 819m above mean sea level
(Digester Size: $10m^3$ and $20m^3$)

Number of detainees
Initial capacity of jail: 60 pers.
Pre-construction planning: 187 pers.
Evaluation period 2009: 203 pers.

Chitwan District Jail:
Altitude: 240m above mean sea level
(Digester Size: $10m^3$ and $35m^3$)

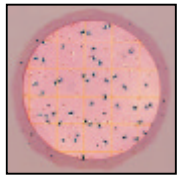
Number of detainees
Initial capacity of jail: 55 pers.
Pre-construction planning: 321 pers.
Evaluation period 2009: 268 pers.

Kanchanpur District Jail:
Altitude: 116m above mean sea level
(Digester Size: $10m^3$)

Number of detainees
Initial capacity of jail: 75 pers.
Pre-construction planning: 74 pers. (•)
Evaluation period 2009: 106 pers. (•)

- Reduction of Solids and Organic load
  95 - 98% reduction of Total Solids and Organic Load

- Reduction of pathogen



3-M Petrifilmtest

> E.Coli

WHO guideline values for agricultural use of greywater, excreta and faecal sludge:

- Restricted irrigation: < 10^5 CFU/100ml
- Unrestricted irrigation of crops eaten raw: < 10^3 CFU/100ml

- Requirements for restricted irrigation fulfilled

> Helminth eggs

WHO guideline values:

- Restricted/unrestricted irrigation: < 1 ova/L

Ascaris lumbricoides

- Requirements only partially fulfilled

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Result of Pathogenic Analysis

Descriptions		Chitwan		Kanchanpur
		10m3	35m3	10m3
E.COLI	Reduction- Influent vs Effluent in Compensation Chamber	92.0%	98.5%	99.7%
	Reduction- Influent vs Effluent in Storage Pit	99.9%	99.9%	99.99%
TOTAL HELMINTH	Reduction- Influent vs Effluent in Compensation Chamber	87.3%	94.4%	84.3%
	Reduction- Influent vs Effluent in Storage Pit	100.0%	100.0%	100.0%

- Influent data for Kaski unavailable
- Due to limited samples results are not statistically representative

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Daily gas production

		Kaski 10m3	Kaski 20 m3	Chitwan 10m3	Chitwan 35m3	Kan'pur 10m3
Monitoring: Measurement/ Observation/ Estimation	April 2009	1260	8620	2610	1920	3130
	May 2009	260	8210	3260	2500	-
	June 2009	2120	9210	3310	4800	3450
	Cooking time (h)	6.5	19.5	9.0	10.5	9.5
	No. of detainees	65	135	115	155	106
	Kitchen waste feeding (kg/d)	3	45	0	0	0
Pre-Construction: Planning/ Expectation	Daily kitchen waste feeding	4	43	0	73	19
	No. of detainees	68	119	115	206	74
	Biogas output	2000	4000	3000	7000	2000
Difference between expected & measured daily biogas production		+6%	+130%	+10%	-31%	+73%

Technical aspects

Process stability (Inhibiting factors)

Ø	Kaski 10	Kaski 20	Chitwan 10	Chitwan 35	Kanchanpur 10	Optimum
pH	7.17	7.05	7.11	7.44	7.20	6.5 - 7.5
Temp. [°C]	26.4	25.6	29.8	28.8	30.0	25 – 35
Redox [mV]	-372	-401	-389	-391	-402	< -330
VFA [mg/L]	49	95	28	46	31	< 1000
NH4-N [mg/L]	504	697	356	458	443	< 1500

Hydraulic Retention time

HRT [days]	23	21	14	33	15	70 - 90

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Technical aspects

Feeding input -> Biogas output (theroretical and measured)

	Kaski 10	Kaski 20	Chitwan 10	Chitwan 35	Kanchanpur 10
Number of persons	65	135	115	155	106
Feaces [0.4kg/cap/d]	26	54	46	62	42
Flush water [3L/cap/d]	195	405	345	465	318
Urine [1.5L/cap/d]	97.5	202.5	172.5	232.5	159
Kitchen waste KW [kg/d]	3	45	0	3	0
Gas per faeces [30L/cap/d]	1950	4050	3300	4650	3180
Gas per KW [115L/kg/d]	345	5175	0	345	0
Total gas potential [L/d]	2295	9225	3450	4800	3180
Total gas (June 09) [L/d]	2120	9210	3310	4995	3450

> Average biogas output from faeces: 28 NL/cap./day
> With addition of kitchen waste: 62 NL/cap./day

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Operational aspects

- Kitchen waste feeding
  Only regularly done in Kaski
  Chitwan*/Kan'pur: Sold to piggery
(* Since Sept 09 used to feed digester)
- Slurry
  No use as fertilizer
  No (aerobic) post-treatment

Kaski 20m3

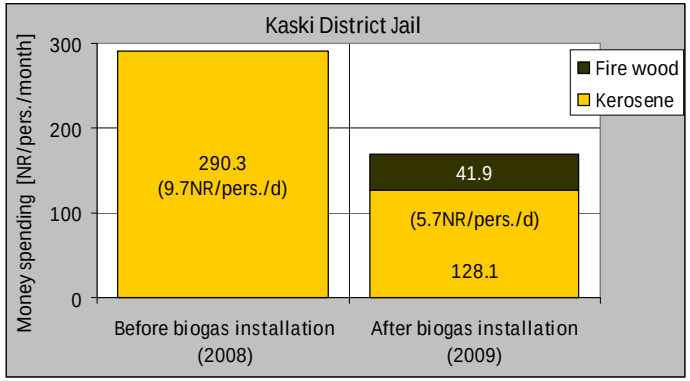
Kaski 10m3

Maintenance aspects

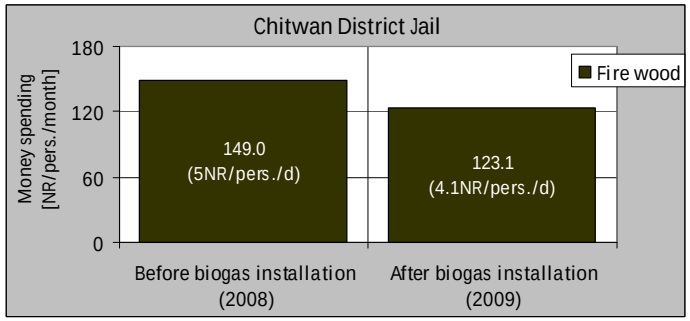
- Lack of internal and external maintenance strategy*

(* In Sept 09 maintence calendar was drawn up and PMD reviewing maintenance)

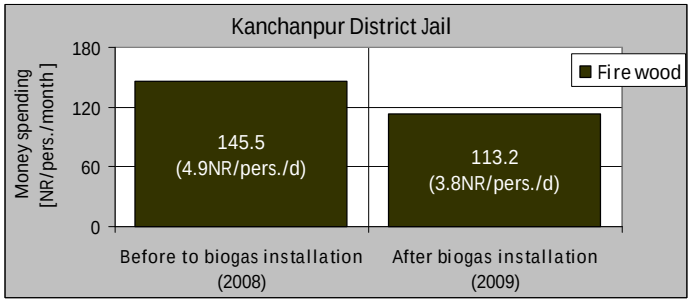
Cooking fuel: money saving



- Kaski DJ
>>> 41% saving



- Chitwan DJ
>>> 17% saving



- Kanchanpur DJ
>>> 22% saving

Economic aspects

10‘000 NR • 140 CHF

• Cost effectiveness

	Kaski	Chitwan	Kanchanpur
Saving of cooking fuel [NR/y]	29‘400	84‘000	41‘100
Saving of septic tank emptying [NR/y]	46‘000	22‘000	2‘200
Cost of biogas system(s) [NR]	511‘000	577‘000	160‘000
Min. amortisation period [year]	1.5	5.4	3.7

* Not considered: Cost of
- Eventual repairing work
- Desludging of digester
- Changes in number of detainees
- Price fluctuations

• Lifespan of biogas system

Acc. BSP-N:	Digester:	min 20 years
Acc. BAT (2009)	Acrylic emulsion paint:	4-6 years
Acc. BAT (2009)	Piping:	7 years

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Environmental aspects

- Mitigating deforestation

  > Annual saving of firewood:
  Chitwan: 10 tons
  Kanchanpur: 4 tons

- Reduction of methane emissions

  - If biogas properly burned
  - If gas escape minimized

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Socio-cultural aspects (Interview with 63 detainees)

- Knowledge of system

  79% of total interviewees know the new sanitation system by name (biogas)

- Objection

  Only 7 detainees (1.2% of total) object biogas use because of faecal origin (Kan'pur)
  -> Acceptance is increasing

- Improvement of living conditions?

  98%: yes

  59%: Less smoke in kitchen
  49%: Improved sanitation/hygiene/health
  38%: Cleaner environment
  35%: Time saving
  35%: Money saving

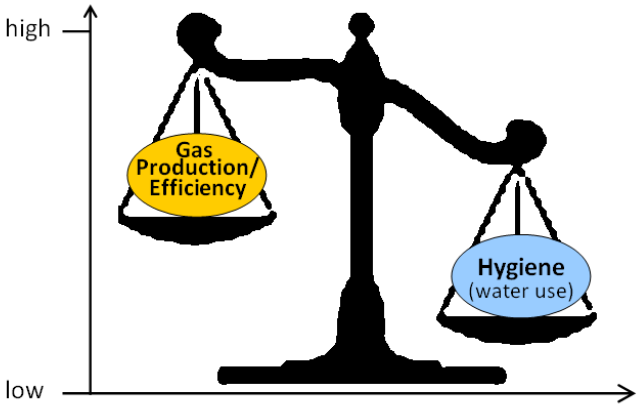
Sanitation/Health aspects

- Comparison Septic tank • biogas system

  All interviewees prefer biogas system

- Water use/hygiene

  Recommended: 1L water per defecation
  Observed: 3L !



- Kitchen: H2S, smoke

  Hazardous H2S-content in biogas (>1000ppm)
  -> regular leakage check in kitchen
  -> complete combustion

  97% of interviewees prefer biogas cooking to firewood/kerosene

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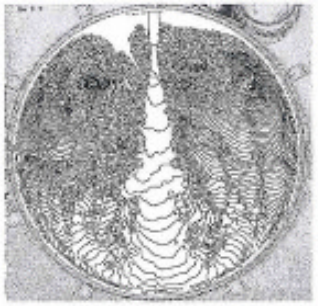
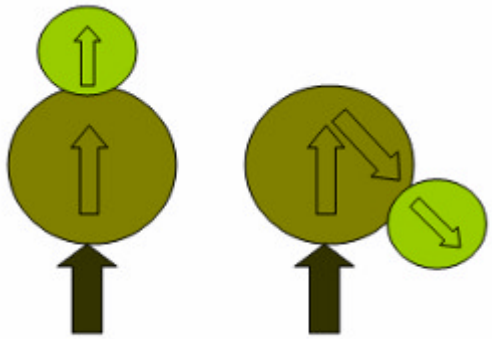
- Design / Construction

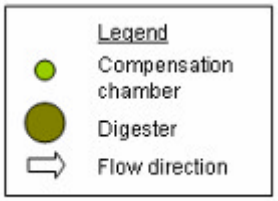
> Buffer wall
-> increased solid retention time -> improved efficiency



Short circuiting



or: Digester inlet and outlet not in line



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• Design / Construction

> Ensure sufficient inlet slope

> Promote slurry use for banana cultivation

-> Widespread in Nepal
-> No contact between fruit and slurry
-> No risk of digester-damage by roots
-> No extensive shading by leaves
-> High nutrient demand
-> High water demand (no water logging)

• Operation/Maintenance:

> Clarify/control responsibilities (duty calendar)
> Annual monitoring (after drawback of ICRC WatHab)

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General

> Technology and design are suitable for treatment of human & kitchen waste on institutional level if system is properly operated and maintained

> Technology is favourably perceived by users
(less indoor air pollution, better hygiene, easy cooking, money & time saving, cleaner environment)

> Domes are gastight

> Room for improvement: Inlet slope, user commitment

> Average quantity of toilet flush: 3L (not 1L) -> low HRT

> Reduction of organic load substantial

> Pathogen reduction needs further analyses

> Slurry is not used as fertilizer -> promote banana cultivation

> No regular maintenance work conducted -> jeopardizing sustainability

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Objectives of biogas installations

- Improvement of human excreta disposal and management (reduction of health risks) ✓
- Provision of renewable energy source as alternative to wood and kerosene ✓
- Improvement of kitchen environment (reduction of health risks) ✓
- Use of slurry as fertilizer X
- Promote the construction of biogas plants on institutional level ✓

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