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DECENTRALIZED SANITATION SYSTEMS FOR THE SOUTHERN ECUADORIAN ANDES, ASSESSMENT AND CHALLENGES

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Southern Andes of Ecuador

Rural and sub-urban population: +/- 700 000
20% still missing improved sanitation; wastewater treatment < 5%

Southern Andes of Ecuador

- **Climate-morphological conditions**
  - **1500 – 3200 m.asl**
  - **Temperatures 12 – 24 ˚C**
  - **No scarcity of fresh water resources**
  - **Rainfall 660 - 3400 mm/year**
  - **Mountain rivers… high self-purification capacity**
- **Domestic wastewater**
  - **Highly diluted: drinking water 150-300 l/hab-day**
  - **Low organic concentration: 100-250 mgBOD/l**
  - **Pathogen concentration: 6-9 log units**
  - **Infiltration and illicit connections**
  - **High concentration of particulate runoff material**

Southern Andes of Ecuador

- **Sanitation long-term objectives**
  - **Efficiency and sustainability: Decentralized systems**
  - **However, efficiency means prioritizing**

- **Resource recovery**
- **Public health (pathogen removal)**
- **Environment (organic matter and nutrients)**
- **Construction and O&M cost**

1. **Public health (pathogen removal)**
2. **Construction and O&M cost**
3. **Environment (organic matter and nutrients)**
4. **Resource recovery**

The review: potential technologies

- **Methodology:**
  - Review of good technological examples at comparable climate conditions
  - Interview to managers and users of DWWT systems
  - **Assessment of many decentralized system constructed in the last two decades**
  - Assessment of Community capacities and willingness for the operation and maintenance of the systems

	Place of study	Weather	Population	Objective / Methodology	Applied Technology	Water Type	Results /Analysis
(Elmitwalli et al., 2003)	Netherlands	T: 13 °C (Winter), 18 °C (Summer)	1000-20000	Feasibility of anaerobic wastewater treatment at low temperatures and low costs of investment and maintenance.	Two stage Hybrid Anaerobic Septic Tank	Domestic Wastewater.	87% reduction of COD at low temperatures. Sludge cleaning after one year.
(Parkinson, 2003)	Peri-urban areas in low-income dev. countries.	Variable.	Varies	Wastewater treatment at low cost and effluent reuse	Anaerobic Treatment, Reactor with baffles and stabilization ponds.	Domestic Wastewater.	Anaerobic treatment: no external energy, small pathogen reduction. Two chambers baffled reactor: similar to UASB. Stabilization ponds: pathogen removal and effluent reuse.
(Langergraber and Muellegger, 2005)	Peri-urban in: Uganda, Germany, Denmark y Finland.	Variable.	No Data	Introduction to EcoSan principles and concepts including re-use aspects	Dry toilets and reuse of nutrients.	Human wastes.	EcoSan systems minimize hygienic risks and protect the environment; help the return of nutrients to the soil, and conserve valuable water resources.
(Kujawa-Roeleveld and Zeeman, 2006)	Peri-urban areas in low-income DC	Temperature: 20°C y 13 °C.	Varies	Gray and black water are analyzed, comparing their composition with their location, lifestyle, customs and facilities	At 20 °C: A UASB, followed by a septic tank. 13 °C: Anaerobic filter (AF) followed by a AH	Gray, black and rainwater.	At high Temp, COD is removed up to 80-90%. At low Temp COD is removed up to 71%. By separating the gray and black waters, 80-95% of nutrients can be recovered..
(Abegglen and Siegrist, 2006)	Solothurn (Switzerland)	Temperature: 16°C,.	250,000	In-situ domestic wastewater treatment, effluent reuse, low drinking water demand.	Membrane reactor: primary clarifier and activated sludge with a submerged membrane plate. Both with aeration	Domestic Wastewater.	Nitrogen and Phosphorus are removed at 90%. Drying is good at low Temp (10°C), Total Organic Carbon (TOC) and COD removal from 90 and 95% respectively.
(Mendez et al., 2008)	Orizaba, Veracruz (Mexico)	Temp max 25; min 16°C; rainfall 2238 mm/y; 1232 m asl	120,995	After a primary and advanced treatment, the best conditions for pathogen removal and reuse	Hom Kinetic Model for fecal coliform (FC) and Salmonella inactivation by Ammonia doses	Municipal and agroindustrial wastewater.	At higher Temp, less ammonia required for microorganisms inactivation.
(Fach and Fuchs, 2010)	Gunung Kidul (Indonesia)	Temperature: between 21 °C and 32 °C	Varies	Potential of reuse of effluents and stabilized sludge from septic tanks	Anaerobic digestion in septic tanks and aerobic filtration. Sludge dehydration, reuse as fertilizer.	Domestic Wastewater.	Sludge obtained from a septic tank and from solid wastes used as fertilizer. Effluent used for irrigation.
(Rojas-Higuera et al., 2010)	Bogotá (Colombia)	Temp: 13 °C, Rainfall: 890 mm/y, 2600 m asl	36 km from Bogotá.	Treatment of sludge from oxidation ponds, and reuse in agriculture.	Chlorination and photo catalytic TiO_2 combined with high Temp.	Sludge from domestic wastewater.	In 8 hours, chlorination does not eliminate coliforms and E. Coli completely. The heterogeneous photocatalysis with TiO_2 remove pathogenic organisms in 30 minutes.
(Nanninga et al., 2012)	Xochimilco (Mexico)	Temp 15 °C, rainfall 60 mm/y, 2240 m asl	415,000	Acceptance of people to decentralized technologies for recover and reuse water, nutrients and energy.	Ecosan toilets, toilets with filters and wetlands.	Domestic WW, rainwater, waste, urine and feces.	Acceptance of people is essential for implementation of decentralized technologies. Recovery of nutrients, water and energy with low cost and protecting the environment.
(Ghaitidak and Yadav, 2013)	Perth (Aus), Calicut (Ind), Dakar (Sen), Amman (Jor), South Africa, Sana-a (Yem).	Different conditions	Varies	Advantages of treating gray water separated with a focus on reuse.	Anaerobic treatment, Wetlands and Filtration.	Gray water.	The best method to ensure reuse is an anaerobic system followed by aerobic system and post disinfection.
(Silva-Leal et al., 2013)	Cañaveralejo, Cali (Colombia)	Temp: 23°C, rainfall 908 mm/y, 1018 m asl	2,060,000	Elimination of pathogens in treated and drying biosolids to get class A qualification.	Thermal drying and alkaline treatment.	Domestic Wastewater.	Temp for thermal drying are 60, 65, 70 and 75°C , 8 to 16 hours. For alkaline treatment doses of quicklime to up 9% for 5 days, gets N reduction. Treatments qualify as class A.

Reference	Place of study	Population	Current infrastructure	Social aspects	Actions / method	Results
(Sundaravadivel and Vigneswaran, 2001)	India: Andipatti, Bodinayakkanur, Cumbum and Theni.	5000-10000	Dry latrines. WW collected in open channels; effluent used in irrigation.	The communities receive little attention from authorities.	Surveys and registration of diseases, water analysis.	With low investment, removal of 70-80% of BOD, and up to 2 log units of FC. O&M acceptable for authorities
(Parkinson, 2003)	Peri-urban, low-income areas in developing countries	Different range	Not access to safe drinking water and sanitation facilities.	WW in direct contact to people, No interest for environment and health problems.	Coordination between government, privates and community, identifying local skills and creating knowledge	Information and knowledge created in the residents for treating their wastewater. Responsible suppliers and technical support were considered in centralized areas.
(Heymans et al., 2004)	South Asian countries: Bangladesh and Vietnam.	No Data	A small percentage of homes have latrines and septic tanks.	deficient environment and public health knowledge in communities, disconnection to government	Community participation guarantees an appropriate management with support of local authorities.	An agreement between the community and governments, has been achieved for a long term management of the DWWT
(N. Viet Anh et al., 2004)	Hanoi, Vietnam	1,7 millions	65% have sewage connection. Black waters are treated in STs and discharged in a river.	The population density is rapidly growing, due to industrialization. High pressure on natural resources	Preparation of system managers for the O&M. Citizen participation without exclusion.	The government is compromised to support and follow up the actions. The community pays a fee for wastewater treatment.
(Beausejour and Nguyen, 2007)	Kim Chung- Lai Xa, Vietnam	4000	In Vietnam 55% of inhabitants had access to latrines in 2006	Rural sector faces urgent sanitation needs, demanding flexible solutions adapted to their local conditions.	Management of solid wastes (from 2003) and Management of liquid wastes (from 2005).	Better hygiene practices at homes. Trained people from the community involved in decision making and system maintenance.
(Kamal et al., 2008)	Urban and Peri-urban areas of south and southeast Asia	1-100 homes	Big cities have poor treatment. Small towns without any collection or treatment.	Lack of coordination between different levels of government with rural communities.	Coordination between the central and local government. The reuse as the key objective with community participation	Coordination between all water companies in each country. Selection of simple and cheap technologies.
(Kema et al., 2012)	Mtwara rural district, Tanzania	203000 people 375 homes	Scarce or no access to ventilated or traditional latrines.	Only 40 out of 118 villages have access to sanitation. Low quality of life	Surveys to collect demographic, socioeconomic, hygiene practices and the type and status of latrines in use.	Less than 50% of the members in each household use latrines. There is lack of education about the importance of personal hygiene.
(Meleg, 2012)	Bahía, Ceará, Piauí, Brazil	No Data	There are access to latrines and primary treatment to small scale.	Low-income communities accept help from private entities or governments.	Model SISAR: the income of big systems, compensates the costs of O&M of small systems, providing also overall support	There was a great acceptation of the SISAR model by inhabitants, and the support of external organisms.
(Fam et al., 2014)	Melbourne, Australia	3,6 millions	Separate sewerage systems (sanitary and storm). Artificial wetlands systems.	Melbourne inhabitants are well aware of planning and collaboration for a good quality of life.	Educational campaigns for a price scheme to compensate the water conservation in homes and industries	Training to local leaders in workshops for decentralized wastewater treatment and reuse of effluents.
(Van Dijk et al., 2014)	Dar es Salaam, Tanzania and Kampala, Uganda	Dar es Salaam (5 millions), Kampala (1,2 millions)	Shared toilets and latrines in poor condition. Open defecation.	Unhealthy environments and high rate of diseases. No investment in sanitation from authorities	Qualitative and quantitative surveys about life style and financial organizations in each neighborhood.	35% willing to improve sanitation, 40% with their self-work and 25% will not contribute by their economic condition.
(Kouamé et al., 2014)	Yamoussoukro, Côte d'Ivoire.	300,000 people (492 homes)	Dry latrines, STs. No sludge disposal. Effluent reuse in agriculture without any treatment.	High levels of diarrhea and malaria, directly associated with the lack of sanitation.	Transdisciplinary research, workshops and mapping. An analysis of the risk factors and health.	A network was created for sharing information between interesting parts, authorities and the local community, in order to improve the quality of life.

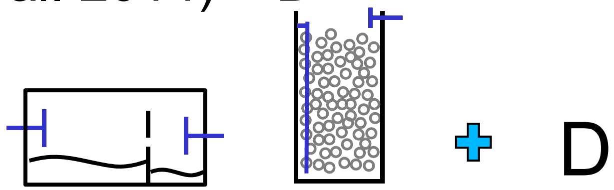
- **Assessment of existing decentralized system constructed in the last two decades**

- **Assessment of existing decentralized system constructed in the last two decades**

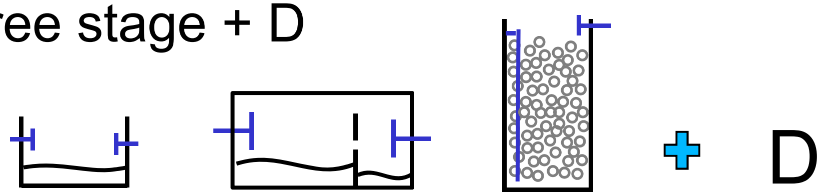
  - More than a half of the systems are not receiving O&M for years
  - 1/3 are collapsed and abandoned
  - Some few are in operation
  - **No one is accomplishing the ultimate objective: pathogen reduction**

- **The main goal:** disinfection
- **The challenge:** to get an adequate effluent for applying any disinfection technology (chlorination, UV radiation, photo catalysis with TiO_2)
- **For highlands > 2400 m.asl**

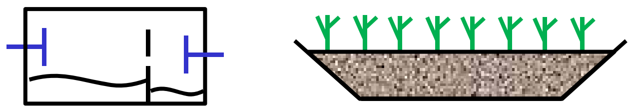
1. Two stage: Septic Tank + Anaerobic filter. Hybrid ST (Sharma et. al. 2014) + D



2. Three stage + D

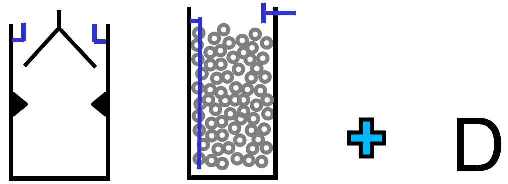


3. Two stage: Septic Tank + Constructed wetland



- **For lowlands**

1. Two stage: UASB + Anaerobic filter + D



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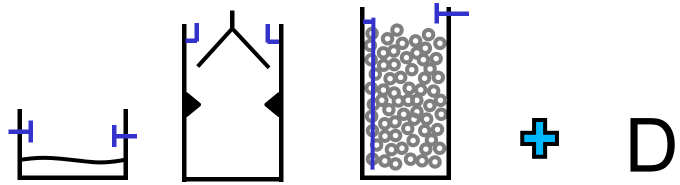

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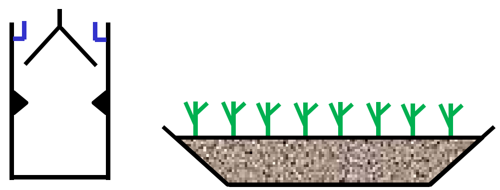

Organization capacities at users level

- The need of **users awareness** about the **benefits** of domestic effluent treatment to preserve the public health and the environment.
- The community **organizational capacities** could be noticeably **improved** with the involvement of community leaders in the O&M responsibilities.
- The public institutions should aim to decentralize and **reinforce** the administrative and organizational capacities of the communities
- In Ecuador, it is still necessary to reinforce **scientific research** towards decentralized WWT technologies and to strengthen the **capabilities** of the **engineers** in the whole process of technology selection, design, and operation and maintenance of the decentralized DWWT systems..

- Public Health as the main objective in the sanitation program at Ecuadorian Andes
- Disinfection is feasible when the effluent presents adequate characteristics
- The temperature is a determinant factor when considering the technical feasibility of the systems
- The anaerobic systems are a feasible alternative, particularly septic tank units or UASB reactors.
- Septic tanks followed by an anaerobic filter or constructed wetlands are good alternatives for both BOD and pathogen reduction.
- These technological alternatives require, however, a validation by pilot experiences
- The level of success of the decentralized system is directly proportional to the level of community involvement.

Thank you for your kind attention

Acknowledgements:

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