UNESCO-IHE
Institute for Water Education

Evaluating various sanitation system alternatives for urban areas by multi criteria analysis – case study of Accra, Ghana

Dr. Elisabeth v. Münch
UNESCO-IHE Institute for Water Education
Delft, The Netherlands
e.vonmunch@unesco-ihe.org

Dr. Adriaan Mels
Wageningen University
Urban Environment Group
adriaan.mels@wur.nl

Presented at Sanitation Challenge Conference, Wageningen, 19 May 2008

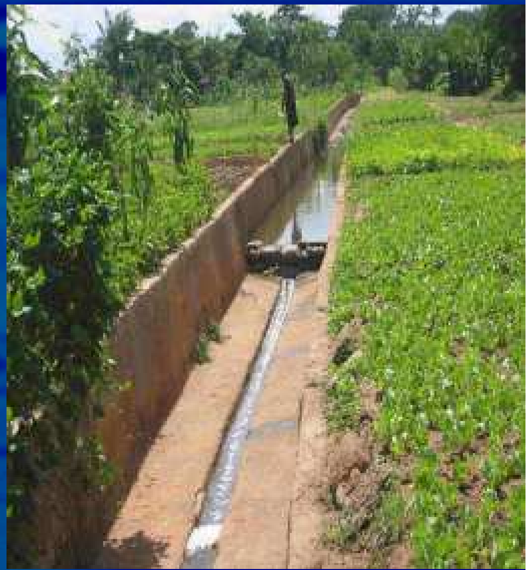
Background: this research project was part of SWITCH project

- Key figures about SWITCH project:
  - 5 yr project period (started: January 2006)
  - EU project with budget of 25 million Euro
  - 32 partners led by UNESCO-IHE
  - This research under theme 4.1-Eco sanitation & decentralised wastewater management in an urban context
  - Website: www.switchurbanwater.eu
- Paper is based on MSc thesis of Kalyani de Silva (2007) at UNESCO-IHE

SWITCH = Sustainable Water Management Improves Tomorrow's City's Health

SWITCH objectives in key words

- **Paradigm shift: SWITCH Strategic Approach**
- **Sustainability: indicators/modeling**
- **Risk management: indicators/modeling**
- **Learning Alliance: steering / demonstration of innovations**



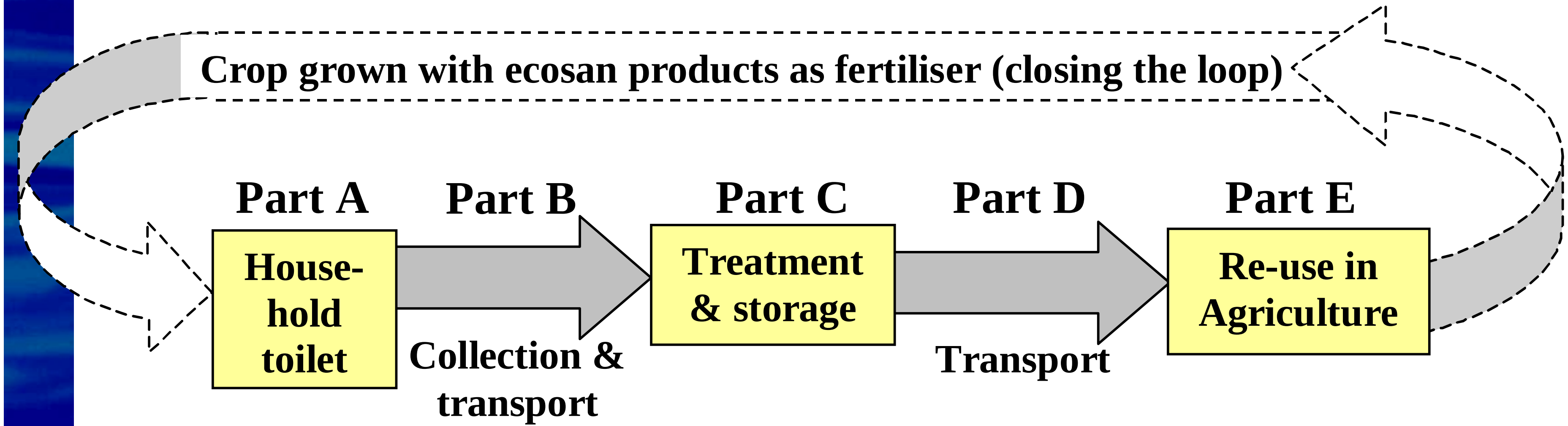
10 demonstration cities in SWITCH (with Learning Alliances)

Accra Metropolitan Assembly (AMA): 1.6 million inhabitants
Accra: capital of Ghana in West Africa

6-step methodology for evaluating various sanitation system alternatives

1. Analyse existing sanitation situation
2. Define possible sanitation options and selection criteria
3. Short-list small number of options
4. Concept designs for short-listed options
5. Cost estimates based on the concept designs
6. Carry out multi-criteria analysis (MCA)

Reminder: Sanitation is a system consisting of <u>five parts</u> (Part A to E)



Urine, faeces, greywater

Trucks or pipes

Trucks or pipes

Fertiliser, soil conditioner, irrigation water

Step 1: Accra: issues and challenges identified by the Learning Alliance

- Rapid growth, especially on the fringes of the city
- Development of slum areas
- Poor access to proper water supply and sanitation by the urban poor
- High losses in the distribution network
- Polluted water resources
- Low cost recovery for water supply services
- Storm water management

Step 1: Sanitation problems in Accra

- Inadequate sanitation facilities
- Pollution of groundwater and surface water sources due to human excreta
- Waterborne diseases and death due to improper wastewater management
- Unsafe reuse of wastewater in urban agriculture

- Low access to improved sanitation in urban areas
  - Estimate for Ghana: 13%
  - Target in 2015: 57%

Step 2a: Define boundaries of the sanitation system

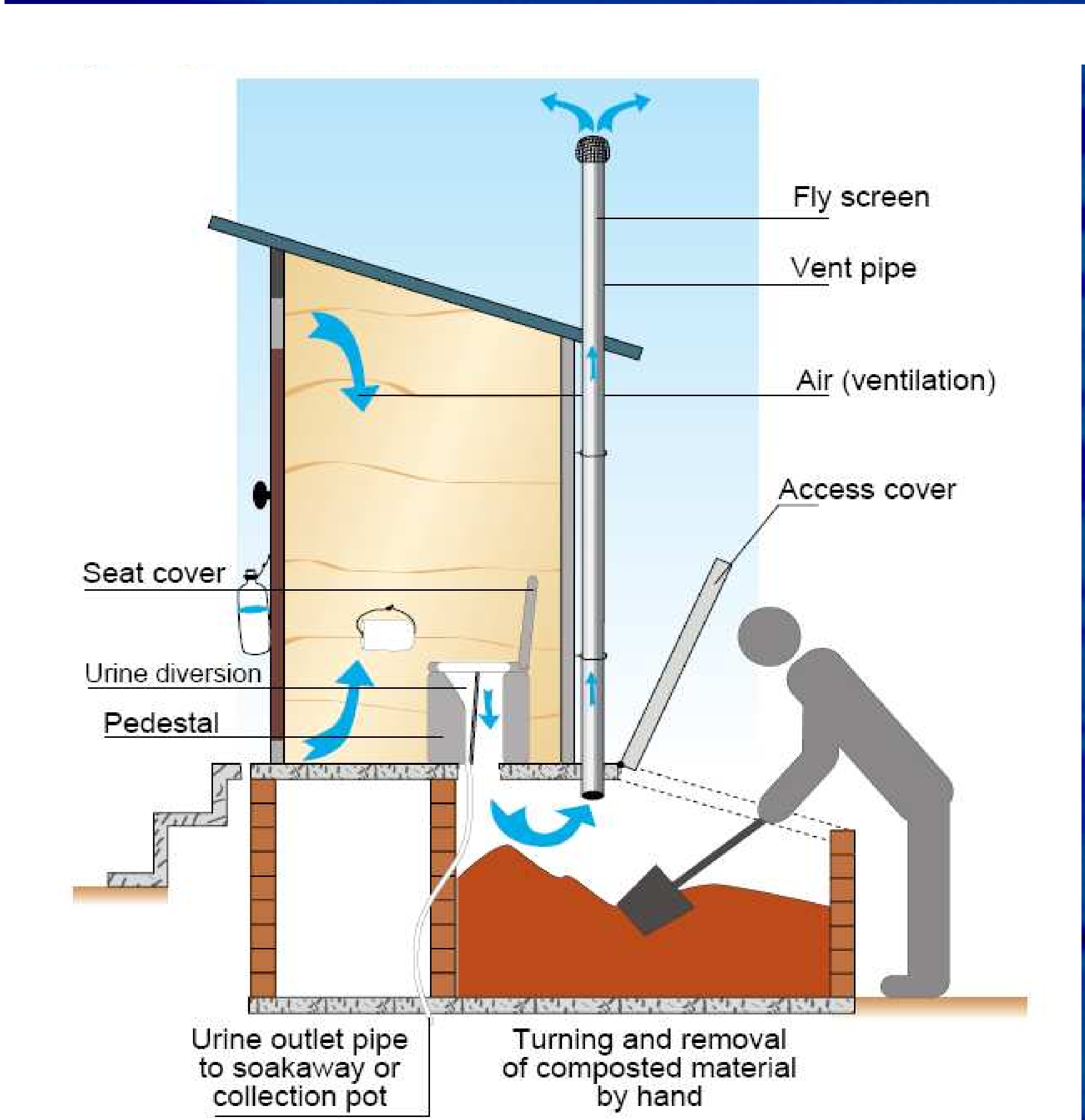
- For this research project, we limited our analysis to:
  - the urban poor in peri-urban areas
  - excreta only (not greywater)

Step 2b: Define available low-cost sanitation options

- <u>Option 1</u>: Ventilated improved pit latrines (VIP) + downstream processing*
- <u>Option 2</u>: Urine-diversion dehydration toilets (UDD) + downstream processing
- <u>Option 3</u>: Simple pit latrines + downstream processing
- <u>Option 4</u>: Pour-flush toilets + septic tank and soak away

* "Downstream processing" refers to Part B, C, D and E

Quick reminder: what is a UDD toilet (urine-diversion dehydration)



- **No connection between faeces vault and soil (unlike for pit latrines)**
- **Urine is not mixed with faeces**
- **Water is not mixed with faeces**
- **Faeces vault is designed to facilitate drying of faeces**

Step 2b: Define selection criteria

1. **Protect <u>groundwater</u> from pollution by excreta as residents in AMA use groundwater as drinking water**
2. **Investment and operation and maintenance <u>costs</u> should be low**
3. **<u>Water</u> should not be used for toilet flushing (water supply is unreliable in AMA)**
4. **Desirable: Produce fertiliser for safe urban agriculture**

Step 3: Short-listing of sanitation options based on selection criteria of Step 2b

- Option 1 *: Ventilated improved pit latrines (VIP) + downstream processing
- Option 2: Urine-diversion dehydration toilets (UDD) + downstream processing
- ~~Option 3: Simple pit latrines + downstream processing~~
- ~~Option 4: Pour-flush + septic tank and soak away~~

Discarded!

* Does not meet selection criterion 1 (groundwater), but kept regardless

Concept design summary (Part A and B)

	Option 1 (VIP system - conventional)	Option 2 (UDD system - ecosan)
Part A (Household toilets)	VIP toilets (59,000 toilets)- outdoor toilets	Double vault UDD toilets (59,000 toilets) – indoor toilets
Part B (Collection and transport of excreta)	4 vacuum tankers to transport the faecal sludge	1 open truck for dried faecal matter 7 open trucks with urine barrels Plastic barrels of 100 L 3 centralised storage points

Design basis:

Population: 265,000 **average household size: 4.5**

One toilet per household

Concept design summary (Part C, D and E)

	Option 1 (VIP system)	Option 2 (UDD system)
Part C (Treatment and storage of excreta)	One centralised plant (anaerobic treatment plant, sludge drying beds)	No treatment required, only storage: • Dried faecal matter: for 6 months on 2 m high piles on concrete slabs • Urine storage: stored in plastic tanks for 2 weeks
Part D (Transport of sanitised excreta)	Open trucks Transport would be shifted to the farmers who buy the fertiliser	
Part E (Reuse in agriculture)	No capital cost items	

Step 5: Cost estimates of short-listed options

- Cost estimates are based on concept designs
- Need to estimate:
  - Capital cost
  - Operating and maintenance cost
  - Net present value (NPV)

(see paper for numbers)

Step 6a: Determine weightings for six aspects of five sanitation parts

Aspect	Part A Toilets	Part B Transp. 1	Part C Treatm.	Part D Transp. 2	Part E Reuse
Social	25	8	5	8	20
Technological	11	17	27	12	15
Economic	27	29	23	29	23
Environmental	16	16	21	21	13
Health	16	10	6	8	17
Institutional	5	20	18	22	12
Total	100	100	100	100	100

Average values of 5 experts
In orange: highest scores for each aspect

Step 6b: Different sub-criteria for 5 parts (example: social aspects for 3 parts)

Part A (toilets)	Part B (transport 1)	Part E (reuse)
Acceptability (comfort)	Willingness of people to work in collection/transport business	Cultural barriers against use of products
Personal security (indoors versus outdoors)	Reliability of collection	Farmers' willingness to utilise the fertiliser
System complexity		

Define indicators for scoring of each sub-criterion
Highest score: 5
Lowest score: 1

Step 6b: Different sub-criteria for 5 parts
(example: institutional aspects for 3 parts)

Part A (toilets)	Part B (transport 1)	Part C (treatment)
Local skills required for construction and O&M	Potential for private sector involvement	Resources necessity (labour, materials)
Training requirements for users	Awareness amongst transport stakeholders	Capacity building needs (training labourers for treatment process)
Training requirements for builders	Capacity building or training for collection and transport workers	Potential for private business and income generating activities
Necessity of community awareness		Responsibility, ownership of the process

Define indicators for scoring of each sub-criterion
Highest score: 5
Lowest score: 1

Step 6c: Weighted scores of MCA
(average of 5 experts; maximum score would be 500)

	Option 1 (VIP system – conventional)	Option 2 (UDD system – ecosan)
Part A (toilets)	314	359
Part B (transport 1)	263	320
Part C (treatment)	239	350
Part D (transport 2)	204	204
Part E (reuse)	265	302

In orange: highest score for each sanitation part

Conclusions

1. **Selection of sanitation systems must encompass more than just the toilets (i.e. transport, treatment and reuse)**
2. **Selection procedure with MCA cannot be generic**
   - → **Reliable concept design is needed**
   - → **Sustainability sub-criteria vary**
3. **For the case study analysed here (Accra peri-urban poor areas), the UDD toilet system scored higher than the VIP toilet system** (based on 5 experts)

Appendix

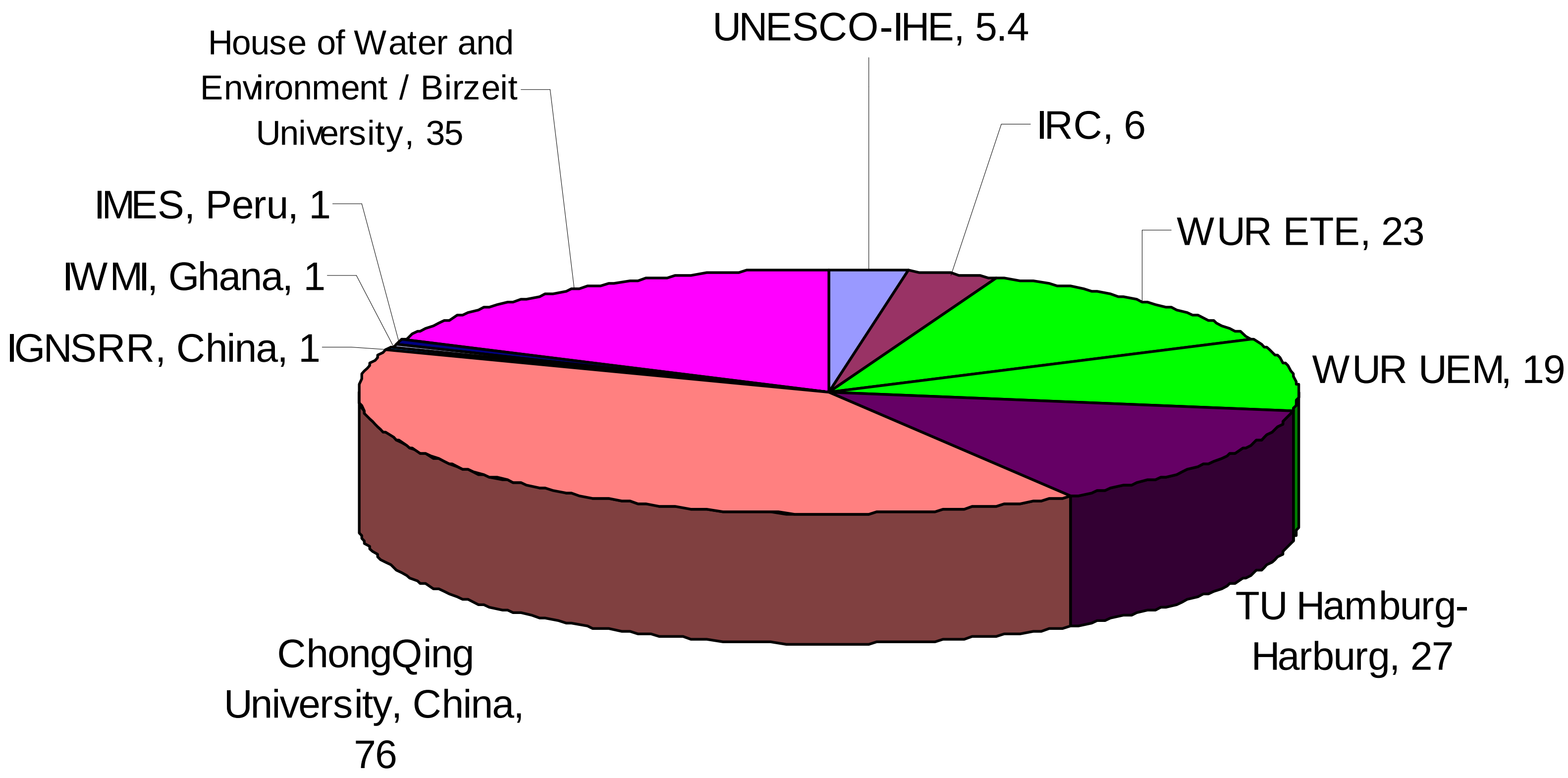
Accra: Learning Alliance members

- Water Directorate, Ministry of Water Resources, Works and Housing
- Water Resources Commission
- Ministry of Local Government Sanitation
- Directorate
- Accra Metropolitan Assembly (WMD, SU, PU)
- Ghana Water Company Limited/AVRL
- Local NGOs (TREND, WaterAid, CONIWAS)
- Hydrological Services Department
- Media (Ghana Broadcasting Company, Ghanaian Times)
- Environmental Protection Agency
- IWMI
- KNUST
- STEPRI
- University of Ghana
- IDA
- WRI
- MOFA
- Farmers' group
- Teshie Assemblyman and community members

Accra: Research focus areas in this demonstration city

- Use of urban water (fresh and waste) for urban agriculture and other livelihood opportunities
- Maximizing the use of natural systems in all aspects of the municipal water cycle
- Governance for integrated urban water management
- Storm water management

Work load distribution of WP 4.1 in SWITCH (9 partners)



Objectives / expected results of WP 4.1 in SWITCH (slide 1 of 2)

- **Global assessment of the adoption, operational functioning and performance of urban ecosan systems**
- **Development of treatment processes for removal of organic micro pollutants (pharmaceuticals, hormones)**
- **Development of strategies and guidelines for agricultural use of nutrients recovered by ecosan systems**

Objectives / expected results of WP 4.1 (slide 2 of 2)

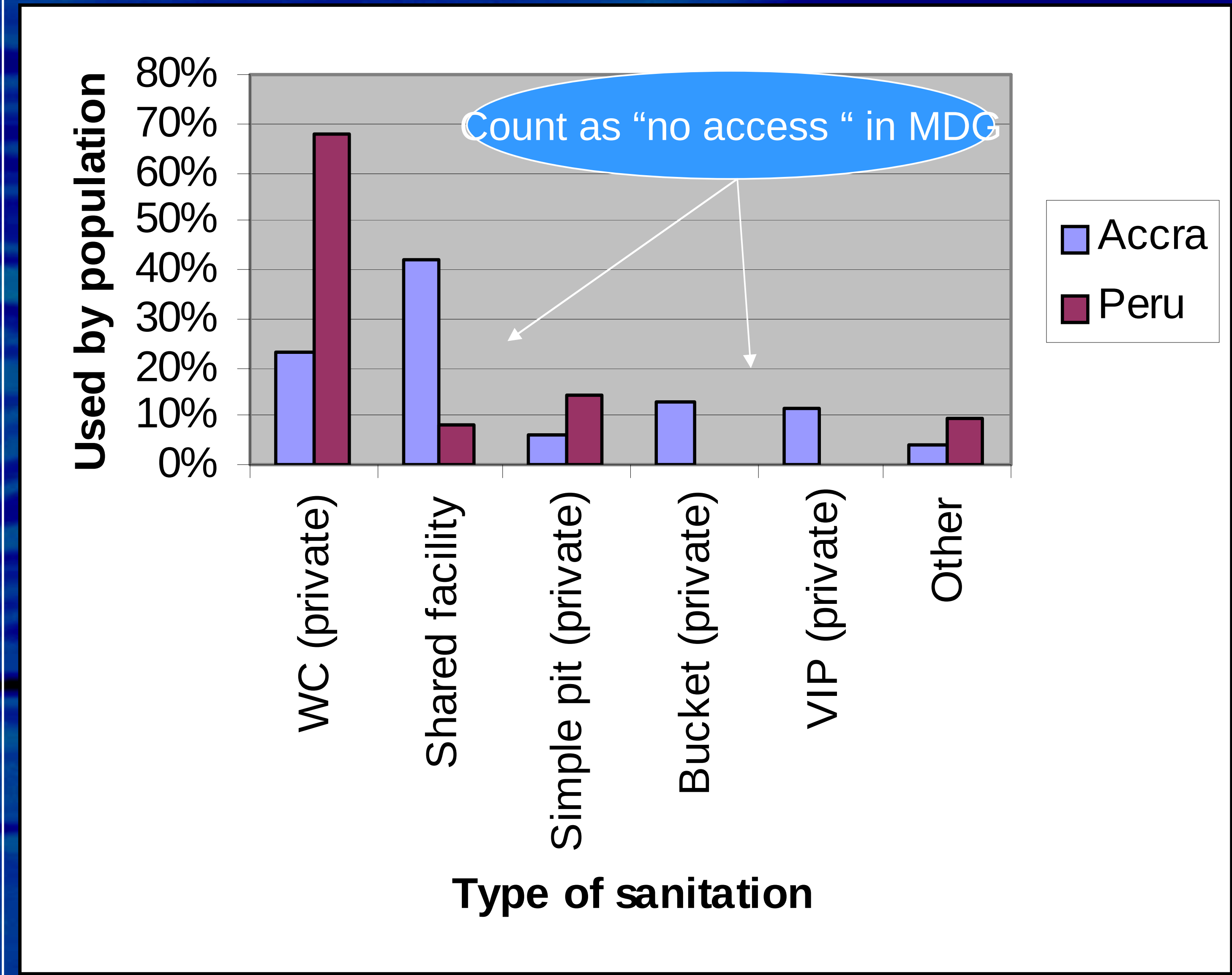
- Guidelines / technical standards for the technology components of urban ecosan systems
- Demonstration project in Beijing and / or of Chong Qing, PR China
- Dissemination of the results through the Learning Alliance, e-learning, various trainings and stakeholder seminars

Demonstration cities and study sites for Work Package 4.1

- Demonstration cities
  - Beijing and Chongqing (western China)

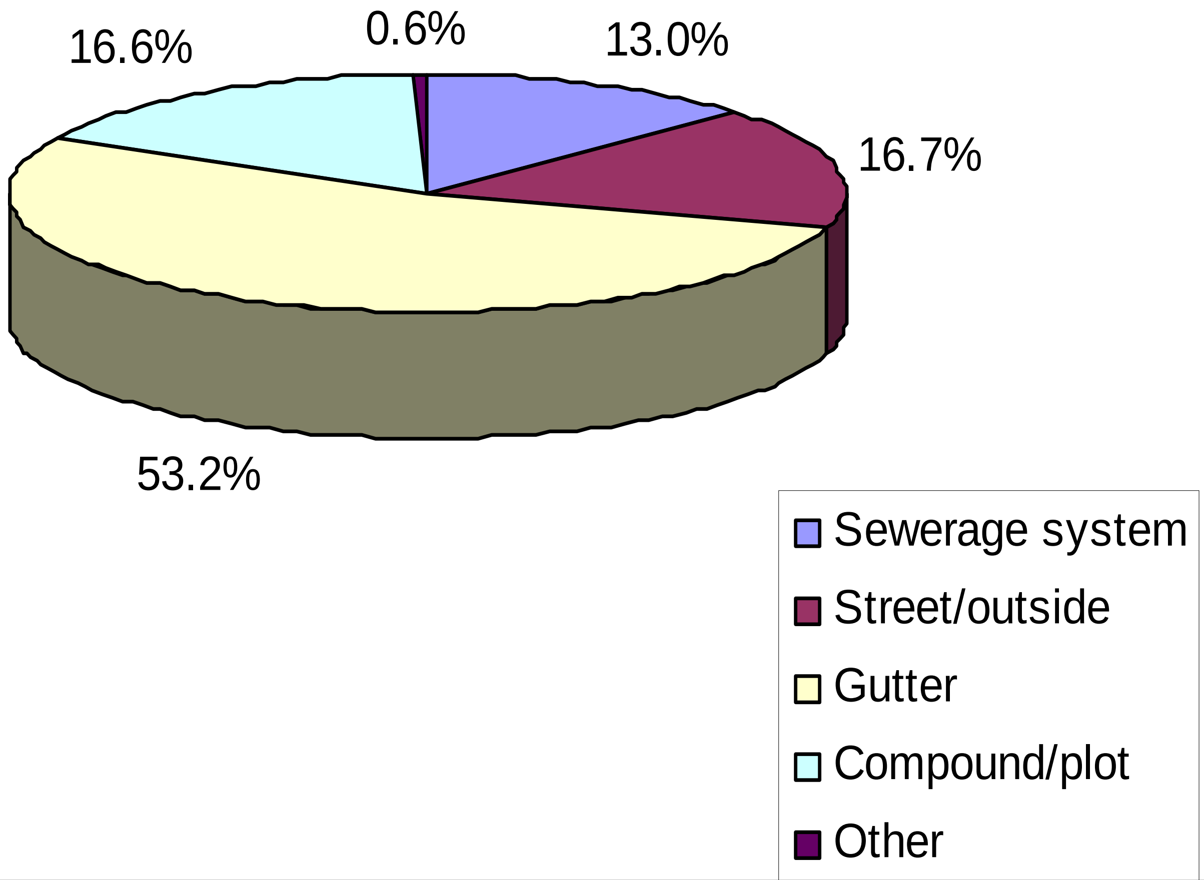
- Study sites (not in description of work)
  - Demosite Anderen, Netherlands (urine diversion)
  - Demosite Sneek, Netherlands (black water digestion)
  - And others (Sweden, Norway, Finland, Germany, …)

Current excreta management systems

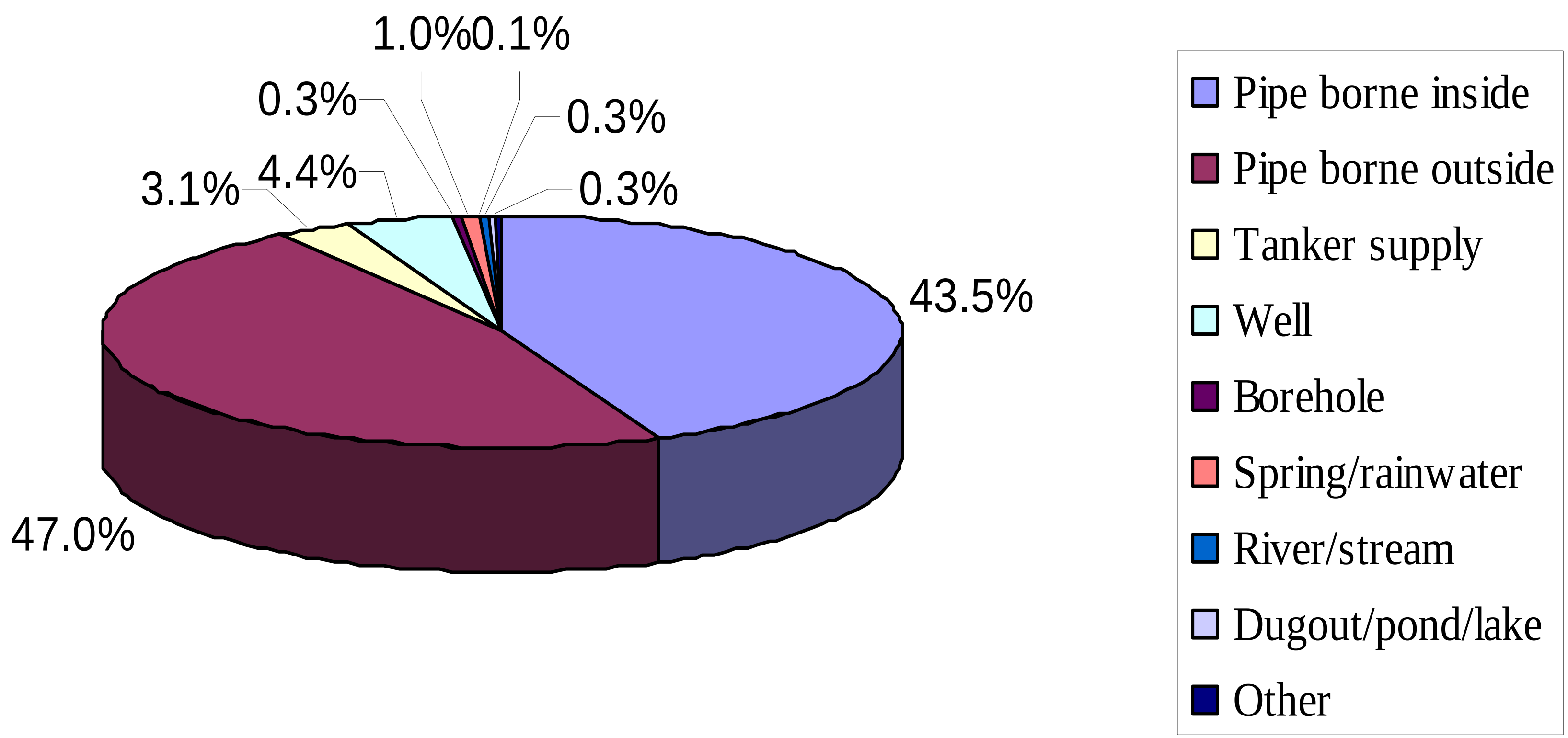


Shared facility: Could be WC, pit, VIP used by more than one family

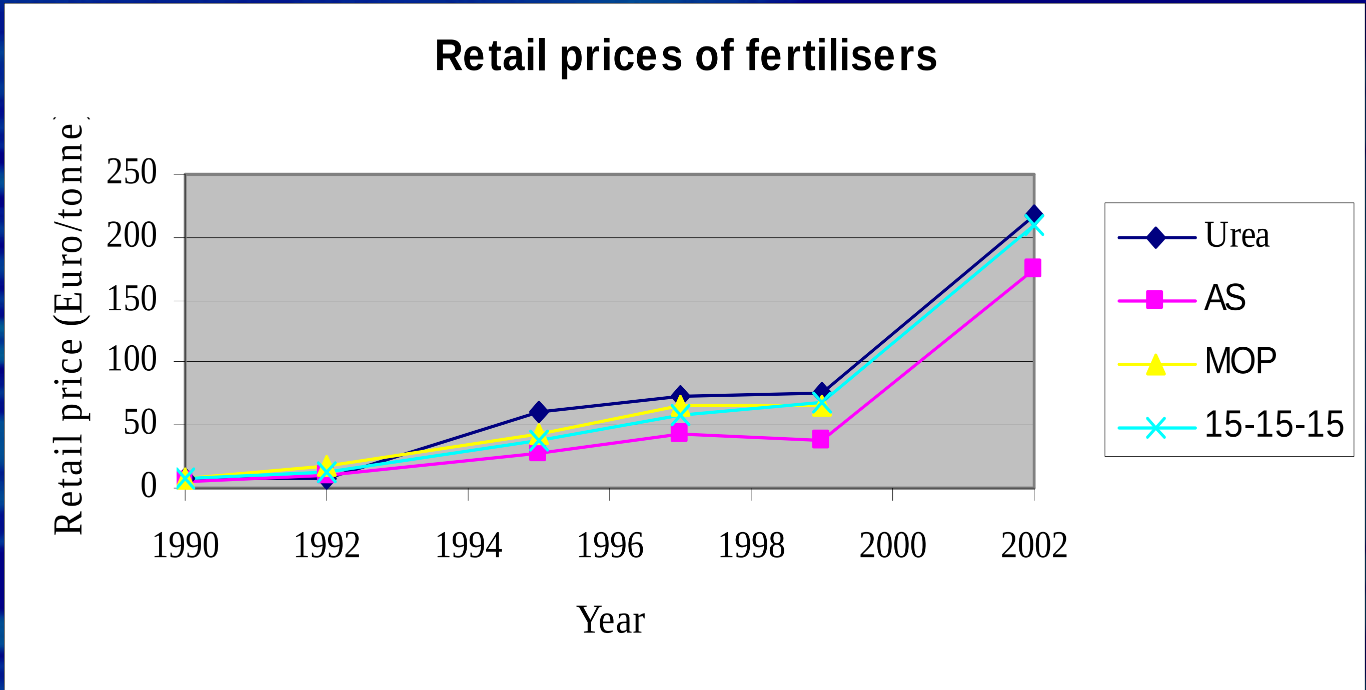
Greywater disposal in use in AMA



Means of water supply in AMA



Fertiliser usage in Ghana



- 80% of fertiliser requirement imported in Ghana
- Large amount of ammonium sulphate (AS), muriate of potash (MOP) imported
- Marginal amount of urea & single super-phosphate (SSP) imported
- Fertiliser prices in 2002: 15-15-15=>209 €/ton , Urea=>218 €/ton

Investment cost

	For both Options, cost = (€)	Option 1	Option 2
Part A	Investment costs of Latrine (€)	6,297,835	7,950,000
Part B	Transport cost from latrine to Treatment plant	440,000	400,000
Part C	Treatment plant	205,000	0
	Land requirement (Value) for treatment plant	153,990	0
	Faecal matter storage	0	29,117
	Land requirement (Value) for faeces storage	0	48,140
	Urine storage tanks	0	1,925,882
	Land requirement (value) for Urine storage	0	81,490
	Subtotal	*358,990*	*2,084,629*
Part D	Trucks to transport the waste and urine	0	0
Part E	Sale of treated sludge or faecal matter	0	0
	Total Investment Costs (million €)	7.1	10.4
	Total Investment Costs (€/cap)	27	39

Step 4: Concept design- Data used for Part A

Input values for Part A	Unit	Option 1 (VIP system)	Option 2 (UDD system)	Comments
No of people sharing one toilet	people	4.5	4.5	Average household size of AMA
Specific sludge production	m3/cap/yr	0.07	0.05	
Desludging period	years	5	2	Alternatively use two vaults for Option 2
Unused pit depth	m	0.6	0	
Substructure cross sectional area (1 x 1.5)	m2	1.5	1.5	Same for both
Superstructure maximum height	m	2	2	Same for both

O & M cost (€/yr)

		Option 1 (VIP)	Option 2 (UDD)
Part A	Operation & Maintenance costs for toilets	0	0
	Material added after defecation (sand)	0	0
	Subtotal	0	*0*
Part B	Removing sludge/ faecal matter from the pit or vault	0	147,222
	Transport of faecal matter from plot to treatment plant / storage site	519,400	22,083
	Urine barrel transport costs from plot to storage site	0	485,833
	Subtotal	*519,400*	*655,139*
Part C	Treatment costs (including labour)	89,040	0
	Staff labour cost for storage facility	0	10,000
	Subtotal	*89,040*	*10,000*
Part D	Transport from treatment plant to disposal/user	0	0
Part E	Income from sale of treated sludge or faecal matter	-17,808	-7,950
	Income from sale of urine	0	-109,313
	Subtotal	*-17,808*	*-117,263*
Total O&M cost (million €/yr)		0.59	0.55
Total O&M cost per capita (€/cap/yr)		2.2	2.1

Step 5: Cost estimation - summary

Parameter	Option	
	Option 1 (VIP system)	Option 2 (UDD system)
Total capital costs (million €)	7.1	10.4
Capital costs per capita (€/cap)	27	39
Total O&M cost (million €/yr)	0.6	0.5
O&M cost per capita (€/cap)	2.2	2.1
Total NPV (million €), based on 12% discount rate and 10 year project lifetime	10.5	13.5