ACF-INTERNATIONAL
MANUAL

Sustainable sanitation for vulnerable population in periurban areas of Ulaanbaatar, Mongolia

Compendium of 14 thematic peered papers

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May 2015
WASH sector
Expertise and Advocacy Department

Action contre la Faim-France

FOREWORD

Action contre la Faim (ACF) has been working in Mongolia since 2001; both in Ulaanbaatar Ger areas (urban formal and informal slums), and the western Bayan Ulgi (province), undertaking multi-year food security, WASH and nutrition programmes.

Both water and sanitation sub sectors are a growing concern: the current method for excreta disposal is using basic, often poorly constructed unsealed pit latrines. The current system is causing intense biological contamination of groundwater resources, and as many Ger[1] areas overly aquifers, endanger the water supplies currently used to supply the city. The unhygienic designs also allow the proliferation of disease spreading flies, and bring issues of odours. Domestic grey water disposal is either into inefficient on-site pits or latrines, or thrown indiscriminately into the street. The latter is causing ice hazards in winter, and providing breeding grounds for disease spreading vectors in summer. Water distribution in peri-urban areas is both a concern in term of sustainable access (especially in winter time) and quality.

The WASH research project (2011-2015) with strong involvement from local partners and academic partners, especially the **University of Sciences and Technology from Beijing, China,** aimed at testing appropriate technologies & solutions; identify effective methods for their promotion; and reinforce the public and private sector to deliver the identified solutions. Specifically it focused on:

- Addressing issues of low water consumption of kiosk users and researching kiosk management
- Identifying and piloting sustainable on-site sanitation options
- Improving domestic water management and other hygiene practices

More generally, the project aimed at exploring how to **'close the loop'** and evolved progressively from technical to environmental and advocacy thematic, especially focusing on green economy and eco-cities approaches. Whilst some aspects of the programme are specific to Ulaanbaatar (such as the climate), the broader issues addressed of improving access and delivery of WASH services to the urban poor are relevant around the world, like Bangladesh, where ACF intervenes.

The current compendium presents the **fourteen peer reviewed publications** produced by the project, on the following issues: **eco development, socio-economics, health WASH related issues, compost and reuse and grey water management.** Those scientific papers should be however red in perspective with the PhD Thesis and the numerous un-peered reports produced by the project, and available in ACF[2].

Dr Jean Lapegue,
Research Project Steering Committee,
ACF-France, May 2015

1 - Peri-urban area, neighbourhood

2 - Please ask Dr. Jean Lapegue, Senior Advisor WASH, ACF-France, jlapegue@actioncontrelafaim.org

TABLE OF CONTENTS

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ACKNOWLEDGMENTS

Thanks go to the authors for their essential contributions to this publication. We especially thank the Scientific and Technical Direction of ACF-France for the funding and coordination of this project: Ioana Kornett, Technical Director, Dr. Jean Lapegue (WASH) and Myriam Ait Aissa (Research).We also thank the Operations Direction of ACF-France, namely Julien Eyrard for the overall operational project management and the Mongolia ACF Mission in the name of its Country Director, Clement Philit and its WASH coordinator, Eric Rheinstein. Ultimately and mostly, we thank the academic support team and structure, Heinz-Peter Mang, Guest-Professor and Senior Engineer, Professor Dr. Zifu Li, from the Centre of Sustainable Environmental Sanitation (CSES), School of Civil and Environmental Engineering, University of Science and Technology Beijing (USTB) and Sayed Mohammad NAZIM UDDIN, PhD Researcher/Project Manager and lead author.

For their review of drafts and suggestions of materials and ideas:

Sayed Mohammad NAZIM UDDIN, PhD Researcher/Project Manager, (CSES & USTB), Dr. Jean Lapègue, Senior WASH Advisor, ACF-France and Julien Eyrard, WASH Advisor, ACF-France

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1. SUSTAINABLE SANITATION FOR VULNERABLE PERI-URBAN POPULATION IN ULAANBAATAR, MONGOLIA: AN INTRODUCTION OF MULTI-LATERAL COOPERATION PROJECT

JADE Conference, november 2013, Tokyo, Japan

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Abstract

Modern Mongolia, the Mongolian People's Republic, has a rich heritage of science and culture, influenced strongly by China and the Russian Federation, which comprise its borders. The country boasts the coldest capital city of the world with an annual mean temperature of -3.7° C and a harsh climate with low precipitation (approximately 200 mm/year). Ulaanbaatar, the capital of Mongolia, has a population of over one million people and is experiencing an influx of migrants from rural areas resulting in many environmental, health and socioeconomic problems. Forest fires, floods, waterborne diseases, unsafe water supply, inadequate sanitation, insufficient heating, absence of suitable roads, high concentration of uranium in its groundwater, wetlands and river pollution due to industrial and agricultural pollution as well as the untreated wastewater from the city's sewage treatment plants, and heavy metal (Arsenic and Lead) pollution in the soils lead the list. Improper wastewater treatment was identified as one of the major causes of Tuul River degradation in the last decade.

Much of the population in the capital city region inhabits Ger areas, which are the peri-urban unplanned informal settlements that surround the city. Ger areas comprise approximately 60 percent of the total population of Ulaanbaatar, and their populations continue to increase. Unlike their urban neighbors that occupy apartments or site-built homes, Ger area residents live in felt tents or yurts (Gers), although recent investigation indicates that even in the Ger areas, some modernization is occurring. Water supply and sanitation have been identified as some of the most pressing needs in the Ger areas of Mongolia where simple, unimproved pit latrines are generally used for solving sanitation problem. To focus on this particular need and to find a sustainable solution for sanitary improvement in peri-urban Mongolia, a PhD research project, jointly executed by University of Science and Technology Beijing (USTB) and Action Contre la Faim (ACF), was initiated in March, 2012. The overall goal of the project is to develop a holistic and sustainable sanitation approach for the benefit of the most vulnerable populations in peri-urban Mongolia. It will be developed, tested, recognized and disseminated through the ACF partner network and other missions. In addition, Eco-City concept (environmentally sustainable cities) will be developed through the contribution of a sustainable sanitation system for the Ger Area of Ulaanbaatar.

Keywords: Sustainable sanitation, resource recovery, ger areas, grey water treatment, eco-city.

Introduction

Modern Mongolia, the Mongolian People's Republic, occupies only about half of the land mass of the great Asian region known throughout history as Mongolia. It has a rich heritage of science and culture, influenced strongly by China and the Russian Federation, which comprise its borders. It is one of the least densely populated countries of the world where approximately 2.9 million people inhabit 1.56 million square kilometers. Furthermore, the country boasts the coldest capital city of the world with an annual mean temperature of -3.7° C and a harsh climate with low precipitation (approximately 200 mm/year) (Hauck 2008; Altansukh 2008; Narangoa, 2009; Aassve and Altankhuyag, 2002].

Ulaanbaatar, the capital of Mongolia, has a population of over one million people and is experiencing an influx of migrants from rural areas resulting in many environmental, health and socioeconomic problems. Forest fires, floods, waterborne diseases, unsafe water supply, inadequate sanitation, insufficient heating, absence of suitable roads, high concentration of uranium in its groundwater, wetlands and river pollution due to industrial and agricultural pollution as well as the untreated wastewater from the city's sewage treatment plants, and heavy metal (Arsenic and Lead) pollution in the soils lead the list [Itoh et al., 2011; Nriagu, 2012; Batjargal, 2010; Altansukh, 2008; Asian Development Bank, 2010]. Improper wastewater treatment was identified as one of the major causes of Tuul River degradation in the last decade [Altansukh, 2008].

Much of the population in the capital city region inhabits Ger areas, which are the peri-urban unplanned informal settlements that surround the city. Ger areas comprise approximately 60 percent of the total population of Ulaanbaatar, and their populations continue to increase. Unlike their urban neighbors that occupy apartments or site-built homes, Ger area residents live in felt tents or yurts (Gers), although recent investigation indicates that even in the Ger areas, some modernization is occurring. Water supply and sanitation problems have been identified as some of the most pressing needs in the Ger areas of Mongolia [Sigel, 2012] where simple, unimproved pit latrines are generally used for solving sanitation problem [GIZ, 2008].

Although Mongolia is 'on track' to meet the MDG drinking water target, but it is 'off track' to meet the sanitation target [UNICEF and World Health Organization, 2012]. The global population is divided into two, urban and rural, most of the report covers these two groups. However, it is urgently needed to focus on peri-urban population where major people are more vulnerable to lack of access to safe drinking water and sustainable sanitation system than other two groups.

Many studies (more than 100) have already been carried out by various Mongolian authorities, NGOs, Universities, consultant companies, and international donor agencies identifying the until today existing challenges on safe and environmentally sound disposal of human excreta and grey water in Ger areas. One concept that has been tried out on a small scale is "ecological sanitation". This approach, which is well-established and widely applied in many parts of the world, aims at reusing nutrients, water and energy contained in wastewater by considering them as resources. There are only few organizations working on ecological sanitation in Mongolia, but many other sanitation projects have been tried. Most sanitation activities are integrated as sub-activity in water supply projects, and their planning, but not their results are well documented. It is therefore quite difficult to get a good sense of what has been done, and how much has been tried. Thus the today remaining challenge focuses on suitable technical and organizational options for grey water management and faecal material treatment taking into account the specific climatic and socio-cultural conditions of Mongolia, and even more specific the conditions of Ulaanbaatar's Ger areas.

Project components

Very few systematic research projects have been conducted on the water, sanitation and hygiene (WASH) sectors in Mongolia and none related to the potential for achieving sanitation improvements utilizing the concepts of 'Ecological Sanitation' (sanitation programs that utilize resource recovery to drive sustainability). To focus on this particular need and to find a sustainable solution for sanitary improvement in peri-urban Mongolia, a PhD research project, jointly executed by University of Science and Technology Beijing (USTB) and Action Contre la Faim (ACF), was initiated in March, 2012. The overall goal of the project is to develop a holistic and sustainable sanitation approach for the benefit of the most vulnerable populations in peri-urban Mongolia. It will be developed, tested, recognized and disseminated through the ACF partner network and other missions. In addition, Eco-City concept (environmentally sustainable cities) will be developed through the contribution of a sustainable sanitation system for the Ger Area of Ulaanbaatar. ACF France is financing the implementation of the project. The project will run up to the end of 2015. Figure 1 shows the project goal, objectives and possible outcomes.

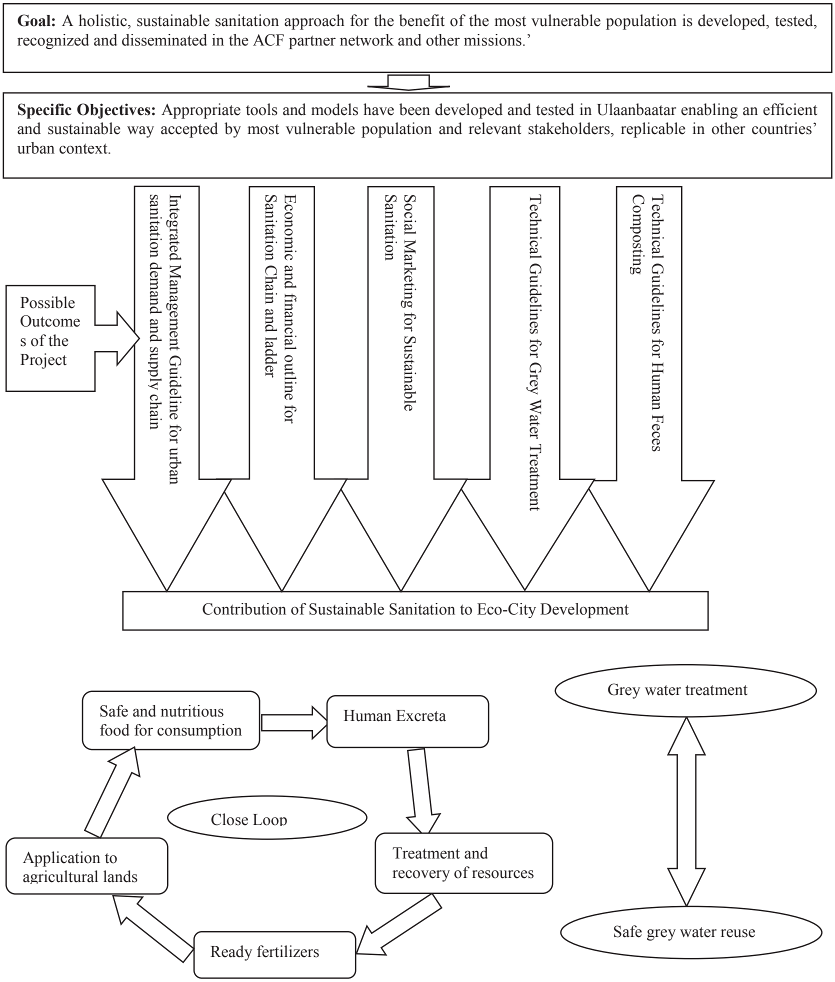

Figure 1: Project goal, objectives and possible outcomes.

ACF's Motivation

The ACF motivation is double: first, the on-going ACF WASH program in Ulaanbaatar needs, at this stage, additional expertise, scientific contribution and a thorough capitalisation. To achieve sustainable sanitation, ACF has opted for the centralised composting of human excreta. It is, in such harsh climate, both a technical challenge and a rather unexplored field. A dedicated scientific contribution is required to analyse and fine-tune the composting process. On top of this ACF must develop a thorough understanding of the economical and marketing aspects of the Compost in Mongolia if to make it viable and replicable. Mongolian students and Universities will collaborate with international students and experts to ensure the 'anchoring' and development of ecosan in Mongolia. Secondly, beyond Mongolia, this research works will provide great contribution to ACF and international humanitarian & development community on ways to address peri-urban sanitary crisis, in cold climate and beyond. It is believed that the ACF WASH experience in Ulaanbaatar has already made great achievements, and it is a unique opportunity to consolidate this work, to produce evidence, to publish guidelines and to disseminate for the benefit of practitioners and researchers.

ACF specific motivations about this research project are, in line with ACF 2015 Strategic framework:

To prevent humanitarian crises, address vulnerability and reinforce longer term resilience to food, water and nutritional crises (Strategic Pillar 2 & Pillar 4)

- To develop an adapted WASH approach to the urban context, which will be the most important at-risk context and thus ACF field of intervention in future
- To develop an approach for scaling-up sanitation and effectively reducing public health risk
- To develop expertise in the ecological sanitation sector

To develop partnerships with local, national and international stakeholders to increase the number of people ACF assist to, and promote sustainability (Strategic Pillar 3)

- To develop know-how in effective PPP partnerships
- To develop international networking and information sharing among the peri-urban humanitarian and development practitioners, the eco-sanitation stakeholders and increase the ACF visibility in the related scientific community
- To initiate and develop a partnership between ACF and USTB-CSES that can represent an added value in term of technical support, Human Resources, networking, and possibly for other sectors than WASH (nutrition, food security)

To build up ACF capacity to ensure effective and efficient responses to humanitarian crises (Strategic Pillar 4)

- To develop ACF expertise in associated new transversal topics like social marketing, social financial mechanisms and product oriented approaches
- To contribute to an improved integration of WASH, food security and livelihood activities
- To promote replicability and sustainability of ACF operational approaches (sharing the results and recommendations with other missions)

This research project intends also

- To review ACF's present practices and policies in relation to implementing integrated sanitation approaches with a specific focus on evidence for successful integrated programmes
- To assess whether and how sustainable sanitation tools could be strengthened to provide a greater understanding of their contribution towards integrated programmes

- To identify and analyse opportunities and constraints to having integrated programmes, including social sanitation marketing partnerships with other agencies
- To recommend practical steps to improve the implementation of integrated sanitation approaches inside complex programmes

Benefits and Advantages of the Project

Interest for the Beneficiaries

Estimated number and type of beneficiaries involved: main geographical areas concerned

Mongolia

- Ger area inhabitants of Ulaanbaatar (60% of the capital population)
- Indirectly all the countryside population living in small cities (at least 1,380,000 persons)
- Local universities

Other ACF missions

- The methodology and the approach developed in Mongolia will be replicable by other ACF missions where projects are implemented in an urban context.
- The expertise and the professional network developed during the research will benefit to other missions (e.g. consultancies, training tools).

International community

- Publication of research results will benefit other international universities, research centres and NGOs, donors and foundations.

Impact of the implementation of results by local staff

- Improvement of living conditions (health protection)
- Contribution to the protection of the beneficiaries' environment (e.g. river, ground water, soil)
- Business opportunities through the development of a sanitation market
- Capacity building of local actors (NGO, local authorities, private sector) to achieve sustainability

Operational Improvement of ACF's Practices

- Improvement of ACF WASH rehabilitation and pre-development approach in urban context
- Contribution to ACF WASH emergency programmes in urban context through the development of technical (e.g. human excreta reuse, grey water management) and non-technical skills (e.g. social marketing, multi sector coordination)

Scientific Interest

Multidisciplinary research project considering the economic, legal, social, environmental and technical aspect of urban sanitation for vulnerable population groups.

Cities are habitats, resource sinks, cultural centres, economic hubs, designed spaces, networks, political powers, and ecosystems. All too often, these different aspects are studied in isolation, but to achieve sustainable development there is an urgent need to integrate different perceptions and models. The population shift towards urban settlements is an epoch-making process. Today, about half of the world's population lives in urban areas. By the year 2050, the proportion in urban regions is expected to grow to 70%, and the total urban population will have doubled [WHO, 2013]. Cities will grow in size and number. It is clear that not one scientific discipline has all the answers, but that the viewpoints of different disciplines must be combined when challenges of urbanization should be resolved.

Two characteristics of ecosystems are nutrient cycling and the influence of infectious diseases, and these examples illustrate how ecological ideas can contribute to understanding and meeting the challenge of urban population growth. Most natural ecosystems are characterised by a closed nutrient cycle, in which the nutrients that plants and animals need are recycled within the system and only very small amounts are transferred (lost) to other systems. Natural ecosystems that are dependent on external inputs and lose a lot of nutrients to other ecosystems are generally unstable and not sustainable. Cities are characterized by mono-directional nutrient flows – they are dependent on large inputs of food from distant areas and dispose of large quantities of waste into surrounding areas. The great quantity of nutrients removed from agricultural land, transported to cities, and then rapidly transferred to the final disposal, is leading to severe environmental problems. In order to close the urban-rural nutrient cycle a comprehensive ecological understanding of cities and agro-ecosystems is required. Therefore an intensive interdisciplinary and trans-disciplinary cooperation of scientists, decision makers, supporting institutions and stakeholders is needed.

The growth of cities causes many severe sanitation and water supply related as well as environmental problems that are highly interlinked. The proposed research project will address this complexity by developing a holistic model that indicates the effects of certain parameter changes on all parts of the whole system.

Technical and scientific challenges due to the specificities of the case study (extreme cold climate, nomadic culture, low community spirit)

An improvement of sanitation cannot be fully achieved by e.g. the construction of new toilets alone. A new legislative environmental sanitation framework for recently settled nomads is urgent, since traditional rights largely lost their meaning. As a direct result of urbanization, great threats to health have arisen due to water, soil and air pollution, especially at household level. Waterborne diseases are found most commonly in low-income Ger neighbourhoods as a result of inadequate sanitation and drainage and incomplete solid waste collection services.

Efforts towards the improvement of access to sanitation services should be integrated within health, education, urban agriculture and development systems, and former nomadic communities must be involved throughout the process. Egalitarian reasons justify efforts to develop innovative and adapted sanitation services for former nomadic people, now settled in Ger areas. Yet, there is a need to establish with more precision measures against sanitation inequalities with regard to the status of the Ger population. Finally, other kinds of services and infrastructure – notably safe water and energy supply – are also crucially important for mitigating the health and environmental risks for Ger households.

Boundaries of the Scope of Work of the Project and the covered Area

This research project is solely focusing on the human excreta (faeces and urine) management chain in the urban (Ger) context. In addition, household level greywater treatment and reuse options are considered under this project to protect the Ger residents from environment and health hazards. The study will be specific to Mongolian urban contexts (extreme temperature, cultural background) to solve the sanitation problems in Ulaanbaatar concerning the MDGs, and therefore, specific results and developed systems of the research are disseminated to other similar regions in developing countries. The study will strengthen the capacity building to local personnel to be replicated in other countries, and to train the young students and researchers to be professionals in future.

Research Hypothesis

- Contribute to the close-loop of nutrient cycle through composting of human excreta.
- Reduction of waterborne diseases.
- Faecal compost produced scientifically will be socially and culturally accepted.
- Faecal compost can replace the chemical fertilizers to some extent.
- Treated greywater can be reused in urban gardening, greening city, peri-urban agriculture etc.
- Treated greywater might create different business options.
- Towards the eco-city development.

CONCLUDING REMARKS

Since foundation in 1979, Action Contre la Faim (ACF) International focusing its activities on an integrated approach, taking various aspects into account: "Nutrition, health and healthcare practices", "Food security and livelihoods", "Water, sanitation and hygiene" and "Advocacy and awareness-raising". In 2010, ACF-International is active in over 40 countries, coming to the aid of around 5 million individuals. Therefore this research project may contribute through promising ecological sanitation/sustainable sanitation systems and strategies to the target communities by exploring and documenting scientifically towards the dissemination.

ACKNOWLEDGEMENT

The support from ACF France, ACF Mongolia is acknowledged.

REFERENCES

Aassve, A., Altankhuyag, G., (2002). Changing pattern of Mongolian fertility at a time of social and economic transition, Studies in Family Planning, 33, 2, 165-172

Altansukh, O., (2008). Surface water quality assessment and modeling: A case study in the Tuul River, Ulaanbaatar city, Mongolia. Master's Thesis, International Institute for Geo-Information Science and Earth Observation, Enschede- The Netherlands.

Asian Development Bank (2010). Mongolia: Ulaanbaatar water and sanitation services and planning improvement, Technical Assistance Report, Asian Development Bank, Manila- Philippines.

Batjargal, T., Otgonjargal, E., Baek, K., Yang, J., (2010). Assessment of metals contamination of soils in Ulaanbaatar, Mongolia. Journal of Hazardous Materials, 184, 1-3, 872-876

GIZ (2008). ECOSAN- Ecological Sanitation in Mongolia, Result oriented monitoring – a rapid appraisal.

Hauck, M., (2008). Epiphtic lichens indicate recent increase in air pollution in the Mongolian Capital Ulaanbaatar, The Lichenologist, 40, 2, 165-168

JADE Conference, November 2013, Tokyo, Japan

Itoh, M., Takemon, Y., Makabe, A., Yoshimizu, C., Koshzu, A., Ohte, N., Tumurskh, D., Tayasu, I., Yoshida, N., Nagata, T., (2011). Evaluation of wastewater nitrogen transformation in a natural wetland (Ulaanbaatar, Mongolia) using dual-isotope analysis of nitrate, Science of The Total Environment, 409, 8, 1530-1538

Narangoa, L., (2009). Mongolia and Preventive Diplomacy and Becoming cosmopolitan, Asian Survey, 49, 2, 358-379

Nriagu, J., Nam, D., Ayanwola, T. A., Din,h H., Erdenechimeg, E., Ochir, C., Bolormaa T., (2012). High levels of uranium in groundwater of Ulaanbaatar, Mongolia. Science of The Total Environment, 414, 722-726

Sigel, S., Altantuul, K., Basandrorj, D., (2012). Household needs and demand for improve water supply and sanitation in peri-urban ger areas: the case of Dharkhan, Mongolia. Environ Earth Sci, 65, 1561-1566

UNICEF and World Health Organization (2012). Progress on drinking water and sanitation, Joint Monitoring Program for Water and Sanitation, New York-USA.

WHO (2013) Urban population growth. Website: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/(accessed August 2013)

2. EVALUATION OF A CLOSED-LOOP SANITATION SYSTEM IN A COLD CLIMATE: A CASE FROM PERI-URBAN AREAS OF MONGOLIA

The 12th IWA Conference on Small Water & Wastewater Systems & 4th Specialized Conference on Resources Orientated Sanitation, November 2-4, 2014, Muscat, Sultanate of Oman.

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ABSTRACT This study examines a closed-loop sanitation system (CLSS) in the ger areas (informal peri-urban settlements) of Ulaanbaatar, Mongolia in order to evaluate system feasibility and to identify the future prospects of CLSS as an alternative to conventional sanitation and drainage options. Results show that the CLSS concept is well understood and accepted by users and that services are being scaled up. Over 50 per cent of respondents used CLSS technologies during both winter and summer, testifying to the potential for scaling up these technologies and services. Moreover, all users responded positively in their evaluation of the emptying services. Despite some problems and challenges, the system proved to be feasible, replicable and acceptable in the study area. It is recommended that the entire CLSS approach be tested through scientific validation to convince more communities, government and other stakeholders about scaling up the system beyond the study area for better health, environmental conservation and resource recovery.

KEYWORDS closed-loop sanitation system / cold climate / composting / emptying services / ger areas / urine-diverting toilets

I. INTRODUCTION: THE CLOSED-LOOP SANITATION SYSTEM

This paper reports on a study exploring the use of a closed-loop sanitation system (CLSS) in an area of Mongolia, in order to evaluate the feasibility of the system in this context and to identify the prospects for its wider use as an alternative to conventional sanitation and drainage systems.

A CLSS (Figure 1), also called ecological sanitation (ecosan), is defined as a circular as opposed to a linear system, that treats all sanitation products as resources rather than wastes, while ensuring protection of public health and the environment.(1) This resource recovery and reuse-oriented sanitation system considers both human faeces and urine as potential sources of nutrients, which are returned to the soil instead of being discharged as wastes to water bodies, deep pits or open spaces. Central components of the human waste disposal process include emptying, collection, transportation, storage, treatment (e.g. composting) and

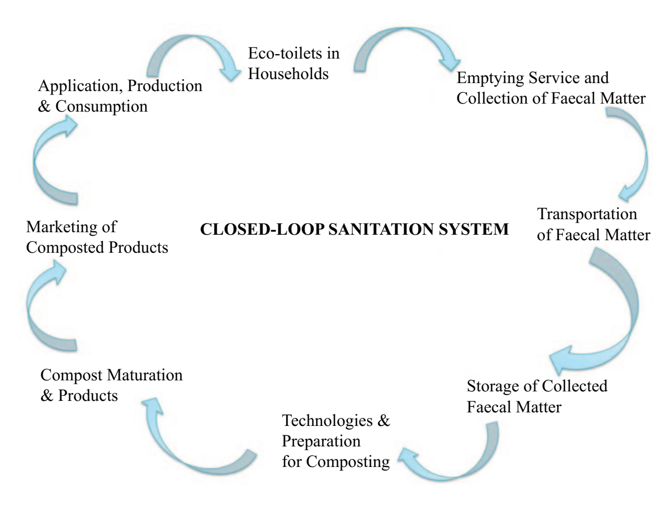

FIGURE 1
Steps of a closed-loop sanitation system

SOURCE: adopted from Uddin, S M N, Z Li, H Mang, E M Huba and J Lapegue (2014), "A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems", *Journal of Water, Sanitation and Hygiene for Development* Vol 4, No 3, pages 437–447.

utilization, as illustrated in Figure 1. Dagerskog and Bonzi have described the system as productive sanitation, whereby human urine and faeces are sanitized and converted into fertilizers for local nutrient management, addressing food security and improving health.(2) Other benefits include reduction of greenhouse gases, reduction of water contaminants, reduction of health and environmental risks, increase of employment opportunities, and greater sustainability.(3)

The system has been implemented in many countries and regions of the world, in different climatic, geological, socioeconomic and sociocultural contexts. Many projects have been successful while others have faced numerous challenges.(4) There have been accounts of social acceptance and effective scaling up of CLSS in tropical countries (for instance, in parts of Kenya and Bangladesh(5)) as well as in the cold climate of Sweden.(6) However, CLSS was not compatible with the sociocultural preferences of rural residents in Pakistan,(7) nor did it work out in apartments in China, where residents were averse to the technical challenges.(8) This study of CLSS implementation in Mongolia's cold climate is an important addition to the existing literature.

II. THE SANITATION SITUATION IN MONGOLIA

Ulaanbaatar, the capital of landlocked Mongolia, faces a range of environmental problems.(9) Recent studies show for instance that the

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1. Esrey, S A (2001), "Towards a recycling society: ecological sanitation - closing the loop to food security", *Water Science and Technology* Vol 43, No 4, pages 177–187; also Esrey, S A, I Andersson, A Hillers and R Sawyer (2001), *Closing the loop: Ecological sanitation for food security*, Swedish International Development Cooperation Agency, Mexico; and Uddin, S M N, V S Muhandiki, J Fukuda, M Nakamura and A Sakai (2012), "Assessment of Social Acceptance and Scope of Scaling Up Urine Diversion Dehydration Toilets in Kenya", *Journal of Water, Sanitation and Hygiene for Development* Vol 2, No 3, pages 182–189.

city faces considerable pollution in its soils and water bodies[10] and that, particularly in the surrounding peri-urban ger area (unplanned, informal settlements), there are a number of challenges in the water, sanitation and hygiene (WASH) sector and in the health sector.[11]

Uddin and colleagues have identified several threats to a safe water supply and sustainable sanitation in the ger area, including approximately 80,000 unhygienic pit latrines,[12] a high prevalence of waterborne diseases and rapid urbanization.[13] *E. coli* has been reported in household drinking water, with higher levels in the summer than winter, which might be due to pathogenic contamination and cross-contamination in the unsafe water collection, transportation and storage system and the unimproved sanitation technologies in the area.[14] Pit latrines are emptied occasionally by conventional vacuum trucks in the ger areas during the summer; however, during the winter, when the temperature goes below 10º C, vacuum trucks cannot be used[15] and alternative solutions need to be explored. Rather than using vacuum trucks, however, most households simply dig a new pit when the existing pit is filled.[16] This will become a challenge in the near future due to the rapid migration of people into the area and also the rocky soil conditions. Household greywater has been routinely disposed of in the pit latrines, soak pits (soakaways) or yards, which also has potential health and environmental hazards and risks due to the high concentration of chemicals (e.g. NH_4^+, NO_3^-) and pathogens (*E. coli*).[17] Most people in the ger area are very interested in appropriate emptying services in order to eliminate the problems related to digging pits and disposing of faecal matter.[18]

III. ACF CLSS INITIATIVES IN MONGOLIA

Ulaanbaatar has seen very few systematic research projects conducted in relation to WASH, and none related to the potential for achieving sanitation improvements utilizing all steps of CLSS suggested in Figure 1. In 2006, GTZ, the German international aid agency, constructed 40 eco-toilets in the ger areas of Ulaanbaatar. However, the implementation of the system did not focus on the entire CLSS process, but only on the toilet component. A rapid appraisal in 2008 concluded that in the majority of cases, the system was not accepted by Mongolian users due to technical problems, limited and infrequent collection, and high construction costs.[19] As a result, the project was discontinued. In its 2008 report, GTZ used the term ecosan to refer to the urine-diverting dry toilets (UDDTs) it had installed. In fact, ecosan is much more than a certain type of toilet. The term refers to any form of recycling of any wastewater products, including compost produced from faeces or urine stored and sanitized and subsequently used as liquid fertilizer.

To focus on the absence of research on interventions using all the CLSS steps, and to find sustainable solutions for health, environment and sanitary improvement in peri-urban ger areas of Ulaanbaatar, Action Contre La Faim (ACF) Mongolia drew from the lessons of the GTZ project and initiated a programme using the full CLSS process, funded by ACF International. This international non-governmental organization, with the collaboration of the University of Science and Technology Beijing (USTB), has focused in Mongolia on preventing acute malnutrition and environmental diseases, through ongoing research and development programmes.

2. Dagerskog, L and M Bonzi (2010), "Opening minds and closing loops – productive sanitation initiatives in Burkina Faso and Niger", *Sustainable Sanitation Practices* Vol 3, pages 4–11.

3. Nakagawa, N, M Otaki, S Miura, H Hamasuna and K Ishiki (2006), "Field survey of a sustainable sanitation system in a residential house", *Journal of Environmental Science* Vol 18, No 6, pages 1088–1093; also Langergraber, G and E Muellegger (2005), "Ecological sanitation—a way to solve global sanitation problem?", *Environment International* Vol 31, No 3, pages 433–444; and Zhou C, J Liu, R Wang, W Yang and J Jin (2010), "Ecological-economic assessment of ecological sanitation development in the cities of Chinese Loess Plateau", *Ecological Complexity* Vol 7, No 2, pages 162–169.

4. See reference 1, Esrey (2001) and Esrey et al. (2001); also see reference 3, Langergraber and Muellegger (2005); Austin, A (2002), *Health aspects of ecological sanitation*, EcoSanRes, South Africa, accessed February 2014 at http://www.ecosanres.org/pdf_files/Nanning_PDFs/Eng/Aussie%20Austin%2028_E25.pdf; Werner, C, P A Fall, J Schlick and H P Mang (2003), *Reasons for and principles of ecological sanitation*, 2nd International Symposium on Ecological Sanitation, Eschborn, April; Nawab, B, I L P Nyborn, K B Esser and P D Jenssen (2006), "Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan", *Journal of Environmental Psychology* Vol 26, No 3, pages 136–246; Stintzing, A R (2007), *Urine Diverting Toilets in Climates with Cold Winters: Technical considerations and the reuse of nutrients with a focus on legal and hygienic aspects*, Women in Europe for a Common Future (WECF), Munich; Karak, T and P Bhattacharyya (2011), "Human urine as a source of alternative natural fertilizer in agriculture: A flight of fancy or an achievable reality", *Resources, Conservation and Recycling*

This CLSS programme was initiated in 2009 at a small scale (120 toilets and the related support) to test the feasibility of the components in one of the ger areas' administrative regions, called Songinokhairkhan District. In this district people have migrated from rural areas and live, for the most part, in traditional yurts (felt tents with a wooden substructure). All initial financial support for the CLSS services, including toilet installations, emptying services, collection and transportation, storage and treatment, was provided by ACF International in order to test the technical feasibility, social acceptability and future replicability of the system. This pilot was also intended to develop the capacity of local partners for handing over the project in the future. This study was carried out in the peri-urban ger areas of Ulaanbaatar in 2012 and 2013 to assess the system feasibility and to identify the prospects for scaling up CLSS at the household or community level in the future.

At present ACF Mongolia implements and maintains the system and its staff are responsible for operating it. However, the private company MonESIK, a local partner of ACF Mongolia, will be taking over the future operation and maintenance of the whole system. This company will also work with the local companies that make the CLSS toilets and will advocate with the government for future scaling up of the system in both the ger areas and other parts of the country. The research has revealed a demand for CLSS toilets in the ger areas, and potential to create a market for this system.

IV. RESEARCH DESIGN AND METHODS

The study was carried out as an ongoing operational research project (2011–2015) entitled "Sustainable Sanitation for Vulnerable Peri-urban Population", jointly executed by USTB and ACF Mongolia, and funded by ACF International France.[20]

The evaluation was carried out through observation of all technical CLSS components and steps (CLSS toilets, emptying services, collection–transportation–storage system, treatment facilities and application of the products), using 10 transect walks in the study area; 72 out of 120 eco-toilets built by ACF were investigated and observed in order to assess technological benefits and shortcomings and the status of maintenance and operation. All the CLSS toilets had been installed outside the ger houses but inside the compounds where houses were located. Toilets are kept separate from houses for sociocultural reasons. Most pit latrines in the ger areas are also separate from the house for this reason.

The emptying of service systems and activities was observed and the emptying service staff were interviewed as key informants to identify the problems encountered during the rollout of the services, seasonal suitability and frequency of emptying cycles during a one-year period. Collection, transportation, storage and treatment systems of faecal matter were monitored to evaluate the processes and to address any challenges and opportunities for future improvements.

A structured questionnaire was administered among the users of CLSS technologies and services using a cluster random sampling method since households were scattered throughout ACF Mongolia's intervention area. 72 households (out of 120 CLSS toilet users) were interviewed. The ACF and World Health Organization (WHO) cluster sampling standard and methodology were followed, in which a 10 per cent margin of error is

Vol 55, No 4, pages 400–408; and Apkan-idiok, A U, I A Udo and E I Braide (2012), "The use of human urine as an organic fertilizer in the production of okra (Abelmoschus esculentus) in South Eastern Nigeria", *Resources, Conservation and Recycling* Vol 62, pages 14–20.

5. See reference 1, Uddin et al. (2012); also Uddin, S M N, V S Muhandiki, A Sakai, A A Mamun and S M Hridi (2014), "Socio-cultural acceptance of appropriate technology: Identifying and prioritizing barriers for widespread use of the urine diversion toilets in rural Muslim communities of Bangladesh", *Technology in Society* Vol 38, pages 32–39.

6. See reference 4, Stintzing (2007).

7. See reference 4, Nawab et al. (2006).

8. Rosemarin, A, J McConville, A Flores and Z Qiang (2012), *The Challenges of Urban Ecological Sanitation: Lessons from the Erdos Eco-Town Project, China*, Stockholm Environment Institute, Practical Action Publishing Ltd, UK.

9. Batjargal, T, E Otgonjargal, K Baek and J S Yand (2010), "Assessment of metals contamination of soils in Ulaanbaatar, Mongolia", *Journal of Hazardous Materials* Vol 184, Nos 1–3, pages 872–876; also Luvsan, M E, R H Shie, T Purevdorj, L Badarch, B Baldorj and C C Chan (2012), "The influence of emission sources and meteorological conditions on SO_2 pollutions in Mongolia", *Atmospheric Environment* Vol 61, pages 542–549; Uddin, S M N, Z Li, H P Mang, E M Huba and J Lapegue (2014), "A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems", *Journal of Water, Sanitation and Hygiene for Development* Vol 4, No 3, pages 437–447; and Uddin, S M N, Z Li, J C Gaillard, P F Tedoff, J Lapegue, H P Mang, E M Huba, O Kummel and E Rheinstein (2014), "Exposure to WASH-borne hazards: A scoping study on peri-urban ger areas in Ulaanbaatar, Mongolia", *Habitat International* Vol 44, pages 403–411.

targeted. SPSS software was used to analyse the data collected through the structured questionnaire-based survey. In addition, a focus group discussion (FGD) was undertaken during the ACF WASH Forum on 26–27 September 2013 with government officials and representatives of private companies and non-governmental organizations to determine the acceptability of CLSS in their minds and the likelihood that it would be scaled up. An additional policy dialogue among these stakeholders was organized at the same forum to discuss the faecal compost applicability, policy formulation and future opportunities. The summary and key outcomes of these discussions were analysed.

Finally, a social marketing study on organic compost utilizers was carried out by ACF in 2010 with a range of potential customers including silvicultural specialists, gardeners, land reclaimers, retailers, agricultural companies and NGOs, drawn from 54 establishments listed in the Business Register of the Agriculture Department & Forestry Division of Mongolia. The aim was to assess the existing market for organic compost and to determine how marketable faecal compost would be in Mongolia.

V. RESEARCH RESULTS

a. Problems and actions by ACF

FGDs with the stakeholders, including ACF internal officers, revealed a range of pre-existing problems when the project began, which ACF aimed to solve gradually. The sanitary problems in the study area included, for instance, very poorly sealed and ventilated pit latrines, bad odour, rocky ground and a high water table, difficulty in digging pits, an extremely cold climate in winter, limited space to create new pit latrines, complaints from neighbours, waterborne diseases, pit latrines that filled with rain water, and a waste of resources. ACF started to test various technological (hardware) and non-technological (software) options to reduce the risks and hazards related to local sanitation problems in holistic or integrated ways. The initial aims of the programmes were to improve the pit latrines through different interventions, community activities and school sanitation programmes; develop toilets that could be emptied such as ventilated improved pit latrines (VIPs) or raised toilets (due to the high water table); and introduce other components of CLSS, including resource reuse and nutrient recycling, treatment of faecal matter through composting, and other potential actions towards resource recovery and better human and environmental health.

b. CLSS technologies: toilets

The construction of CLSS toilets around the ger areas was part of the ACF WASH programmes. Several toilet models have been constructed and piloted by ACF since 2009, including raised and non-raised UDDTs; bucket dry toilets; single- and double-vault solar toilets, and Zip-Zap toilets (described below).[21] Three VIP toilets were also installed to test. These are not properly CLSS toilets, but are an improvement over the traditional pit latrines.

The CLSS concept of human wastes (faeces and urine) as resources to be conserved and recycled to increase soil fertility and water-holding capacity rather than as wastes to be discarded was fully accepted. People easily

10. See reference 9, Uddin, Li, Mang, Huba and Lapegue (2014).

11. See reference 9, Uddin, Li, Mang, Huba and Lapegue (2014) and Uddin, Li, Gaillard et al. (2014); also Uddin, S M N, Z Li, H P Mang, T Ulbrich, A Schubler, E Rheinstein, E M Huba and J Lapegue (2014), "Opportunities and challenges of greywater treatment and reuse in Mongolia: Lessons learnt from piloted systems", *Journal of Water Reuse and Desalination* Vol 4, No 3, pages 182–193.

12. Girard, C (2009), "Feasibility of pit-larine emptying services, ger areas, Ulaanbaatar, Mongolia", Master's thesis, Cranfield University, Cranfield.

13. See reference 9, Uddin, Li, Mang, Huba and Lapegue (2014).

14. See reference 9, Uddin, Li, Gaillard et al. (2014).

15. MUST (2010), *Trial research for emptying Ger district pit latrine*, Mongolian University of Science and Technology, Ulaanbaatar.

16. See reference 12.

17. See reference 11, Uddin, Li, Mang, Schubler et al. (2014); also Uddin, S M N, Z Li, H P Mang, J F Adamowski, T Ulbrich, R Ryndin, J Norvanchig and S Cheng (2014), *Greywater treatment in peri-urban nomadic communities: A case study on 'greenhouse system' in Ulaanbaatar, Mongolia*, 12th IWA Conference on Small Water & Wastewater Systems & 4th Specialized Conference on Resource Oriented Sanitation, 2–4 November, Muscat.

18. See reference 15.

19. GTZ (2008), *ECOSAN - Ecological Sanitation in Mongolia: Result oriented monitoring, August 2008 – a rapid appraisal*.

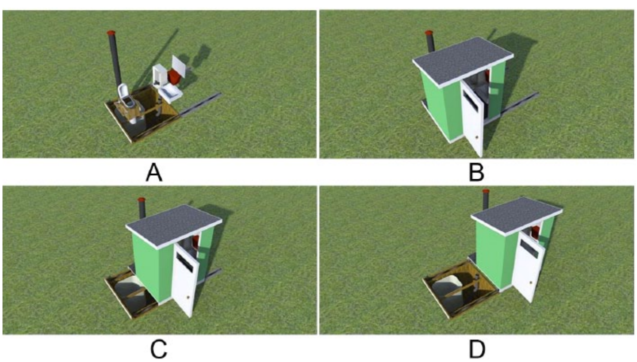
20. Uddin, S M N, Z Li, H P Mang, E M Huba, J Lapegue and J Eyrard (2013), *Sustainable sanitation for vulnerable peri-urban population in Mongolia: An introduction of a multi-lateral cooperation project*, Proceedings of the 12th JADE Conference, Japan Association of Drainage and Environment, Tokyo, 9 November.

understood the reuse and recycling concept as a result of the awareness programmes and other activities in the intervention areas. In addition, faecal matter was collected from the toilets frequently and households experienced no bad odour or flies. Digging pits for pit latrines is a difficult task due to the specific hydromorphic characteristics of the mountainous terrain of the study area; this also encouraged the choice of CLSS toilet models, most of which do not require a pit. This was the major driver towards the acceptance of CLSS toilets by the ger residents. The Zip-Zap toilet (which can be moved during the emptying services) in particular needs only a shallow cavity to set the container in (Figures 2A, 2B, 2C and 2D).

The original 120 CLSS toilets constructed in the study area were more recently supplemented by 250 additional toilets to scale up the system and to move local residents further up the technological ladder (Figure 3 and Figure 4). Field investigations have indicated a range of advantages and shortcomings of the different CLSS toilet models, as described in the following pages and summarized in Table 1.

VIP toilets: Only three VIP toilets were installed; they were not scaled up as an option because of the difficulty of emptying the pits, especially in winter.

Double-vault solar toilet: 19 of these were introduced in 2009 at the beginning of the ACF WASH programmes to test the model, make use of the learning for further technical improvement and increase the awareness of the ger residents. No pit is required for these toilets. They are built above ground with concrete lining to avoid any groundwater contamination. These toilets do not divert urine. Generally there is an extension of the vault (Photos 1A, 1B and 1C) towards a solar panel that absorbs the heat and accelerates decomposition of the faeces. The double-vault system provides an alternative chamber when one is filled, allowing for less frequent emptying service and collection. The initial purpose of using this toilet model was to allow decomposition onsite in the toilet as recommended by Esrey et al.[22] However, full decomposition



FIGURES 2A–2D
Sketches of a Zip-Zap toilet

SOURCE: ACF (2011).

21. USTB and ACF (2010), *Suitability of different technology options for greywater and human excreta treatment/disposal units in Ger areas on Ulaanbaatar, Mongolia*, University of Science and Technology Beijing and Action Contre La Faim, Ulaanbaatar.

22. Esrey, S A, J Gough, D Rapaport, M Simpson-Herbert, J Vargas and U Winblad (1998), *Ecological sanitation*, Swedish International Development Cooperation Agency (SIDA), Department for Natural Resources and the Environment, Stockholm.

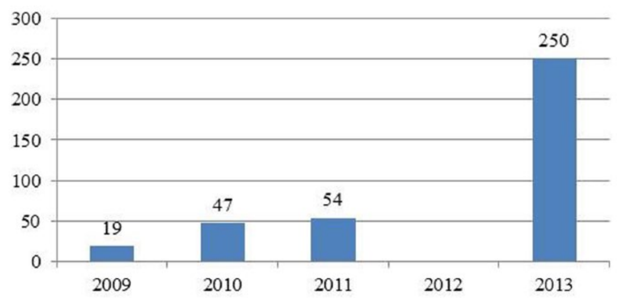


FIGURE 3
Number of CLSS toilets constructed by ACF Mongolia during the period from 2009 to 2013

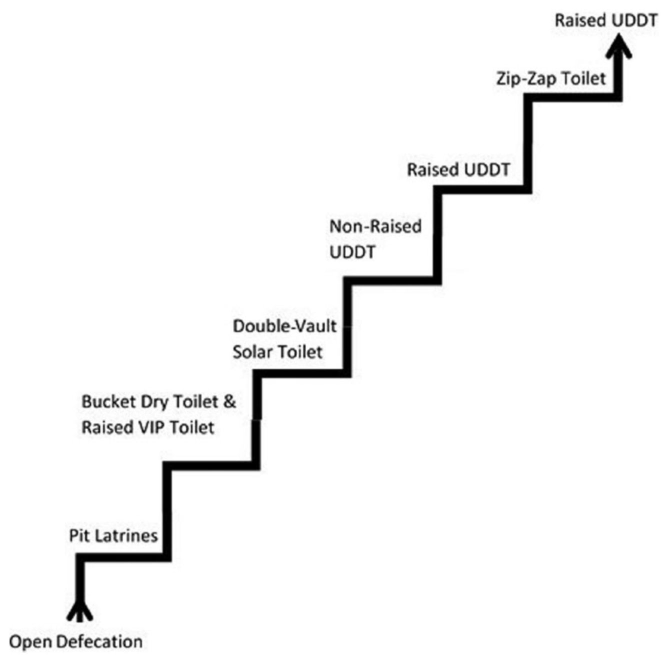


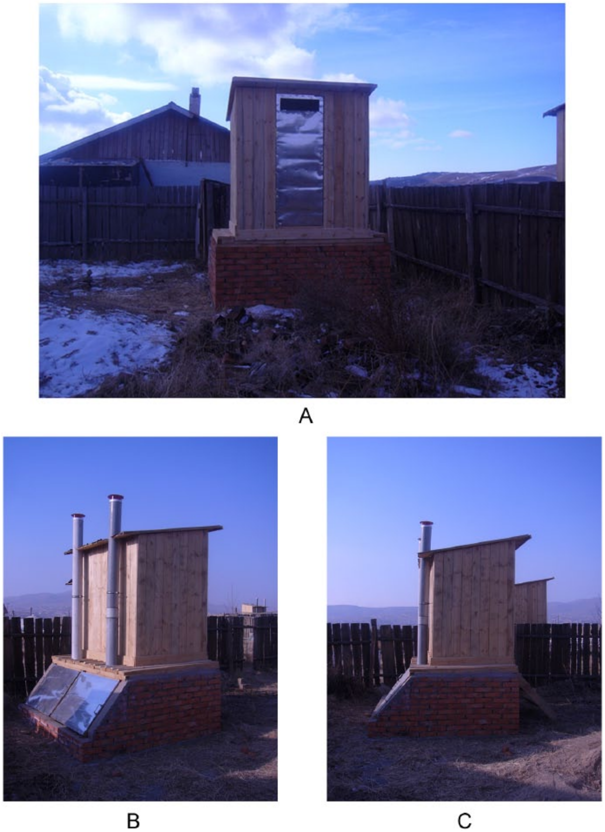
FIGURE 4
Technological ladder including CLSS toilets in the study area

TABLE 1
ACF CLSS toilets, their advantages and their shortcomings

Type of toilet/year of installation	Number of toilets	Advantages	Shortcomings
Bucket dry toilet (2009)	2	• Can be used in the house • No ground water contamination	• No ventilation pipe • No urine diversion • Potential health risks unless the bucket or container system is carefully designed
Non-raised UDDT (2009)	5	• Urine diversion • Less groundwater contamination because faeces are stored in containers • Sawdust as a bulking agent is added to faeces to reduce moisture	• Low-quality material is used for the superstructure • Small hole for urine diversion • Availability of sufficient sawdust could be a challenge in future
Double-vault solar toilet (2009)	9	• Involves solar heating • Alternating storage allows for less frequent emptying and collection	• No urine diversion • Squatting during defecation • Difficulty in collection due to absence of a container • Bad odour and flies
Raised UDDT (2010)	46	• Ventilation pipe is attached • Feasible in rocky and high water table areas • Presence of windows for cross-ventilation • A toilet seat (pedestal) is available • Sawdust is added after defecation	• No sucking turbine vent • Low-quality material is used for the superstructure • Small diameter of the urine diversion pipe (clogging occurs during winter)
Raised UDDT (2011)	33	• Reduction of smell and flies • Sealed windows of transparent glass for light reflection • Sucking turbine vent • Emptying service is very easy and convenient	• No openable window for cross-ventilation • Swelling and cracking of the superstructure • No collection of urine • Unscreened ventilation pipes are used • Access difficulties for the elderly and small children
Zip-Zap toilet (2010–2011)	22	• Easy accessibility for elderly and small children • Less expensive than a raised toilet • Requires no water except for hand washing	• No openable window for cross-ventilation • Not feasible in rocky and high water table areas • Difficulties with emptying • Urine is not collected
Total 2009–2011	120*		
Raised UDDT (2013)	250	Newly built toilets. Monitoring is still ongoing.	

NOTE: *The total number of toilets is 120 including the three VIP toilets described in Section Vb.

was unsuccessful due to the short sunshine period during the long winter and the night-time temperature drop. Therefore, faeces are collected twice a year and brought to the composting site for proper composting.



PHOTOS 1A–1C
Views of a double-vault solar toilet

© ACF (2009).

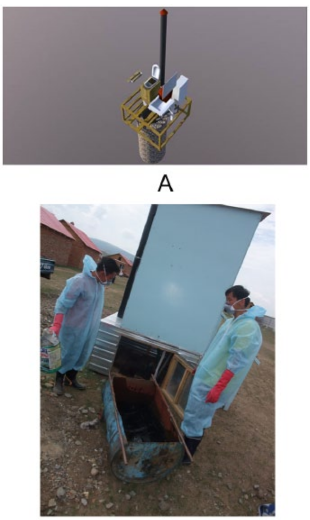
Non-raised UDDTs: Five UDDTs were installed in 2009. The principle of the UDDT is to separate human urine and faeces, which are collected in a storage container. In the study area, these toilets divert urine into a urine pit through a diversion pipe, leaving it uncontaminated by faeces and also reducing the volume of matter that needs treatment. Users sprinkle a handful of locally available materials such as sawdust, wood ash, dry soil or other liming materials on the faeces, which helps them to dry up in the chamber rapidly and activates decomposition.

This allows their conversion to bio-fertilizers within six months, and ensures the destruction of pathogens.[23] It also prevents foul odours. The emptying service removes the full container and replaces it with an empty one. Faeces are then transported to the composting site.

Raised UDDTs: 79 of these models were installed during 2010 and 2011. This type of toilet (Figure 5A and Figure 5B) prevents both surface and ground water contamination, especially in areas with a high water table and hard rocks, since it sits above ground level. The chamber of this toilet is a little higher than that of the regular UDDT to protect from flooding and rainwater. After a period of time (three months), the container for the faeces, which can be accessed through the back of the structure, is removed and transported to a composting facility. A ventilation pipe with a cap cover is attached above the roof with a staircase for accessibility. Initially a 120-litre steel container was used, but since 2011, the programme has used a 100/120-litre plastic container with handles to avoid corrosion and for easy collection and emptying. This toilet model is in high demand among the ger residents. In 2013, when 250 additional toilets were installed, the previous design was improved through the use of larger pipes (150 millimetres) for urine diversion to prevent clogging during the winter period. This model was chosen for its convenience of operations and maintenance, easy empting services and user preferences.

Zip-Zap toilet: A total of 22 Zip-Zap toilets (Figures 2A–2D) were installed in 2010 and 2011 to assess their practicality. This is another form of

23. Onyango, P, O Odhiambo and A Oduor (2009), *Technical Guide to EcoSan Promotion*, EU-GTZ-SIDA, Nairobi, 121 pages.



A

B

FIGURES 5A AND 5B
Raised urine-diverting dry toilet

SOURCE: Uddin, S M N (2013).

UDDT involving a pit to hold a large steel container for faeces (urine simply runs into the unlined section of the pit). The wheeled toilet superstructure is moved forward on an iron rail in order to access the container for emptying. This type of toilet is less expensive to build than a raised toilet, and easier for old people and small children to access because there are no stairs. Some shortcomings were found, which are listed in Table 1.

c. Emptying, collecting, transporting and storing

At three-month intervals, emptying services are carried out in each household by ACF. Clean and empty containers are exchanged for the filled ones, which are transported to the composting site for further hygienization. A recent improvement, as noted, includes the use of plastic containers with handles for easier emptying. The emptying service addresses the various disadvantages of existing CLSS toilets. Emptying service officers have been trained and are aware of personal hygiene and the steps needed to avoid pathogen transmission during the services, including the use of protective, synthetic lotion, and the avoidance of food consumption, smoking/drinking or excessive communication to prevent transmission of disease. Operators use washable clothes, latex gloves, strong work gloves, boots, and masks with carbon filters. Despite these precautions some shortcomings were observed during the service, including traces of faeces left in containers, leaking containers, containers with no handles, and splashing of faeces on the ground due to poorly fastened screws or clamps. A major problem in the summer is the strong odour during the process of emptying and collection. This can be addressed by proper maintenance and the use of sufficient bulking materials after each defecation. In winter, there is no odour problem, but the faeces turn into ice blocks and are much harder to break up, requiring the use of shovels and crowbars.

Results from the household survey showed that 90 per cent of respondents among the CLSS toilet users receive manual emptying services and 5 per cent use mechanical vacuum tankers. No respondents currently pay for emptying services, as they are provided by ACF Mongolia. However, 77 per cent of respondents were willing to pay MNT 10,000 (US$ 5 as of October 2013) for each emptying service; the rest were unwilling to pay any money, perhaps due to their low income level. This suggests that the whole system might reasonably be handed over to a private company for operation and maintenance, with user fees supporting the service.

Faecal matter in the collecting containers is typically very dry, particularly faeces from UDDTs, and thus conventional suction pumps cannot be used to suck the faeces out of the container. As for the non-UDDTs, the faeces are in liquid form in the container and in the vaults during the short summer (April/May to August/September), and need to be transported carefully and safely to the composting site, given the rough, mountainous roads in the ger areas. However, during the winter, faeces turn into ice blocks in all of the toilets. Two officers are needed to manually lift the faeces collection container out of the toilets, a highly labour-intensive task. They cover the container with a lid, move it onto the truck platform and replace it with an empty container. The truck can safely hold eight containers.

During the summer, operators remove their boots when boarding the truck and place them on the truck platform; in the winter they cover them with plastic. After use, they store the tools in the dirty tools box on the truck platform. Upon arrival at the treatment unit, the staff unload the full containers and manually empty them into 220-litre barrels, using the shovels and crowbars. Trucks, equipment and tools are cleaned on a daily basis, with clean water and chlorination to disinfect the tools. A concrete slab is used for washing the emptying equipment. The greywater after washing goes to a filtered soak pit for treatment. Generally no significant cleaning is undertaken during the winter due to low risk of contamination.

The collected faeces are kept in a storehouse at the composting site during the summer and outside when there is insufficient storage space during the winter. The amount of space required to accommodate the entire system when it is scaled up will become clearer as ongoing research is completed. Figure 6 shows the emptying services, including the collection, transportation and storage at the composting site.

d. Treatment through composting

ACF has been testing three types of compost production to treat the collected faeces for pathogen reduction. These include indoor winter composting, greenhouse composting and outdoor summer composting.

For winter composting, human faeces were co-composted with various substrates including sawdust, straw and wood chips in a semi-contained winter composting facility. The winter composting system is an airtight and fully controlled system requiring an energy supply. The temperature in this facility was monitored to evaluate the effect of the ambient temperature. Figure 7 shows temperature readings from 27 January to 27 February 2012. The average outdoor low temperature during this period ranged from -32°C

FIGURE 6
Collection, transportation and storage system for human faeces

SOURCE: Uddin, S M N (2013).

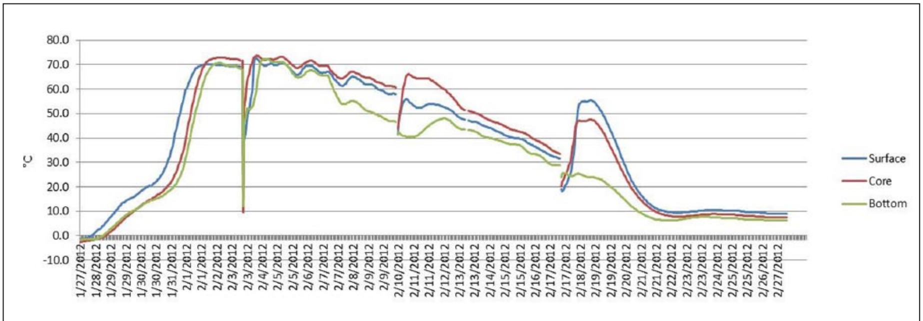


FIGURE 7
Temperature readings of composting in the winter facility (in °Celsius)

SOURCE: Field data from 27 January–27 February 2012, ACF Mongolia.

to -25°C and average high temperature ranged from -15°C to -7°C. The average ambient temperature in the facility was over 20°C, and the core compost heap temperature reached over 70°C for over a day and over 50°C for nine days, which meets the international standards in terms of temperature.(24) This confirms the practicality of composting human faeces in a cold climate, particularly in the Mongolian context.(25)

Research conducted by Uddin et al. and Mahmood et al. using both the winter facility (July–August 2013) and the greenhouse (September–November 2013) has shown that the process meets the composting standards of many developed countries, including WHO guidelines, in terms of temperature. The study on greenhouse composting indicated that the ambient temperature in the greenhouse dropped from 39 to 4°C. The outside average day temperature was 13 to -3°C and the average night temperature ranged from 0 to -15°C. The temperature even reached 70°C during the thermophilic stage; this high temperature could be influenced by either the ambient temperature of the greenhouse or the easily digestible carbon source that was added, i.e. food waste. Temperatures above 55°C and 65°C were maintained for two weeks and more than one week respectively, which satisfies all the sanitation requirements and standards.(26)

Outdoor composting and greenhouse composting both come under the category of "open – hot composting". Neither process takes place in an airtight controlled container, and no energy consumption is necessary in either case. Greenhouse composting simply extends the months during which compost production is possible. Windrows (long rows of organic material that are turned regularly to produce compost) are used outdoors, and block composting in the greenhouse, where several blocks/slots are built for ease of aeration and monitoring.(27) After the compost is mature, a winter hygienization process takes advantage of the country's cold winter temperature outdoors, allowing for pathogen die-off.

Currently, sufficient sawdust and wood chips are readily available as bulking material for co-composting, since ger houses are constructed from wood (including the structure beneath the felt yurt cover). Further research is

24. WHO (2006), *Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 4: Excreta and Greywater Use in Agriculture*, World Health Organization, Geneva, 204 pages.

25. Liu, X and J Mertens (2011), *Human feces composting: Pilot options & reinforcing local capacities to improve access to water, sanitation and hygiene in Ger areas of Ulaanbaatar, Mongolia*, Trial report, Ulaanbaatar.

26. Uddin, S M N, Z Li, H P Mang and J Lapegue (2014), "Sustainable sanitation towards eco-city Development", Second Symposium on Urban Mining, Bergamo, 19–21 May; also Mahmood, I B, Z Li, S M N Uddin, H P Mang and J Germer (2015), "Co-composting of fecal matter in Mongolia using two different technologies", *Journal of Water, Sanitation and Hygiene for Development* Vol 5, No 1, pages 165–171.

27. See reference 26, Uddin, Li, Mang and Lapegue (2014) and Mahmood et al. (2015).

needed to investigate whether sufficient bulking materials (e.g. sawdust, wood chips and straw) for co-composting will be available when the system is scaled up for the entire ger area. There is also the possibility of using alternative and available materials such as food waste or green/brown waste (nitrogen-rich/carbon-rich biodegradable waste) for co-composting faecal matter.

e. Safety, productivity, marketing and regulations

The compost resulting from the process was found to be both hygienic and effective. A joint study conducted with the Mongolian State University of Agriculture in 2012 indicated that there was no *Salmonella* or *E. coli* in the compost produced by ACF. In addition, no indicator bacteria were found in the products (e.g. spinach) produced using the faecal compost. The use of compost had positive effects for productivity. A field experiment conducted by the Mongolian State University of Agriculture comparing the application of ACF faecal compost and mineral fertilizers to produce spinach indicated that the compost use resulted in slightly higher yields than the mineral fertilizers. It is hoped these results will pique the interests of both government and non-governmental agencies in scaling up CLSS. Still ongoing is a study to assess the economic feasibility of the compost and the composting systems, which to date has shown that the demand for organic compost is considerably higher than for chemical fertilizers – with 80 per cent of those interviewed confirming their interest in organic compost. The price of one kilogram of compost was MNT 800–1,000 (equivalent to US$ 0.46–0.58).(28) Since arable land and permanent crops cover 1.3 million hectares in Mongolia,(29) there is significant potential for the marketing of compost. The current research has focused, however, not only on agricultural applications, but also such uses as city greening, home gardening, horticulture, production of animal fodder, and the improvement of polluted soils and mining areas.

Currently Mongolia does not regulate faecal composting and compost application. ACF and USTB are advocating regulation on the basis of evidence from this research. Policy dialogue during the FGD revealed a strong interest in our findings on the part of various stakeholders and users. This research may convince the Mongolian government to formulate policies and regulations on faecal compost and its application, which could enhance the scaling up of the system in the ger areas and other parts of the country for better health, environment and resource recovery. There are standards and guidelines from various countries, including China, Canada and the USA, as well as WHO guidelines, that could be followed.(30)

f. Social acceptance of CLSS

Survey results indicated that technologies and the services of CLSS are socially accepted by all users of CLSS toilets in the study area. The results regarding users' preferences for CLSS toilets relative to pit latrines indicated that 72 per cent of respondents were in favour of CLSS, because of the benefits/advantages listed in Table 1 in Section Vb. The remainder of the respondents (28 per cent) preferred a pit latrine because of the kinds of shortcomings described in Table 1. The reasons most often cited by users for liking the CLSS toilets were the benefits for the environment, the user friendliness, and the absence of flies and bad odours (Figures 8A and 8B).

28. ACF (2012), *Compost marketing study: Customer survey for soil amendments, Ulaanbaatar, Mongolia*, Action Contre La Faim Mongolia, Ulaanbaatar.

29. FAO (2001), *Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and Other Countries in Transition*, Food and Agriculture Organization, Proceedings of the Regional Technical Meeting on Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and Other Countries in Transition, Budapest, 6–10 March, accessed March 2015 at http://www.fao.org/docrep/005/y2722e/y2722e00.htm.

30. See reference 23; also see reference 24; U.S. Environmental Protection Agency (1993), *Standards for the Use or Disposal of Sewage Sludge* (40 Code of Federal Regulations Part 503), Washington, DC; CCME (2005), *Guidelines for Compost Quality*, PN1340, Canadian Council of Ministers of the Environment, Winnipeg; and BioAbfV

(2006), *Bioabfallverordnung (Verordnung über die Verwertung von Bioabfällen auf landwirtschaftlich, forstwirtschaftlich und gärtnerisch genutzten Böden)*, Bundesgesetzblatt.

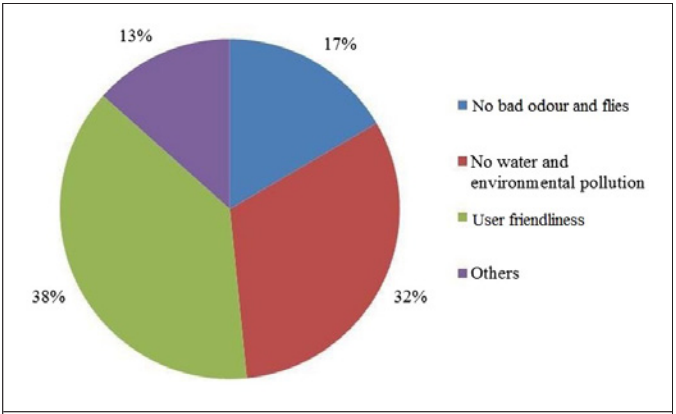


FIGURE 8A
Reasons for using the CLSS toilets

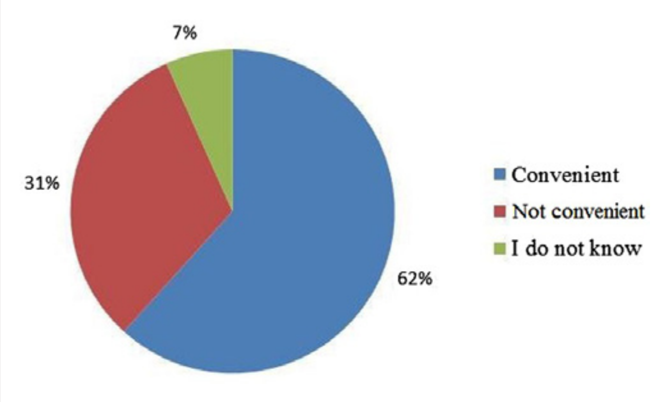


FIGURE 8B
Convenience for users during the winter

Sixty-two per cent of respondents also felt the toilets were convenient during the winter, although the remainder still faced problems.

A large percentage of the respondents (73 per cent) were eager to recommend CLSS toilets to their neighbours or non-users, provided improvements were made to their convenience and the disadvantages were addressed. A number of respondents noted that visitors from more rural areas frequently inquired about how to obtain a CLSS toilet. Nearly all the visited households with CLSS toilets had ACF contact numbers in case of emergencies, the need for emptying services or requests for new toilets. Eighty per cent of the respondents received training and were involved in ACF sanitation programmes to maintain the toilets and operate them properly. Seventy per cent of respondents cleaned their toilets weekly, 10 per cent daily, and the remainder on an as-needed basis. Ninety-three per cent of respondents faced no difficulties with maintenance, and all felt that maintenance costs were reasonable.

Results from the focus group discussion with representatives of the government, private sector and NGOs suggested that the majority accepted the CLSS and felt the need to improve the health and environmental conditions of the ger areas. However, government officials were reluctant to have compost used on food products given the lack of policy in this regard, and suggested the need for more discussions and evidence to formulate such a policy. They suggested initially using the compost only for non-consumable ends such as horticulture. The marketing of the faecal compost still requires further research.

VI. CONCLUSIONS AND RECOMMENDATIONS

Water, sanitation and hygiene are global concerns, together responsible for millions of deaths every year. There is an urgent need for sustainable alternative sanitation solutions in order to protect human and environmental health from WASH-related risks and hazards, from the local to the global level. Based on results from the study area, CLSS and its technologies can be considered viable alternative sanitation solutions with high potential for diminishing human and environmental health risks and hazards.[31] The evaluation presented in this study illustrated that, despite some challenges, the CLSS concept is well accepted by users in the ger areas and is clearly replicable, given the positive responses of all users of the technologies and services. In particular, the study proved that CLSS and its technologies are feasible in Mongolia's cold climate and an asset for its water-stressed regions. There is a strong potential for scaling up these services across ger areas and beyond. Over half of the interviewed CLSS toilet users testify to the convenience of the systems during both winter and summer. In every step of the CLSS process, the system proved to be feasible, replicable and acceptable in the study area. A detailed survey among the users of CLSS technologies and services is still needed to determine the extent of the reduction of WASH-borne diseases and environmental contamination in places utilizing the CLSS process.

31. See reference 1, Uddin et al. (2012).

In addition to these benefits, the recovery of resources or nutrients from these CLSS solutions could reduce the usage of chemical fertilizers in agro-production processes, decrease dependency on natural mineral resources and reduce food insecurity. The composting side of the process also requires further research, but preliminary results indicate that it is a practical direction to move in. Different composting options appear feasible. While greenhouse composting was found to be more practical than winter composting in terms of energy consumption, winter composting is preferable in terms of productivity and technology. The safety of the compost and the agro-products that resulted from its use were demonstrated in an effort to convince more communities, government officials and non-governmental agencies. A further detailed social study is recommended to assess the social acceptability of faecal compost and agro-product consumption. Guidelines are required for the formulation of regulations and policy towards the wider implementation and replication of these systems. If the use of the compost for food products is deemed unacceptable, alternative options for the application of faecal compost also exist for horticulture, the production of non-consumable agro-products, animal fodder, urban gardening, home gardening and soil improvement for peri-urban polluted soils. In addition, compost products can be applied for land reclamation in mining areas. The marketability of the compost and the financial feasibility of transport still have to be investigated. Based on the wider compost standards and guidelines, processes of composting should be tested for standardization rather than testing products produced by using faecal compost. Suitable prototypes for composting should be tested in both the summer and winter seasons. More research on the assessment of helminth (parasitic worm) numbers in the compost is highly recommended for the safety of the products. Mongolia also needs greater capacity development within local laboratories for testing for pathogens.

FUNDING

We thank ACF International France and ACF Mongolia for the support provided.

REFERENCES

ACF (2012), *Compost marketing study: Customer survey for soil amendments, Ulaanbaatar, Mongolia*, Action Contre La Faim Mongolia, Ulaanbaatar.

Apkan-idiok, A U, I A Udo and E I Braide (2012), "The use of human urine as an organic fertilizer in the production of okra (Abelmoschus esculentus) in South Eastern Nigeria", *Resources, Conservation and Recycling* Vol 62, pages 14–20.

Austin, A (2002), *Health aspects of ecological sanitation*, EcoSanRes, South Africa, accessed February 2014 at http://www.ecosanres.org/pdf_files/Nanning_PDFs/Eng/Aussie%20Austin%2028_E25.pdf.

Batjargal, T, E Otgonjargal, K Baek and J S Yand (2010), "Assessment of metals contamination of soils in Ulaanbaatar, Mongolia", *Journal of Hazardous Materials* Vol 184, Nos 1–3, pages 872–876.

BioAbfV (2006), *Bioabfallverordnung (Verordnung über die Verwertung von Bioabfällen auf landwirtschaftlich, forstwirtschaftlich und gärtnerisch genutzten Böden)*, Bundesgesetzblatt.

CCME (2005), *Guidelines for Compost Quality*, PN1340, Canadian Council of Ministers of the Environment, Winnipeg.

Dagerskog, L and M Bonzi (2010), "Opening minds and closing loops – productive sanitation initiatives in Burkina Faso and Niger", *Sustainable Sanitation Practices* Vol 3, pages 4–11.

Esrey, S A (2001), "Towards a recycling society: ecological sanitation - closing the loop to food security", *Water Science and Technology* Vol 43, No 4, pages 177–187.

Esrey, S A, I Andersson, A Hillers and R Sawyer (2001), *Closing the loop: Ecological sanitation for food security*, Swedish International Development Cooperation Agency, Mexico.

Esrey, S A, J Gough, D Rapaport, M Simpson-Herbert, J Vargas and U Winblad (1998), *Ecological sanitation*, Swedish International Development Cooperation Agency (SIDA), Department for Natural Resources and the Environment, Stockholm.

FAO (2001), *Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and Other Countries in Transition*, Food and Agriculture Organization, Proceedings of the Regional Technical Meeting on Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and Other Countries in Transition, Budapest, 6–10 March, accessed March 2015 at http://www.fao.org/docrep/005/y2722e/y2722e00.htm.

Girard, C (2009), "Feasibility of pit-larine emptying services, ger areas, Ulaanbaatar, Mongolia", Master's thesis, Cranfield University, Cranfield.

GTZ (2008), *ECOSAN - Ecological Sanitation in Mongolia: Result oriented monitoring, August 2008 – a rapid appraisal*.

Karak, T and P Bhattacharyya (2011), "Human urine as a source of alternative natural fertilizer in agriculture: A flight of fancy or an achievable reality", *Resources, Conservation and Recycling* Vol 55, No 4, pages 400–408.

Langergraber, G and E Muellegger (2005), "Ecological sanitation—a way to solve global sanitation problem?", *Environment International* Vol 31, No 3, pages 433–444.

Liu, X and J Mertens (2011), *Human feces composting: Pilot options & reinforcing local capacities to improve access to water, sanitation and hygiene in Ger areas of Ulaanbaatar, Mongolia*, Trial report, Ulaanbaatar.

Luvsan, M E, R H Shie, T Purevdorj, L Badarch, B Baldorj and C C Chan (2012), "The influence of emission sources and meteorological conditions on SO_2 pollutions in Mongolia", *Atmospheric Environment* Vol 61, pages 542–549.

Mahmood, I B, Z Li, S M N Uddin, H P Mang and J Germer (2015), "Co-composting of fecal matter in Mongolia using two different technologies", *Journal of Water, Sanitation and Hygiene for Development* Vol 5, No 1, pages 165–171.

MUST (2010), *Trial research for emptying Ger district pit latrine*, Mongolian University of Science and Technology, Ulaanbaatar.

Nakagawa, N, M Otaki, S Miura, H Hamasuna and K Ishiki (2006), "Field survey of a sustainable sanitation system in a residential house", *Journal of Environmental Science* Vol 18, No 6, pages 1088–1093.

Nawab, B, I L P Nyborn, K B Esser and P D Jenssen (2006), "Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan", *Journal of Environmental Psychology* Vol 26, No 3, pages 136–246.

Onyango, P, O Odhiambo and A Oduor (2009), *Technical Guide to EcoSan Promotion*, EU-GTZ-SIDA, Nairobi, 121 pages.

Rosemarin, A, J McConville, A Flores and Z Qiang (2012), *The Challenges of Urban Ecological Sanitation: Lessons from the Erdos Eco-Town Project, China*, Stockholm Environment Institute, Practical Action Publishing Ltd, UK.

Stintzing, A R (2007), *Urine Diverting Toilets in Climates with Cold Winters: Technical considerations and the reuse of nutrients with a focus on legal and hygienic aspects*, Women in Europe for a Common Future (WECF), Munich.

Uddin, S M N, Z Li, J C Gaillard, P F Tedoff, J Lapegue, H P Mang, E M Huba, O Kummel and E Rheinstein (2014), "Exposure to WASH-borne hazards: A scoping study on peri-urban ger areas in Ulaanbaatar, Mongolia", *Habitat International* Vol 44, pages 403–411.

Uddin, S M N, Z Li, H P Mang, J F Adamowski, T Ulbrich, R Ryndin, J Norvanchig and S Cheng (2014), *Greywater treatment in peri-urban nomadic communities: A case study on 'greenhouse system' in Ulaanbaatar, Mongolia*, 12th IWA Conference on Small Water & Wastewater Systems & 4th Specialized Conference on Resource Oriented Sanitation, 2–4 November, Muscat.

Uddin, S M N, Z Li, H P Mang, E M Huba and J Lapegue (2014), "A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems", *Journal of Water, Sanitation and Hygiene for Development* Vol 4, No 3, pages 437–447.

Uddin, S M N, Z Li, H P Mang, E M Huba, J Lapegue and J Eyrard (2013), *Sustainable sanitation for vulnerable peri-urban population in Mongolia: An introduction of a multi-lateral cooperation project*, Proceedings of the 12th JADE Conference, Japan Association of Drainage and Environment, Tokyo, 9 November.

Uddin, S M N, Z Li, H P Mang and J Lapegue (2014), "Sustainable sanitation towards eco-city Development", Second Symposium on Urban Mining, Bergamo, 19–21 May.

Uddin, S M N, Z Li, H P Mang, T Ulbrich, A Schubler, E Rheinstein, E M Huba and J Lapegue (2014), "Opportunities and challenges of greywater treatment and reuse in Mongolia: Lessons learnt from piloted systems", *Journal of Water Reuse and Desalination* Vol 4, No 3, pages 182–193.

Uddin, S M N, V S Muhandiki, J Fukuda, M Nakamura and A Sakai (2012), "Assessment of Social Acceptance and Scope of Scaling Up Urine Diversion Dehydration Toilets in Kenya", *Journal of Water, Sanitation and Hygiene for Development* Vol 2, No 3, pages 182–189.

Uddin, S M N, V S Muhandiki, A Sakai, A A Mamun and S M Hridi (2014), "Socio-cultural acceptance of appropriate technology: Identifying and prioritizing barriers for widespread use of the urine diversion toilets in rural Muslim communities of Bangladesh", *Technology in Society* Vol 38, pages 32–39.

U.S. Environmental Protection Agency (1993), *Standards for the Use or Disposal of Sewage Sludge* (40 Code of Federal Regulations Part 503), Washington, DC.

USTB and ACF (2010), *Suitability of different technology options for greywater and human excreta treatment/ disposal units in Ger areas on Ulaanbaatar, Mongolia*, University of Science and Technology Beijing and Action Contre La Faim, Ulaanbaatar.

Werner, C, P A Fall, J Schlick and H P Mang (2003), *Reasons for and principles of ecological sanitation*, 2nd International Symposium on Ecological Sanitation, Eschborn, April.

WHO (2006), *Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 4: Excreta and Greywater Use in Agriculture*, World Health Organization, Geneva, 204 pages.

Zhou, C, J Liu, R Wang, W Yang and J Jin (2010), "Ecological-economic assessment of ecological sanitation development in the cities of Chinese Loess Plateau", *Ecological Complexity* Vol 7, No 2, pages 162–169.

3. A STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS ANALYSIS ON INTEGRATING SAFE WATER SUPPLY AND SUSTAINABLE SANITATION SYSTEMS

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ABSTRACT

This paper applies a 'comprehensive' strengths, weaknesses, opportunities, and threats (SWOT) analysis to compare the 'before and after' scenarios of integrating a safe water supply (SWS) into a sustainable sanitation system (SSS) in the peri-urban Ger areas of Ulaanbaatar. Qualitative field investigations, including interviews and focus group discussions, are conducted with stakeholders and key informants to collect data on the scenarios before the SSS and to develop a conceptual framework after the SSS implementation. The before-implementation scenario has one strength, that is, the interest of communities and NGOs toward the SWS–SSS integration, which facilitates the acceptance and up-scaling of sustainable technologies. The after-implementation scenario shows additional strengths, such as community acceptance and satisfaction with SSS. The identified weaknesses are attributed to the lack of community-based organizations, community participation, and inter-sector coordination. The marketing of SSS, the involvement of banks and micro-credit systems, and the reuse of treated greywater have been identified as opportunities. The before-implementation scenario identifies the use of pit latrines and the lack of political will as the primary threats, whereas the after-implementation scenario identifies technology innovations for the extreme cold as a primary threat. The application of the SWS–SSS integration in other cases must be investigated further.

Key words | integration, safe water supply, sustainable sanitation system, SWOT, urban development, WASH

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INTRODUCTION

The research, development, and implementation of sustainable sanitation systems (SSS) involve several concepts, such as complete sanitation, ecological sanitation, environmental sanitation, and resource-reuse-oriented sanitation (Langergraber & Muellegger 2005; Schertenleib 2005; Nelson & Murray 2008; Zurbrugg & Tilley 2009). SSS is a holistic approach that combines an efficient safe water supply (SWS) with improved sanitation techniques to recover nutrient and energy resources, reuse treated greywater, improve health conditions, and protect the environment. Improved sanitation plays a key role in ensuring public health and access to safe drinking water (Fry *et al.* 2008). SuSanA (2013) defined sustainable sanitation 'as a system which protect and promote human health by providing a clean environment and breaking the cycle of disease. In order to be sustainable, a sanitation system has to be economically viable, socially acceptable, technically and institutionally appropriate, it should also protect the environment and the natural resources' (www.susana.org). Safe drinking water has microbial, chemical, and physical characteristics that satisfy the WHO guidelines or national standards on drinking water quality (WHO

2014). Although the target of drinking water supply met the Millennium Development Goals (MDGs) in 2010 (WHO 2012), the quality should be maintained and monitored to improve the health and environment conditions in the world (e.g., Uddin *et al.* 2013a). Esrey *et al.* (1991) investigated the improvements in water supply and sanitation, particularly on human excreta disposal, water quality, and personal and domestic hygiene, which can reduce the occurrence of waterborne diseases. Therefore, the integration of SWS into sanitation and hygienic practices in both low- and high-income countries may reduce waterborne diseases such as diarrhea, which is currently the second leading cause of child mortality in the world (two billion cases with 1.5 million child deaths each year).

Most low-income countries will be unable to satisfy the MDG sanitation target of halving the number of people without access to adequate sanitation by 2015 (Zurbrugg & Tilley 2009; WHO 2011). Sanitation coverage is expected to reach 67% in 2015, with 580 million people still lacking access to adequate sanitation (WHO 2012). Guzha *et al.* (2005) recommended that the ecological/sustainable sanitation concept and the reuse of human excreta, both feces and urine, should be implemented in catchment areas as alternative excreta management options, which could prevent the watershed from diffusing pollution to some extent. Although conventional systems can restore resources, these technologies are very expensive and anti-poor (Patersan *et al.* 2007). Therefore, less expensive processes, such as biogas production and composting of human and organic wastes, are recommended to recover a considerable amount of nutrients for agricultural use.

The current study is performed in the Mongolian People's Republic, which has approximately 3.2 million residents (CIA 2013). The continuous influx of rural migrants into the capital city of Ulaanbaatar, which has a population of more than one million, has resulted in numerous environmental, health, and socioeconomic problems (Altansukh 2008; ADB 2010; Batjargal *et al.* 2010; Itoh *et al.* 2011; Nriagu *et al.* 2012). Mongolia is 'on track' and 'off track' in satisfying the drinking water and sanitation targets of MDG, respectively (UNICEF & WHO 2012). The safety and quality of drinking water in the peri-urban areas of Ulaanbaatar is not monitored at the household level (Uddin *et al.* 2013a). Moreover, the health and environmental situation in the Ger areas needs to be improved. The current study performs a strength, weakness, opportunities, and threats (SWOT) analysis to compare the 'before and after' scenarios of SWS–SSS integration in the peri-urban Ger areas (informal settlements) of Ulaanbaatar. Such integration can be replicated in other low- and middle-income regions to improve their health and environment conditions as well as to recover their resources.

METHODOLOGY

This study has been conducted as part of an ongoing PhD research project in Ulaanbaatar that is jointly performed by the University of Science and Technology Beijing (USTB) and Action Contre la Faim (ACF) International, which has likewise funded the study. The peri-urban Ger area of Ulaanbaatar (Figure 1) was investigated in 2012. This informal settlement houses 60% of the city's population, which continues to increase every year (Sigel *et al.* 2012).

This study applies SWOT as a research tool, which presents several applications in business (Hill & Westbrook 1997), environmental management (Nikolaou & Evangelinos 2010), solid waste management (Srivastava *et al.* 2005), and energy planning and sustainable energy development studies (Terrados *et al.* 2007; Markovska *et al.* 2009). However, SWOT has never been applied in water, sanitation, and hygiene (WASH) studies.

The WASH-related scenarios in Ulaanbaatar are investigated through qualitative field investigations, such as transect walk, focus group discussions (FGDs), and semi-structured interviews with community members and stakeholders. A conceptual framework has been developed for the SSS–SWS integration scenario based on the findings from the existing literature, discussions, and expert interviews.

Five transect walks are performed with the help of key informants and local staff members from ACF Mongolia to observe, listen, learn, and familiarize the Ger area, as well as to identify the problems, conditions, and structure of the settlements. The existing practices and technologies in these areas (i.e., types of toilets, greywater discharge systems, and hygiene scenarios) are addressed and noted during the transect walk for the SWOT analysis.

Fifteen semi-structured key informant interviews are performed with community members, sector stakeholders,

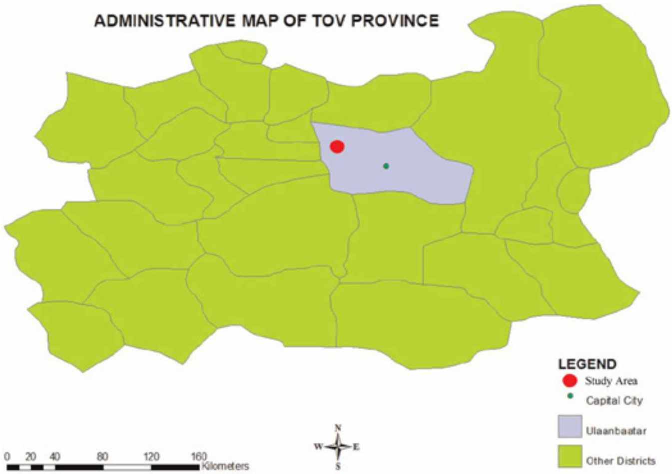


Figure 1 | Map of the study area.

government officials, university teachers, and community-based organizations (CBOs). WASH-related questions are asked during the interviews. The interviews are likewise audio/video recorded by the authors to facilitate the SWOT analysis. The recorded interviews are repeatedly checked to validate the gathered and analyzed interview data.

Ten stakeholders are interviewed, and six members of CBOs have participated in an FGD during the ACF WASH conference in Ulaanbaatar. Another FGD is performed during the International Conference on Water Research in Singapore in January 2013 to obtain supplementary views/opinions. Questions on WASH and SWS–SSS integration are asked during these sessions. Mongolian translators are likewise present during these sessions.

SWOT ANALYSIS RESULTS

Table 1 shows the SWOT analysis results of the data from the semi-structured interviews and FGDs. SWOT is applied to categorize the results into different components and develop comparative scenarios of the SWS–SSS integration.

DISCUSSION

Strengths

Several organizations, such as ACF, UNICEF, World Bank, Xac Bank, and World Vision, work directly and indirectly with the WASH sector of Mongolia (see World Bank 2010). These organizations work at different levels, such as communities and schools, in the rural, peri-urban, and urban areas of Ulaanbaatar. Although insufficient in the Ger area context, the WASH interventions of these organizations can encourage future collaborations and plans for SWS–SSS integration. The presence of NGOs, including their local partners, as well as their strong interests toward WASH may result in the future acceptance and up-scaling of SWS and SSS technological interventions that can improve the overall health and environmental conditions in Mongolia. The strengths before the integration, such as the community interest toward SWS and SSS technological interventions, must be considered in the future designing and planning of various programs for encouraging active community participation. More than 500 water kiosks have been established in Mongolia where Ger residents

Table 1 I Comparative scenarios of SWOT before and after SSS-SWS integration.

Before integration	After integration
Strengths	
• Organizational interests • Existence of many local and national NGOs. • WASH programs/interventions of different organizations at the community and school levels across the country • Community interests to SSS	• Strong institutional support mechanism, network, and effective communication system • Catalyze organizational interests and build their capacity • Effective inter-sector coordination among the stakeholders • Implementation of effective policies and regulations • Fair financial mechanism • Increased community interest and capacity • High awareness on WASH • Increased number of CBOs and enhanced community participation • Increased number of skilled people in the Mongolian WASH sector • Proper flow of WASH-related information • Improvement of health and environmental conditions • Technological innovation
Weakness	
• Weak Institutional network. • Lack of organizational capacity in WASH • Lack of inter-sector coordination among the stakeholder • Lack of skilled people in Mongolian WASH sector • Lack of WASH-related information • Limited awareness on WASH at the community level • Few CBOs • Limited community participation • Few community initiatives • Low income • Limited community capacity • Interest toward external funding • Lack of financial contribution from the government • Lack of services for emptying human feces • Lack of policies in the greater WASH sector • Poor maintenance of existing technologies • Low technological innovation • Absence of a greywater drainage system	• Interest toward external funding • Low income • Lack of infrastructural development
Opportunity	
• Training and education. • Creation of employment opportunities.	• Resource Center establishment • Community mobilization and youth group formation. • Micro business development related to water kiosk, composting human feces and greywater treatment and reuse for future employment creations. • Development of effective sanitation marketing. • Involvement of available micro-credit organizations in the WASH sectors. • Emptying service development for employment. • Integrated approaches can be applied in WASH. • Higher possibility to reduce water borne diseases • Nutrient recovery and bio-energy production. • Application of human feces compost in home gardening, greening city and horticultural lands.
Threat	
• Existing unhygienic pit latrines. • Unfavorable Climate (extreme cold). • Migration from rural and Urbanization. • Insufficient government support in terms of policy making, financial contribution, political willingness etc. • People's habit/attitude/lifestyle (nomadic mentality) • Water borne diseases.	• Unfavorable Climate (extreme cold). • Urbanization and migration from rural. • Pit latrines.

collect their water for drinking and other purposes (World Bank 2010). However, the FGD data show that the quality of water from these kiosks, particularly the water storage, collection, transportation, and purification, is neither guaranteed nor monitored. Most Ger residents use second-hand and hazardous materials, such as plastic containers, to collect and transport water from the kiosks and to store them in their households. The traditional sanitation facilities, such as pit latrines and soak pits, may increase the vulnerability of the Ger area residents to WASH-borne diseases (Uddin *et al*. 2013a).

The conceptual scenario after SSS–SWS integration shows several strengths (Figure 2). For instance, the strong institutional network and effective coordination system for WASH intervention can enhance the capacity of organizations and communities for improving their awareness and participation in WASH-related initiatives by establishing a proper flow of WASH-related information. Moreover, the availability of training and education initiatives may increase the number of skilled workers in the Mongolian WASH sector. The establishment of a WASH information center can strengthen WASH-related research and development activities. Uddin *et al*. (2012) reported that CBOs could motivate and educate people toward accepting and up-scaling sustainable sanitation technologies. They likewise identified the 'Tolgit' CBO as a key player in the sanitation of the Ger areas in Ulaanbaatar. The establishment of additional CBOs can help plan, design, and implement overall WASH-related activities in communities through the 'bottom up' approach.

Weaknesses

Several weaknesses, such as the weak institutional network, the absence of coordination, and the lack of WASH-related policies, have been identified in Mongolia. The weak legal and institutional frameworks have been considered as obstacles in the implementation and up-scaling of sanitation technologies, especially for ecological sanitation, in several countries (Stintzing 2007). No WASH-related policies have been implemented in Mongolia despite the immense potential of the country to incorporate or develop SWS- or SSS-related policies. Low income has likewise been identified as a weakness in the traditional sanitation system. The sanitary condition has been rated as 'poor' for more than a century, which concerns all community members including the poor (Welch 1893). Therefore, the weakness

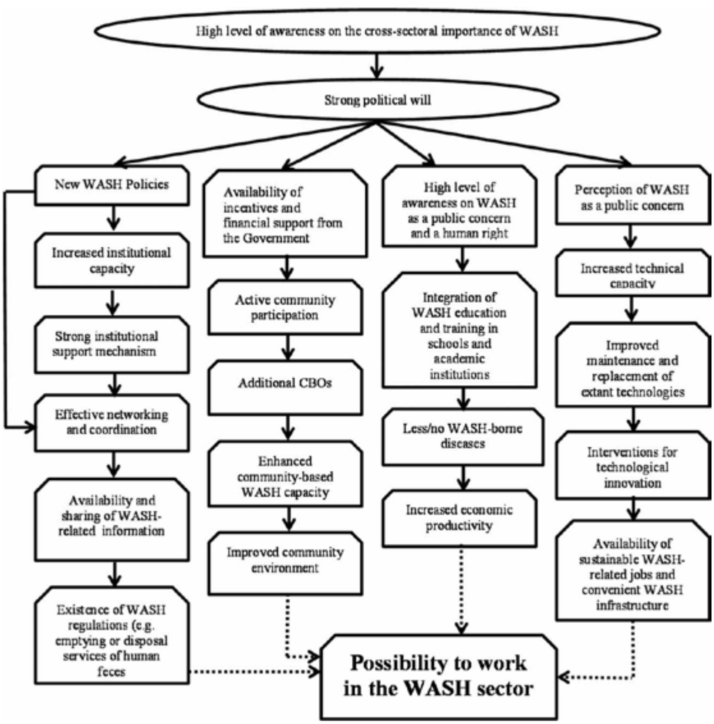


Figure 2 | Combined WASH-borne strength after SSS–SWS integration.

of the entire system negatively affects the entire society including the study area. The lack of awareness on the cross-sectoral importance of WASH and on political will has been identified as a major cause of the weaknesses in the existing system (Figure 3).

Mongolia lacks a department or a ministry that can organize or formulate WASH-related activities and policies. The Ministry of Nature, Environment, and Green Development is responsible for increasing the water resources in Mongolia. Some WASH-related construction projects in the country are being handled by the Ministry of Construction and Urban Development. However, government departments and stakeholders in Mongolia do not coordinate with one another for the proper planning of policies and activities, which has been a long-standing issue in other low-income countries (Koudstaal *et al*. 1992; Solo *et al*. 1993; Allen *et al*. 2006). The WASH sector of Mongolia likewise lacks qualified and skilled workers, which has been identified as a major weakness (McGarry 1980). The weaknesses in the after SSS–SWS integration scenario include humans, which will create business and marketing opportunities. Household greywater treatment and reuse can be considered as another business option for solving the water shortage problem in the Ger areas of Ulaanbaatar. Effective sanitation marketing may be implemented in the WASH sector of Mongolia, such as the development of an emptying service system for urine-diverting toilets, the composting and application of human feces from these toilets, the application of sanitized urine in agricultural lands, the recovery of nutrients through other processes, and the production of bio-energy. The compost that is produced from human feces and treated greywater can be used in home gardening, which is a common interest among the residents of Ger areas. The compost can likewise be applied for greening cities and other horticultural lands. Figure 4 shows the proposed mechanism of the SWS–SSS integration in which a high concentration (e.g., chemical oxygen demand) of greywater can be treated and reused to prevent health and environmental hazards and solve the water scarcity problem in the area to some extent. Human feces can be treated through composting within the closed-loop sanitation system to prove the feasibility of the system, prevent the proliferation of WASH-borne diseases, and recover resources (Uddin *et al*. 2013a, 2013b). Water kiosks, particularly multi-service water kiosks, can be integrated within the SSS to prevent potential contaminations that are caused by unplanned greywater discharge and by unimproved sanitation technologies.

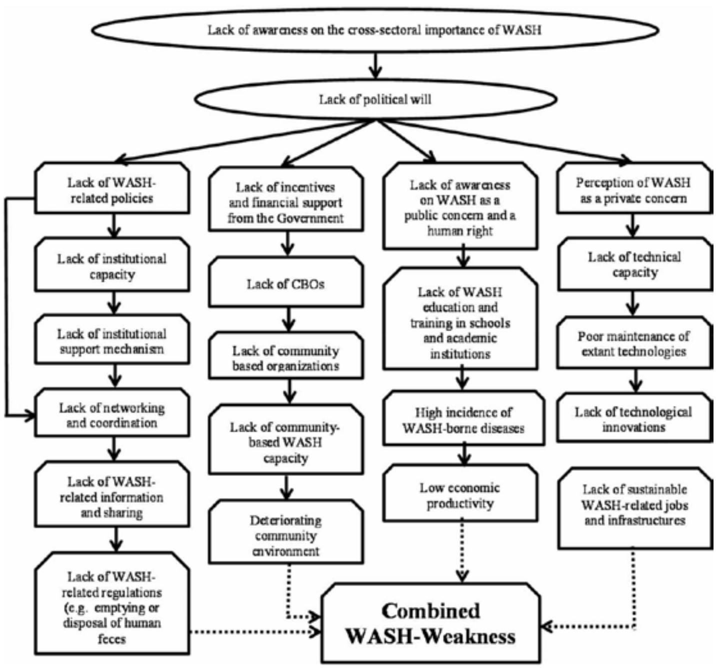
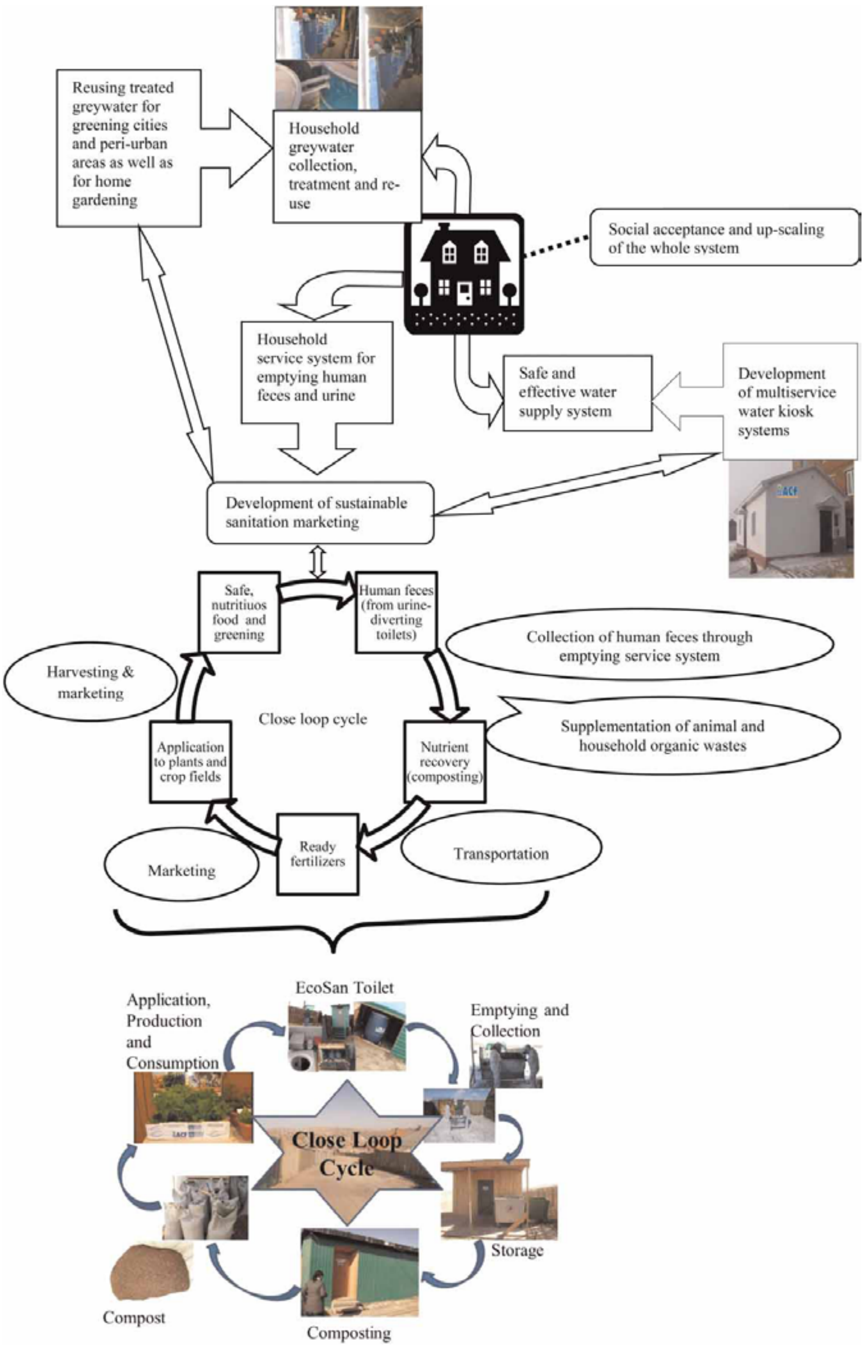


Figure 3 | Root and underlying causes of WASH-borne weaknesses.


Reusing treated greywater for greening cities and peri-urban areas as well as for home gardening
Household greywater collection, treatment and re-use
Social acceptance and up-scaling of the whole system
Household service system for emptying human feces and urine
Safe and effective water supply system
Development of multiservice water kiosk systems
Development of sustainable sanitation marketing
Safe, nutritiuos food and greening
Human feces (from urine-diverting toilets)
Collection of human feces through emptying service system
Harvesting & marketing
Close loop cycle
Application to plants and crop fields
Nutrient recovery (composting)
Supplementation of animal and household organic wastes
Ready fertilizers
Marketing
Transportation
EcoSan Toilet
Application, Production and Consumption
Emptying and Collection
Close Loop Cycle
Storage
Compost
Composting

Threats

The existing pit latrines in the Ger areas of Ulaanbaatar have been identified as threats to the SSS–SWS integration. The lack of a drainage system in the Ger areas prompts the residents to use pit latrines or soak pits to drain greywater, which causes flooding in the roads as well as in and out of households. The threats before SSS–SWS integration include the extreme cold climate, the existence of non-environmental-friendly technologies (i.e., pit latrines), and the lack of political willingness (Table 2), whereas the threats after SSS–SWS integration include the extreme cold climate, the urbanization and migration, and the existing pit latrines. The improvement and proper integration of SWS into SSS may solve the threat of the extreme cold weather.

Table 2 | Threats before SSS and possible solutions.

Factors	Threat before SSS	Possible solutions
Technological	Existing unhygienic pit latrines and unsafe water supply systems including water transportation, collection and storage (Sigel et al., 2012; GIZ, 2008; Girard, 2009) may becoming threat for the residents of the gGerer areas. There is no drainage system in the Ger areas. Greywater is drained towards the pit latrine/soak pit/yard which may cause health hazards or environmental problems.	Technology innovation and sustainable sanitation technologies such as urine diverting toilets and household greywater treatment system may reduce the threats (Jenssen et al., 2005). Proper monitoring of water transportation, collection and storage systems may ensure the safe water supply. In addition, extreme cold weather can be dealt with the improved sustainable sanitation technologies (Stintzing, 2007).
Political	Mongolia is still 'off-track' in progressing to achieve the sanitation MDGs (UNICEF and WHO, 2012). It seems that the government has lack of political willingness and less interest in policy making to improve the sanitary condition of the country including the ger areas.	Proper integration of SWS and SSS with concrete evidences (see for instance, McGarry, 1980) may motivate political leaders to increase their interests and to lead them to formulate WASH related policies.
Financial	Lack of financial contribution from government to the technological innovation and to improve the overall sanitary condition in the study area.	Government might be encouraged due to the success and benefits of the SWS and SSS integration. They might get actively involved to contribute and implement the future activities related to sustainable sanitation.
Social	Although there is a demand of sustainable sanitation technologies, still social acceptability of those technologies is not much high due to their lifestyle, attitude and nomadic mentality. Additionally migration is occurring without any planning from different areas to the peri-urban Ger areas of Ulaanbaatar.	Education and awareness regarding the SWS and SSS may change the behavior and attitude for social acceptance more (Uddin et al., 2012). Furthermore, sustainable sanitation/resource oriented sanitation may contribute towards the Eco-City development of the peri-urban Ger areas where migrant people may have opportunity to stay with proper planning.
Health	Rate of waterborne diseases are considerably higher among the ger-area residents and particularly children are highly affected. It has been addressed that there are 10,000 cases of diarrhea in Mongolia each year and dysentery is the second most prevalent disease. In addition, the rate of hepatitis A in Ulaanbaatar reaches 7 times the international average (GIZ, 2008). Lack of integration of SWS and SSS might be one of the reasons of this health hazards in Ulaanbaatar.	Holistic/comprehensive approach of sustainable sanitation can dramatically reduce the waterborne diseases in the study area and beyond (Uddin et al., 2012). Better waste management, improved water supply and sanitation, awareness through education and literacy, proper drainage system etc. can be considered in the integration process for reducing the threat.

Several studies have identified many challenges, particularly in low-income countries, in improving the global water supply and sanitation condition (Bhagwan *et al.* 2008; Tornqvist *et al.* 2008; Whittington *et al.* 2009; Roma & Jeffrey 2010; Kathy 2011). Several drawbacks and threats are caused by the traditional sanitation concepts and the implementation of technologies that are hazardous to the environment and to the health of people (Esrey *et al.* 2001; Werner *et al.* 2004). The water supply and sanitation conditions in Mongolia have been identified as among the most pressing problems in the Ger areas (Sigel *et al.* 2012) where residents rely on simple, unimproved pit latrines to solve their sanitation problems. Approximately 80,000 pit latrines are constructed in the Ger areas of Ulaanbaatar for this purpose (GTZ 2008; Girard 2009). The unhygienic sanitation technology and unsafe water supply in these areas may increase the prevalence of waterborne diseases (Sigel *et al.* 2012; Uddin *et al.* 2013a), which can only be decreased by the proper management of human feces and guaranteeing a safe drinking water supply (Esrey *et al.* 1991). These objectives can be fulfilled by the SWS–SSS integration, which can reduce the vulnerability of Ger residents to WASH-borne diseases.

CONCLUSION

The scenario before SSS–SWS integration demonstrates few strengths, such as the interest of communities and NGOs toward SWS and SSS, which facilitates the acceptance and up-scaling of related technologies. The conceptual scenario after SSS–SWS integration, which has been constructed based on the previous literature and stakeholder interview data, demonstrates additional strengths, such as community acceptance, satisfaction with SSS, and development of SWS for a vulnerable population. The identified weaknesses are attributed to the lack of CBOs, community participation, policies in the WASH sector, and inter-sector coordination. The marketing of SSS, the involvement of banks and micro-credit systems, the reuse of treated greywater as a source of plant nutrient, and the strengthened inter-sector coordination have all been identified as opportunities from the integration. The threats before the SSS–SWS integration include the extreme cold, the use of pit latrines, and the lack of political will, whereas the threats after the SSS–SWS integration include the technological innovations that deal with the extreme cold, the demand for SSS technologies, and the increased interest of central and municipal governments. The application of the SWS–SSS integration in other cases must be investigated further.

The findings support the integration of SWS into SSS to decrease the prevalence of waterborne diseases that are caused and transmitted by fecal-contaminated water to improve the overall environmental condition in Ulaanbaatar. Such integration can likewise reduce water consumption, recover resources (i.e., plant nutrients), and improve soil conditioners to fulfill future nutrient demands. Moreover, the integration can reduce the weaknesses and threats of the existing system and convert them into sustainable strengths and opportunities. The financial sources and cost recovery of the SWS–SSS integration must be explored further to lift the burden of the poor residing in the study area and in other parts of the world.

ACKNOWLEDGEMENT

Support from ACF International and ACF Mongolia for this study are acknowledged.

REFERENCES

Allen, A., Davila, J. D. & Hofmann, P. 2006 *Governance of Water and Sanitation Services for the Peri-Urban Poor, A Framework for Understanding and Action in Metropolitan Regions*. The Development Planning Unit, London, UK.

Altansukh, O. 2008 *Surface water quality assessment and modeling: A case study in the Tuul River, Ulaanbaatar city, Mongolia*. Master's Thesis, International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands.

Asian Development Bank 2010 Mongolia: Ulaanbaatar water and sanitation services and planning improvement. Technical Assistance Report. Asian Development Bank, Manila, Philippines.

Batjargal, T., Otgonjargal, E., Baek, K. & Yang, J. 2010 Assessment of metals contamination of soils in Ulaanbaatar, Mongolia. *J. Hazard. Mater.* **184** (1–3), 872–876.

Bhagwan, J. N., Still, D., Buckley, C. & Foxon, K. 2008 Challenges with up-scaling dry sanitation technologies. *Water Sci. Technol.* **58** (1), 21–27.

CIA 2013 Mongolia, https://www.cia.gov/library/publications/the-world-factbook/geos/mg.html (accessed October 2013).

Esrey, S. A., Potash, J. B., Roberts, L. & Shiff, C. 1991 Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bull. World Health Organ.* **69** (5), 609–621.

Esrey, S., Andersson, I., Hillers, A. & Sawyer, R. 2001 *Closing the Loop: Ecological Sanitation for Food Security*. Publications on Water Resources No. 18, Swedish International Development Corporation Agency (SIDA), Mexico City, Mexico.

Fry, L. M., Michelcic, J. R. & Watkins, D. W. 2008 Water and nonwater-related challenges of achieving global sanitation. *Environ. Sci. Technol.* **42**, 4298–4304.

Girard, C. 2009 *Feasibility of pit-latrine emptying services, Ger areas, Ulaanbaatar, Mongolia*. Master's Thesis, School of Applied Science, Cranfield University, UK.

GTZ 2008 ECOSAN- Ecological Sanitation in Mongolia, Result oriented monitoring – a rapid appraisal. Germany. http://www2.gtz.de/Dokumente/oe44/ecosan/en-ecological-sanitation-in-mongolia-2008.pdf (accessed May 2014).

Guzha, E., Nhapi, I. & Rockstrom, J. 2005 An assessment of the effect of human feces and urine on maize production and water productivity. *Phys. Chem. Earth* **30**, 840–845.

Hill, T. & Westbrook, R. 1997 SWOT analysis: it's time for a product recall. *Long Range Plan.* **30** (1), 46–52.

Hunter, P. R. 1997 *Waterborne Disease Epidemiology and Ecology*. John Wiley & Sons, Chichester, UK.

Itoh, M., Takemon, Y., Makabe, A., Yoshimizu, C., Koshzu, A., Ohte, N., Tumurskh, D., Tayasu, I., Yoshida, N. & Nagata, T. 2011 Evaluation of wastewater nitrogen transformation in a natural wetland (Ulaanbaatar, Mongolia) using dual-isotope analysis of nitrate. *Sci. Total Environ.* **409** (8), 1530–1538.

Jenssen, P. D., Maelum, T., Krogstad, T. & Vrale, L. 2005 High performance constructed wetlands for cold climate. *J. Environ. Sci. Health A* **40** (6–7), 1343–1353.

Kathy, E. 2011 Water, sanitation and wastewater management: some questions for National Water Security in South Africa. *Global Issues Water Policy* **2**, 73–96.

Koudstaal, R., Rijsberman, F. R. & Savenije, H. 1992 Water and sustainable development. *Nat. Resour. Forum* **16** (4), 277–290.

Langergraber, G. & Muellegger, E. 2005 Ecological sanitation – a way to solve global sanitation problem? *Environ. Int.* **31**, 433–444.

Markovska, N., Taseska, V. & Pop-Jordanov, J. 2009 SWOT analyses of the national energy sector for sustainable energy development. *Energy* **34**, 752–756.

McGarry, M. G. 1980 Appropriate technologies for environmental hygiene. *Proc. Roy. Soc. Lond. Ser. B* **209**, 37–46.

McGarry, M. G. & Stainforth, J. 1978 *Compost, and Biogas Production From Human and Farm Wastes in People's Republic of China*. International Development Research Center, Ottawa, Canada.

Meinzinger, F., Kroger, K. & Ottepohl, R. 2009 Material flow analysis as a tool for sustainable sanitation planning in developing countries: case study of Arba Minch, Ethiopia. *Water Sci. Technol.* **59** (10), 1911–1920.

Nelson, K. L. & Murray, A. 2008 Sanitation for unserved populations: technologies, implementation challenges, and opportunities. *Annu. Rev. Environ. Resour.* **33**, 119–151.

Nikolaou, I. E. & Evangelinos, K. I. 2010 A SWOT analysis of environmental management practices in Greek mining and mineral industry. *Resour. Policy* **35**, 226–234.

Nriagu, J., Nam, D., Ayanwola, T. A., Dinh, H., Erdenechimeg, E., Ochir, C. & Bolormaa, T. 2012 High levels of uranium in groundwater of Ulaanbaatar, Mongolia. *Sci. Total Environ.* **414**, 722–726.

Patersan, C., Mara, D. & Curtis, T. 2007 Pro-poor sanitation technologies. *Geoforum* **38**, 901–907.

Roma, E. & Jeffrey, P. 2010 Evaluation of community participation in the implementation of community-based sanitation systems: a case study from Indonesia. *Water Sci. Technol.* **62** (5), 1028–1036.

Schertenleib, R. 2005 From conventional to advanced environmental sanitation. *Water Sci. Technol.* **51** (10), 7–14.

Sigel, S., Altantuul, K. & Basandrorj, D. 2012 Household needs and demand for improve water supply and sanitation in peri-urban ger areas: the case of Dharkhan, Mongolia. *Environ. Earth Sci.* **65**, 1561–1566.

Solo, T. M., Perez, E. & Joyce, S. 1993 Constraints in providing water and sanitation services to the urban poor. WASH Technical Report No. 85, U.S. Agency for International Development, Washington, DC.

Srivastava, P. K., Kulshrestha, K., Mohanty, C. S., Pushpangadan, P. & Singh, A. 2005 Stakeholder-based SWOT analysis for the successful municipal solid waste management in Lucknow, India. *Waste Manage.* **25**, 531–537.

Stintzing, A. R. 2007 *Urine Diverting Toilets in Climates with Cold Winters, Technical Consideration and the Reuse of Nutrients With A Focus on Legal and Hygiene Aspects*. Women in Europe for a Common Future (WECF), Munich, Germany.

SuSanA 2013 Introduction of sustainable sanitation. Sustainable Sanitation Alliance. http://www.susana.org/lang-en/sustainable-sanitation?template=susanaprint (accessed August 2013).

Terrados, J., Almonacid, G. & Hontoria, L. 2007 Regional energy planning through SWOT analysis and strategic planning tools. Impact on renewables development. *Renew. Sust. Energ. Rev.* **11**, 1275–1287.

Tornqvist, R., Norstrom, A., Karrman, E. & Malmqvist, P. A. 2008 A framework for planning of sustainable water and sanitation systems in peri-urban areas. *Water Sci. Technol.* **58** (3), 563–570.

Uddin, S. M. N., Muhandiki, V. S., Fukuda, J., Nakamura, M. & Sakai, A. 2012 Assessment of social acceptance and scope of scaling up urine diversion dehydration toilets in Kenya. *J. Water Sani. Hyg. Dev.* **2** (3), 182–189.

Uddin, S. M. N., Li, Z., Gaillard, J. C., Mang, H. P., Rheinstein, E., Huba, E. M., Lapegue, J., Kummel, O. & Rheinstein, E. 2013a WASH-borne vulnerability: A scoping study on peri-urban ger areas in Mongolia. 2013 Beijing International Environmental Technology Symposium, 20–23 October, Beijing, China.

Uddin, S. M. N., Li, Z., Mang, H. P., Ulbrich, T., Schubler, A., Rheinstein, E. & Huba, E. M. 2013b Opportunities and challenges of greywater treatment and reuse in peri-urban Ger areas of Ulaanbaatar, Mongolia. 11th IWA Conference on Small Water & Wastewater Systems and Sludge Management, 28–30 October, 2013, Harbin, China.

UNICEF 2009 *Diarrhea: Why Children are Still Dying and What Can Be Done*, New York, USA.

UNICEF 2011 *Mongolia: Wash in School and Kindergartens*. Project design documents, Mongolia.

UNICEF and World Health Organization 2012 *Progress on Drinking Water and Sanitation*, Joint Monitoring Program for Water and Sanitation, New York, USA.

Welch, W. H. 1893 Sanitation in the relation to the poor. *Charities Rev.* **2** (4), 203–214.

Whittington, D., Hanemann, W. M., Sadoff, C. & Jeuland, M. 2009 The challenges of improving water and sanitation services in less developed countries. *Foundations and Trends in Microeconomics.* **4** (6–7), 469–609.

World Bank 2010 *Managing Urban Practices in Mongolia, Best Practices in Scenario-Based Urban Planning*. Washington, DC.

World Health Organization 2009 *Diarrheal Disease*. Fact Sheet N-330, World Health Organization, http://www.who.int/mediacentre/factsheets/fs330/en/index.html (accessed September 2012).

World Health Organization 2011 *World Health Statistics*. World Health Organization, Geneva, Switzerland.

World Health Organization 2012 *Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the Mdg Target and Universal Coverage*. World Health Organization, Geneva, Switzerland.

World Health Organization 2014 *Health Through Safe Drinking Water And Basic Sanitation*. http://www.who.int/water_sanitation_health/mdg1/en/ (accessed March 2014).

Zurbrugg, C. & Tilley, E. 2009 A system perspective in the sanitation-human waste from cradle to grave and reincarnation. *Desalination* **248** (1–3), 410–417.

First received 24 October 2013; accepted in revised form 9 May 2014. Available online 17 June 2014

4. SUSTAINABLE SANITATION TOWARDS ECO-CITY DEVELOPMENT

The 12th IWA Conference on Small Water & Wastewater Systems & 4th Specialized Conference on Resources Orientated Sanitation, November 2-4, 2014, Muscat, Sultanate of Oman.

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SUMMARY: Now-a-days sustainable sanitation or resource recovery and reuse oriented sanitation is considered as one of the problem-solvers in the field of water, sanitation and hygiene (WASH) to tackle various WASH-borne challenges in sustainable ways. This study was carried out in the Ger (traditional felt tent) areas of Ulaanbaatar, Mongolia during the period of 2012 and 2013 on various solutions of sustainable sanitation which may contribute towards the environmental friendly city or sustainable city or eco-city development in terms of resources/nutrients recovery, greywater treatment, reuse and water saving, safe water supply, reduction of water-borne diseases and protect environment from various pathogens and chemical contaminants. A range of sustainable sanitation technologies (e.g. Urine diverting toilets, composting human feces through semi-contained and greenhouse technologies, household greywater treatment through underground, greenhouse and ice-block treatment units) were designed, constructed and monitored under an ongoing research project 'sustainable sanitation for vulnerable peri-urban population in Ulaanbaatar, Mongolia' executed by Action Contre La Faim (ACF) Mongolia and University of Science and Technology Beijing funded by ACF France to assess the feasibility and replicability of the technologies in extreme cold climatic conditions which are also replicable to other parts of the world. The study reveals that sustainable sanitation technologies can fulfill the requirements of many eco-city principles in different ways. Eco-toilets may improve the health and environmental situation than any other existing unimproved sanitation technologies in the study area, composting human feces through greenhouse is the most suitable than semi-contained composting facility to treat human feces and recover nutrients for agro-production and other horticultural application. Greywater treatment through greenhouse and ice-block units seem technically and socially more feasible and acceptable than underground unit to fulfill partial demand of water in the study area and to protect from health and environmental hazards. Although there were some challenges faced, various business opportunities can be created due to innovation of numerous technologies under sustainable sanitation programs. It is recommended to test various options in holistic/integrated way to develop the eco-city in the study area or beyond for global sanitary improvement. In addition, it can be argued that efficiency, appropriateness, and affordability of the sustainable sanitation technologies should be one of the initial steps towards the eco-city development in the study area and other parts of the world particularly in low income regions.

1. INTRODUCTION

Sustainable sanitation is defined and characterized as a system in recent years in research, development and implementation under various water, sanitation and hygiene (WASH) interventions where resources/nutrients can be recovered from human wastes through 'closed-loop',

Proceedings SUM 2014, Second Symposium on Urban Mining
Bergamo, Italy; 19 – 21 May 2014

greywater can be treated and reused at household/community level, human health can be protected and promoted after breaking the cycle of diseases, and environment can be protected by source separation and treatment of feces and urine. In order to be sustainable, a sanitation system has to be economically viable, socially acceptable, technically and institutionally appropriate, it should also protect the natural resources (Nelson & Murray 2008; Langergraber & Muellegger 2005; Schertenleib 2005; Zurbrugg & Tilley, 2009; SuSanA, 2013).

On the other hand, the concept of eco-city (later eco-communities, eco-village, and eco-town) was developed around four decades ago. Various principles, dimensions, and ideas of eco-city have been applied and included in many studies (see for instance, Urban Ecology, 1996; Roseland, 1997; Hald, 2009). Urban metabolism (such as circle of energy, waste and emissions, as well as the protection of the environment) was considered in the first concept of eco-city in urban context. (Hald, 2009). Chinese eco-city, for instance, Dongtan has target for world's first purpose-built eco-city which is designed to consider environmentally, socially, economically and culturally sustainable city. Renewable energy, waste recycling and reuse including human sewage were considered, the aim was to collect 100% of all waste in the city and recover up to 90% of collected waste. Human sewage was to be processed for energy recovery, irrigation and composting to greatly reduce or entirely eliminating landfill sites (IBRD & World Bank, 2008; Hald, 2009).

Composting is one of the oldest bio-technological processes and it can be considered as one of the components of sustainable sanitation concept. Composting was already used by Chinese peasants 4000 years ago (Gottschall, 1984). Composting has been recognized historically as an 'organic method' for gardening and farming, and for a waste management technique (Blum, 1992). It is becoming more popular to recycle organic wastes for economic, agriculture, environmental (Tuomela et al., 2000) and health reasons. Additionally, it is called as biological waste treatment process (Agamuthu et al., 1999) and applied for stabilization and sanitization of sewage sludge (Dumontel et al., 1999). Therefore, human feces composting would provide safe and valuable soil amendment to improve soil fertility and to produce agro-products. In addition, major pathogens will be reduced/killed by proper composting process with appropriate technologies at local settings and it will ultimately drive to have better lifestyle and improved health and environmental condition (Harada, 2007).

Greywater treatment and reuse is also being considered as one of the solutions of sustainable sanitation in the world. Greywater definitions and characteristics are well documented in a range of studies (see for instance, Jeppesen, 1996; Ghaitidak and Yadav, 2013). Greywater treatment and reuse can be one of the potential options to solve the problems of water scarcity and pollution. During the past decades greywater have gained dramatic attention to treat and reuse in some countries with different climatic patterns including cold region to tackle the shortage of water, to minimize health hazards, to conserve environment and to reduce environmental risks (Jeppesen, 1996; Jenssen et al., 2005; Domenech and Sauri, 2010). To fulfill the requirement of eco-city principles to some extent and to develop the reuse and recycling based societies greywater treatment and reuse would be one of the options of sustainable sanitation.

This study was carried out in the Ger (traditional felt tent) area of Ulaanbaatar, Mongolia on various solutions of sustainable sanitation which may contribute towards the environmental friendly city or sustainable city or eco-city development in terms of developing 'closed-loop-sanitation-systems, recovery of resources/nutrients through human feces composting, greywater treatment and reuse and water saving through multiple technological options, safe water supply, reduction of water-borne diseases and protection of environment from various pathogens and chemical contaminations as well as to reduce the exposure of WASH-borne hazards.

2. MATERIALS AND METHODS

2.1 Study area

Mongolia, is distinguished as 'Modern Mongolia', which is landlocked by China and the Russian Federation. The detailed of the study area (Figure 1) has been discussed elsewhere (Uddin et al., 2013). Mongolia is not 'on track' to meet the sanitation targets of Millennium Development Goals (MDGs) (UNESCAP, 2011; UNICEF and WHO, 2012) and majority of population particularly in the Ger areas of Mongolia using unimproved and unhygienic sanitation technologies(e.g. pit latrines, soak pits) for solving sanitary problems (Sigel, 2012).

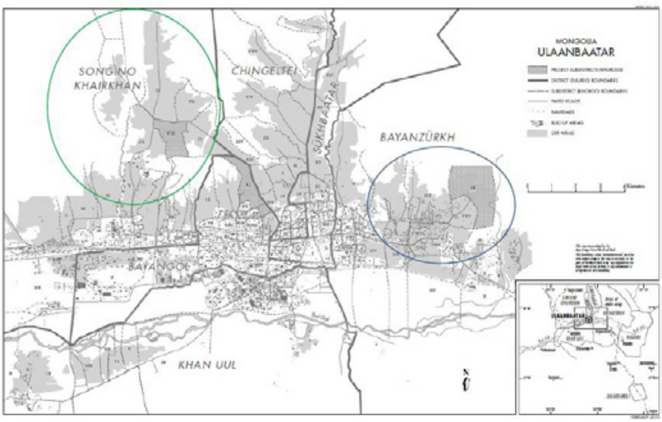

Figure 1. Map of the study area.

2.2 Experimental setup

A range of sustainable sanitation technologies (e.g. urine diverting toilets, composting human feces through semi-contained, greenhouse, household greywater treatment through greenhouse and ice-block treatment units) were investigated to assess the suitability and replicability of the technologies in extreme climatic conditions.

2.2.1 Investigating urine diverting toilets/eco-toilets

There were 120 Eco-Toilets installed by ACF Mongolia in the Ger areas since 2009. Both primary data (personal observation/visual inspection and structured questionnaire survey during the period of June and July 2013) and secondary data (ACF staff and its existing document) were used to evaluate the current toilets situation and their technological shortcomings for providing recommendations in improving the future eco-toilets' design.

2.2.2 Composting human feces

Two different methods and technological options of human feces composting were applied including the semi-centralized/ semi-contained composting unit and greenhouse composting unit. Two greenhouses were constructed, one for compost maturation and another for composting in 2013. The principle of semi-contained composting facility is to run composting during the winter period and the greenhouse composting is for extending the summer composting for getting more output of the compost. Temperature effect was monitored by using automatic *hobo data-logger* for both composting processes to assess the technical feasibility in the cold climatic condition. Table 1 shows initial moisture content (MC), total carbon (TC), total nitrogen (TN) of feces and other additives for 5 different trials of composting.

Table 1. Composting trials (1-4) conducted in semi-contained composting facility (Jul-Aug 2013) and trial 5 in greenhouse (Sep-Nov 2013).

Trial 1					Trial 2				
Feedstock	Mixing Ratio	MC(%)	TC(%)	TN(%)	Feedstock	Mixing Ratio	MC(%)	TC(%) dm	TN(%) Dm
F	1	87	48.5	4.5	F	1	87	48.5	4.5
SD	1	8	55	0.1	WC	1	13	54	0.15
ST	1	7.7	51	0.6	ST	1	7.7	51	0.6
Trial 3					**Trial 4**				
F	1	87	48.5	4.5	F	1	87	48.5	4.5
SD	1	8	55	0.1	SD	1.5	8	55	0.1
WC	1	13	54	0.15					
Trial 5									
F	1	87	48.5	4.5					
SD	1	8	55	0.1					
ST	1	7.7	51	0.6					
FW	1	78.5	29.7	0.8					

F-Feces, SD- Sawdust, WC- Woodchip, ST-Straw, FW-Food Waste

2.2.3 Household greywater treatment

To date, very few studies have been carried out in countries with cold climates, and in conditions where water consumption is significantly less (average 8 l/day/person) than the WHO standard. After reviewing various technological options, three models of greywater treatment units were developed and two were piloted during the first phase of the research project. An evaluation was done on the previous greywater systems during the period of November and December 2012, in order to assess technical shortcomings and the challenges of operation and maintenance by the users (Uddin et al, 2013). A greenhouse greywater treatment unit (GH-GWTU) was upgraded based on the evaluation and technical shortcomings and an ice-block greywater treatment unit (IB-GWTU) was designed and constructed during the summer in 2013 to assess the technical feasibility in the study area. Chemical analysis was done for the GH-GWTU and the monitoring of greywater disposal is ongoing for the IB-GWTU.

3. RESULTS AND DISCUSSIONS

3.1 Sustainable sanitation technologies and services

3.1.1 Eco-toilets

Construction of eco-toilets around the Ger areas was the part of ACF WASH programs. Several toilet models such as: Urine Diverting Dry Toilet (UDDT); Ventilated Improved Pit (VIP) and Raised VIP; Bucket Dry Toilet; Single and Double Vault Solar Toilet, were constructed and piloted by ACF in 2009 (USTB & ACF, 2010). The raised eco-toilet concept was fully accepted because it focuses on the principle that human wastes (feces and urine) are resources to be conserved and recycled to increase soil fertility and water holding capacity, not as a waste to be cast away. The specific hydromorphic characteristics of the area also promoted the choice of this model. The current systems include 120 eco-toilets in the study area. Recently more 250 eco-toilets were constructed by ACF to up scale the system.

3.1.2 Emptying services

The emptying service addresses the existing eco-toilets. A key principle of eco-toilet is the urine diverting system. The Urine diverting seat is installed in the toilet cabin and urine is disposed in the urine pit through the urine pipe. Dry feces are collected in the collection bucket with sawdust. As a procedure, the user is requested to sprinkle sawdust in the chamber after defecation. This on one side, preventing bad odors, on the other side is activating the composting process (a carbon source is provided to bacteria present in the feces). It also has the advantage to reduce the waste volume, as well to protect the urine (sterile) from the feces (generally toxic). The emptying service covers the replacement of the feces collecting buckets. The staff of emptying services have been trained and aware of personal hygiene and protection in order to avoid pathogens transmission during the services. Therefore, all the necessary precautions were taken such as protective gadgets, synthetic lotion, and avoid eating, smoking or excessive laughing during emptying service to prevent themselves from contagious diseases. At every three months interval, emptying services are carried out by ACF from household to household. The filled buckets are exchanged with clean and empty ones, and transported to the composting site for further hygienization.

3.1.3 Collection, transportation and storage

The collection of feces is arranged after completing emptying services by using the small truck run by the emptying officers of ACF. The road communication systems need to take necessary precautions for transportation. Fecal matters in the collecting buckets are very dry; therefore, conventional suction pumps cannot be used to suck out the feces from the bucket. Two officers are manually extracting the feces collecting bucket from the eco-toilets. They cover the bucket with a lid and move it on the truck platform and replace the full bucket with an empty bucket in the toilet. The truck can currently host 8 buckets in order to optimize and make the service safer. The collected feces are stored in a store-house at the site of treatment/composting during the summer and outside (in case of lack of spaces) during the winter when the temperature is at freezing level.

3.2 Composting human feces

3.2.1. Composting in semi-contained facility

Figure 2 shows the variation of temperature against time period of composting. For the trials (1-4) in semi-contained composting facility, temperatures were monitored at bottom, core and top of the piles. The ambient temperature ranged from 18-24°C (while the outside average day temperature ranged from 20-24°C and night from 8-12°C) which did not have any significant influence on the composting process. The maximum temperatures reached in Trial 1, 2, 3 and 4 were 60.6, 63.0, 60.1 and 64.2°C respectively. Also, the periods of temperatures that were maintained above 55°C were 11days, 15days, 10days and 16days as shown respectively. There was no significant difference in the obtained temperatures for the first three trials, whereas, the trial 4 took a complete one week before reaching thermophilic phase, this could be as a result of no bigger particles to create more space for aeration and also, the sawdust used in all the trials was from pine trees that contains high acidity level and lignin contents, which are not easily digestible by the microorganisms.

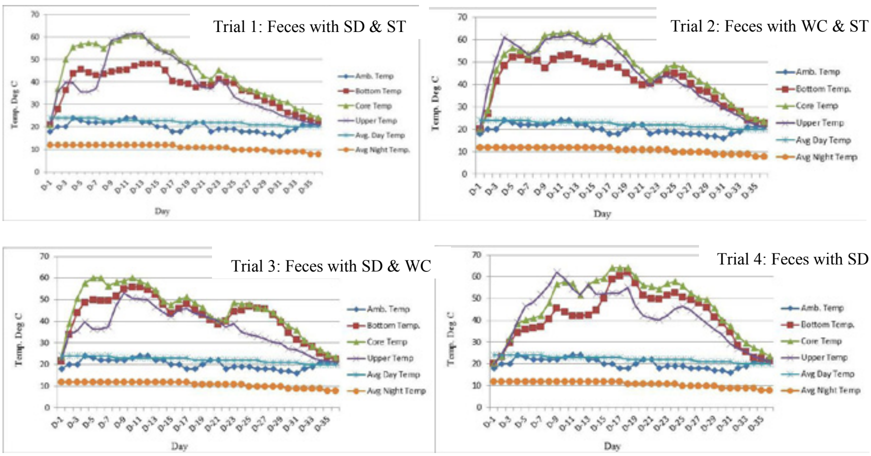

Figure 2. Temperature monitoring of co-composting fecal matter with different additives.

Turning played a significant role and influenced the temperature variations, for every turning made on weekly basis; there was slight increase in the temperatures. If only the center/core of compost reaches thermophilic phase, turning becomes imperative to ensure all other parts of the piles are well sanitized. Currently composts of all trials from semi-contained facility are under outdoor temperature for winter hygienization. A chemical and biological analysis will be carried out after winter to assess the nutrient and pathogen contents in the composts.

3.2.2. Composting in greenhouse

For this trial, *data logger* was horizontally placed at the center of the pile and temperatures were monitored as shown in Figure 6. The ambient temperature in the GH dropped from 39 to 4°C as there was corresponding drop in outside day temperature from 13 to -19°C respectively at the end of the trial. At the fourth day of composting, the temperature reached 70°C; this high temperature could either be influenced by ambient temperature of the GH or the easily digestible carbon source that was added i.e food waste. The temperatures above 55 and 65°C were maintained for 2 weeks and more than a week respectively, which satisfies all the sanitation requirements including Germany standard. After two weeks of composting with declining temperature, the pile was firstly turned to ensure other parts were exposed to high temperature for proper hygienization. After turning, the temperature rose up back to 65°C and gradually coming down as outside temperature dropped below 0°C. The sufficient high temperatures obtained in this trial were in line with observation made by Niwagaba et al. (2009) and Germer et al. (2010) that mixing of food waste to feces provided easily digestible carbon to the microbes and maintained high temperature for longer period of time.

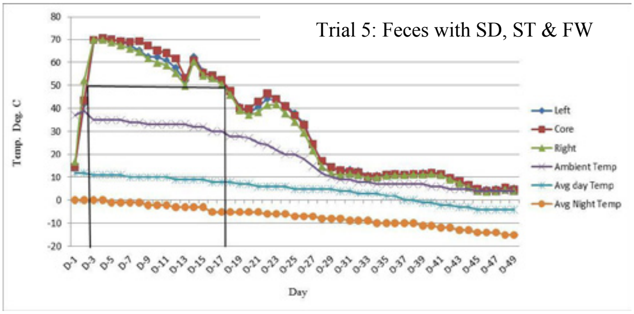

Figure 3. Temperature monitoring in greenhouse composting unit.

3.3. Greywater treatment

3.3.1. Greenhouse treatment unit

The basic principle of the GH-GWTU is to extend the summer period for more treatment and production of treated greywater. The households will store greywater during the whole winter period in plastic buckets. The chemical analysis of the influent and effluent shown the highest removal rate of COD (94%), NH_4^+ (98%), NO_2^- (99%), NO_3^- (72%), P (98%), and TSS (92%) were achieved. Regarding the TSS, the maximum removal rate was 92% which is much higher than the results reported in Chaillou et al. (2011). Although the maximum removal rate of COD was 94%, the effluent standard is still over the suggested guideline in other countries. In Mongolian case, there is no standard and guidelines for greywater reuse. This is completely new for Mongolian ger residents. Table 2 shows the chemical test results and the removal rate of greywater.

Table 2. Tests results of each week during the period of two months (Sep-Oct) 2013

Parameter	Influent(mg/l)		Effluent(mg/l)		Avg. Temp (Outside GH) ^{o}C		Avg. Temp (Inside GH) ^{o}C		Max Removal Rate (%)
	Max	Min	Max	Min	Day	Night	Day	Night	
COD	4824	385.9	1399	193	11	-0.5	25	11	94
NH_4^+	328.6	1.76	28.2	0.64					98
NO_2^-	1.133	0.162	0.15	0.013					99
NO_3^-	13.6	1.64	3.87	0.25					72
P	12.276	4.08	4.536	0.188					98
TSS	1484	66	300	44					92

3.3.2. Ice-block treatment unit

This system is based on storing water during the entire winter freezing period as an ice block, and then starting treatment during the summer/non-freezing period. A suitable site was selected after visiting seventeen sites in the study area based on defined factors such as availability of land for construction, agricultural lands and activities for reusing treated greywater, household interest regarding the Ice-Block Unit and water reuse. Three major components (storage pond—septic tank—constructed wetland) were set up at the household level. Storage capacity for 7.5 months (mid-October to May) corresponding to 225 days for three residents was tested with a consumption of 8 l/p/d (24 l/d x 225 d = 5400 l). The Ice-Block Unit is currently in the storage/freezing stage (mid-October to May), and it is being monitored for disposal of greywater. Treatment will be subsequently monitored to analyze the water quality both for chemical (e.g. TSS, COD, $N\text{-}NH^{+}_{4}$, PO_4^{-}) and biological (e.g. *E. coli*) parameters, and to investigate the Ice-Block Unit's feasibility, adaptability, and potential for Mongolia. Socio-economic assessment will be carried out for up- or down-scaling either at the household or at the community level. A manual will be prepared based on the monitoring results and maintenance experience of the households.

3.4. Contribution to eco-city development

Figure 4 shows the principles of the eco-city which developed several decades ago and the contributions from sustainable sanitation to fulfill those principles partially or fully.

Eco-City Principles		Contributions to Sustainable Sanitation (SuSan)
Restoration of urban environment.	→	Source separation, and treatment of human feces, and urine, greywater.
Support local agriculture, urban greening project and community gardening.	→	SuSan recovers nutrients, and recycles from human waste, organic solid waste and reuse greywater through close-loop-cycle.
Promote recycling, innovative appropriate technology and resource conservation.	→	SuSan encourages in recycling resources and conserving nature by innovating appropriate technology and reducing fecal and chemical pollution.
Work with businesses to support ecologically, sound economic activity and while discouraging pollution, waste, and the use and production of hazardous material.	→	SuSan gives opportunities to develop environment friendly business where pollution is discouraged.
Promote voluntary simplicity and discourage excessive consumption of the material good.	→	SuSan promotes simple technological solutions where material consumption is less.
Increase public awareness of ecological sustainability issues.	→	SuSan enhances public participation and break socio-cultural taboos through awareness towards sustainability.

Figure 4. Contribution of sustainable sanitation (SuSan) to Eco-City Development (Adopted from Urban Ecology,1996)

4. CONCLUSIONS

The study reveals that eco-toilets may improve the health and environmental situation by reducing the external pathogen contacts than any other existing unimproved sanitation technologies in the study area. Composting human feces through greenhouse is more suitable than semi-contained composting facility to treat human feces and recover nutrients for agro-production and other horticultural application. High removal rate of different chemical parameters was achieved by using GH-GWTU. Despite IB-GWTU is currently under monitoring, initial performance shown that it is technically feasible and socially accepted by the user. Both units may have potentiality to fulfill partial demand of water in the study area and to protect from health and environmental hazards. Although there were some challenges faced, various business opportunities can be created due to innovation of numerous technologies under sustainable sanitation programs. It is recommended to test various options in holistic/integrated way to develop the eco-city in the study area or beyond for global sanitary improvement. In addition, it is argued that efficiency, appropriateness, and affordability of the sustainable sanitation technologies should be one of the initial steps towards the eco-city development in the study area and other parts of the world particularly in low income regions. It may be one of the ways to reduce WASH-borne risks, hazards and vulnerability due to absence/lack/failure of WASH system.

AKNOWLEDGEMENTS

Supports from ACF Mongolia and ACF International Frances are acknowledged.

REFERENCES

Agamuthu, P., Choong, L.C., Hasan, S. and Praven, V.V. (1999). Kinetic evaluation of composting of agricultural wastes. Environmental Technology, vol. 21, n. 2, 185-192.

Blum, B. (1992). Composting and the roots of sustainable agriculture. Agricultural History, vol. 66. n. 2, 171-188.

Domenech, L., and Sauri, D. (2010). Socio-technical transitions in water contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. Resources, Conservation and Recycling, vol. 55, 53-62.

Chaillou, K., Gerente, C., Andres, Y., and Wolbert, D. (2011) Bathroom greywater characterization and potential treatmens for reuse. Water Air Soil Pollut, vol. 215, 31-42.

Dumontel, S., Dinel, H. and Baloda, S. B. (1999). Pathogen reduction in sewage sludge by composting and other biological treatments: A review. Biological Agriculture and Horticulture, vol.16, 409-430.

Gaitidak, D. M. and Yadav, K. D. (2013). Characteristics and treatment of greywater – a review. Environ Sci Pollut Res, DOI 10.1007/s11356-013-1533-0.

GERES (2004). Solar greeniouse for the Trans-Himalayas: a construction manual. Reneable Energy and Environmental Group, Aubagne, France.

Gottschall, R. (1984). Kompostierung. Alternative Konzepte, 45. C.F. Muller, Karlsruhe, 296 (German) in Ginkel, V. J. T. (1996). Physical and biochemical processes in composting material. PhD Thesis, Wageningen Agricultural University, Wageninggen, The Netherlands.

Germer, J., Boh, M.Y., Schoeffler, M., and Amoah, P. (2010). Temperature and deactivation of microbial faecal indicators during small scale co-composting of faecal matter. Waste management, vol. 30, n. 2, 185-191.

IBRD & World Bank (2008). Climate resilient cities: a primer on reducing vulnerabilities to climate change impacts and strengthening disaster risk management in East Asian cities. The International Bank for Reconstruction and Development/The World Bank, Washington D. C. USA.

Hald, M. (2009). Sustainable urban development and the Chinese Eco-City: concepts, strategies, policies and assessments. FNI Report 5, Fridtjof Nansen Institute, Lysaker, Norway.

Harada, H. (2007) A proposal of Advanced Sanitation System and Attempts to Improve Vietnamese Sanitation, Doctoral Dissertation, Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan.

Jenssen, P.D., Maehlum, T., Krogstad, T. and Vrale, L. 2005. High performance constructed wetlands for cold climates. Journal of Environmental Science and Health, vol. 40, 1343-1353.

Jeppesen, B. 1996. Domestic greywater re-use: Australia's challenge for the future. Desalination, vol. 106, 311-315.

Langergraber, G. & Muellegger, E. (2005). Ecological sanitation - a way to solve global sanitation problem? Environment International, vol. 31, 433-444.

Nelson, K. L. & Murray, A. (2008). Sanitation for unserved population: technologies, implementation challenges and opportunities. Annu. Rev. Environ. Resour, vol. 33, 119-151.

Niwagaba, C., Nalubega, M., Vinnerås, B., Sundberg, C. and Jönsson, H. (2009). Substrate composition and moisture in composting source-separated human feces and food waste. Environmental Technology, vol. 30, n. 5, 487-497.

Schertenleib, R. 2005 From conventional to advanced environmental sanitation. Water Science and Technology, vol. 51, n. 10, 7-14.

Sigel, S., Altantuul, K. and Basandrorj, D. (2012). Household needs and demand for improve water supply and sanitation in peri-urban ger areas: the case of Dharkhan, Mongolia. Environmental Earth Sciences, vol. 65, 1561-1566.

SuSanA (2013) Introduction of sustainable sanitation. (wesite: http://susana.org/lang-en/sustainable-sanitation). (accessed November 2013)

Roseland, M. (1997) Dimension of the eco-city, Cities, vol.14, n.4, 197-202.

Tuomela, M., Vikman, M., Hatakka, A. and Itavaara, M. (2000). Biodegradation of lignin in a compost environment: a review. Bioresource Technology, vol. 72, 169-183.

Uddin, S.M.N., Li, Z., Gaillard, J.C., Mang, HP., Rheinstein, E., Huba, E.M. Lapegue, J, Kummel, O., and Rheinstein, E. (2013). WASH-Borne vulnerability: A scoping study on peri-urban ger areas in Mongolia. 2013 Beijing International Environmental Technology Symposium, 20-23 October, Beijing, China.

Uddin, S.M.N., Li, Z., Mang, HP., Ulbrich, T., Schubler, A., Rheinstein, E., and Huba, E.M., (2013). Opportunities and challenges of greywater treatment and reuse in peri-urban ger areas of Ulaanbaatar, Mongolia. 11th IWA Conference on Small Water & Wastewater Systems and Sludge Management, 28-30 October, 2013, Harbin, China.

UNESCAP 2011 Statistical Yearbook for Asia and the Pacific. United Nations, Thailand.

UNICEF & WHO 2012 Progress on drinking water and sanitation. Joint Monitoring Program for Water and Sanitation, New York, USA.

Urban Ecology (1996) Mission statement and accomplishments, In Roseland, M. (1997) Dimension of the eco-city, Cities, vol. 14, n. 4, 197-202.

USTB & ACF (2010). Suitability of different technology options for grey water and human excreta treatment / disposal units in Ger areas in Ulaanbaatar, Mongolia.

Zurbrugg, C. & Tilley, E. 2009 A system perspective in the sanitation-human waste from cradle to grave and reincarnation. Desalination, vol. 248, n. 1-3, 410-417.

2 - SOCIO-ECONOMICS STUDIES

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1. EXPLORING FUNDING FOR SUSTAINABLE SANITATION IN MONGOLIA: PERCEPTIONS FROM STAKEHOLDERS AND COMMUNITIES

37th WEDC International Conference, Hanoi, Vietnam, 2014

SUSTAINABLE WATER AND SANITATION SERVICES FOR ALL IN A FAST CHANGING WORLD

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REFEREED PAPER 1970

One of the major challenges for scaling up sustainable sanitation (SuSan) technologies and services is the sources of finances. Perceptions of stakeholders and communities may trigger them to overcome this challenge by exploring viable financing mechanisms and sources for widespread replication of SuSan technologies and services from the local to the global scale. This approach was studied through household surveys combined with semi-structured key informant interviews among various SuSan users and institutional stakeholders in the peri-urban Ger areas of Ulaanbaatar, Mongolia. The results showed that the existing technologies and services are highly subsidized and still partly shared by the households. Micro-finance organizations (including banks), government subsidies, private companies and community fundraising through building social capital may be considered as potential sources of finance for SuSan projects in Mongolia. A re-invented idea of 'Corporate Responsibility' is an interesting direction in which to explore possible financial sources and an effective mechanism for sustainability in the water, sanitation and hygiene (WASH) sector.

Introduction

In Mongolia, particularly in the peri-urban "Ger" areas of Ulaanbaatar, most residents face a range of challenges in the water, sanitation and hygiene (WASH) sector. They still use pit latrines and soak pits in unhygienic conditions and have unsafe water supply systems (ACF Mongolia, 2009; Uddin et al., 2013a; Uddin et al., 2013b). As a result, hepatitis A and diarrheal diseases are still prevalent (Davaalkhan et al., 2009) and 3.5% of the annual deaths in Mongolia are WASH-related (Caldieron and Miller, 2010; UN WATER, 2013).

One of the key strategies for overcoming these public health challenges is to develop safe water supply and improved sanitation systems. This are especially crucial in a peri-urban context where the risks of contamination of water resources are high due to the density of the population, the global hydromorphic status of the area, limited access to water, especially in winter, and the nature and practices of the resident community (new residents, nomadic culture, poverty, limited hygiene education and practices) (Caldieron, 2013; Uddin et al., 2013a; World Bank, 2006).

In addition to socio-cultural and geographical factors, one of the major challenges for scaling up sustainable sanitation (SuSan) technologies (e.g. urine-diverting dry toilets that reduce environmental pollution and health hazards and also help in resource recovery) and services (e.g. emptying, collection, transportation, treatment) in low and middle-income regions around the world is sourcing finance to build new infrastructures and to maintain the existing ones. Other common obstacles to widespread replication of SuSan technologies and services in many parts of the world include high construction costs, dependency on external funding, lack of political willingness to carry out large-scale investment and lack of proper cost-benefit analysis (Uddin et al., 2014; Uddin et al., 2012; World Bank, 2009). Perceptions of institutional stakeholders and communities may trigger them to overcome these challenges by exploring viable financing mechanisms and sources for widespread replication of SuSan technologies and services from the local to the global scale.

This study was carried out between June and November in 2013 under an ongoing PhD research project jointly implemented by Action Contre la Faim (ACF) Mongolia and the University of Science and Technology Beijing (Uddin et al., 2013c). It was supported by various international and national universities such as the Mongolian University of Science and Technology, the Mongolian State University of Agriculture, the Technical University of Berlin, and the Martin Luther Universitat Halle-Wittenberg, and funded by ACF France. Its purpose was to find out the perceptions of peri-urban nomadic communities and institutional stakeholders related to exploring sources of finances for scaling up SuSan technologies and services in the study area, which could be considered for replicating in other parts of the world.

Materials and methods

The main research method was to conduct interviews with community members (clients), institutional stakeholders and key informants (the key persons from the institutional stakeholders and communities who were interviewed informally). In addition, secondary data were collected from the wider literature related to this study.

Questionnaire survey

A household survey, with structured questionnaire, was conducted between June and November in 2013 in the peri-urban (Ger) areas of Songinokhaikhan and Bayanzurkh Districts of Ulaanbaatar, Mongolia, among the users, non-users and service receivers of SuSan technologies (i.e. eco-toilets) and services (i.e. emptying services). The survey assessed community perceptions on financing sustainable sanitation, income generation, willingness to pay for the technologies and services and their benefits. Seventy two out of 120 users of eco-toilets were interviewed and equal number of non-users was also included in the questionnaire survey.

Semi-structured key informant interview

In addition, to ensure triangulation of the household survey result, a total of 10 institutional stakeholders and 10 key informants from government and non-government organizations, healthcare institutions/hospitals, insurance and banks, service and business providers, and companies were interviewed using a semi-structured questionnaire throughout the year of 2013, to assess views/perceptions on financial sources, future financing in the sector and willingness to provide finances and business opportunities.

Results and discussions

Benefits and costs of eco-toilets and services

The results of the household survey confirmed that eco-toilets generate strong benefits at household level, even though these cannot be systematically quantified in monetary terms. Comfort and cleanliness especially were stated by a 48% of eco-toilet users as great advantages compared to their old latrines. Other advantages, such as absence of odor and flies, presence of a toilet seat, good design, an emptying service and health benefits, were stated by the remaining respondents (52%).

The costs of eco-toilets are divided between infrastructure and services. An eco-toilet costs ten times as much to build as a pit latrine in this area (about 272,000 MNT/ 155 USD compared with 30,000 MNT/17 USD), due to its specific technology (urine diversion, double pit, separate container for excreta). The average household monthly income in the area is 600,000 MNT/341 USD, therefore willingness to pay for eco-toilets is still low in the communities. Only 12 % stated they would pay 200,000 MNT/114 USD and 3 % would pay 300,000 MNT/170 USD, which drastically challenges replication and coverage.

In relation to services, the survey result showed that a negligible number of respondents would agree to pay 10,000MNT/6 USD per emptying. Other maintenance costs such as yearly supply of sawdust for the eco-toilet range from 0 MNT to 200,000 MNT/113 USD.

Exploring a set of options to promote scaling up ecosanitation

Since buying an eco-toilet involves high up-front costs, which pose a barrier to low-income households, several options are explored in order to facilitate covering this high initial investment.

Micro financing

The results from the interviews among the institutional stakeholders, particularly banks, revealed that micro-credits and loan systems are still new for Mongolia and for the Ger residents of Ulaanbaatar, who have migrated from the countryside. Lending schemes like micro-credit have only been available, especially to low-income families, for the last 20 years. However, the financial sector has been growing and spreading fast in recent years and there is now a variety of microfinance institutions and a lot of activities in Mongolia.

In the Ger areas of Ulaanbaatar, the national bank "XacBank" is involved in traditional microfinance in different ways such as providing conventional small loans to local residents, partnered with an international microfinance-lending organisation. The focus of the loans is mainly on small businesses, green lending (e.g. for insulation, energy efficiency) and the newest one, which started in 2012, is for water and sanitation. During the interviews with residents, a first question was about knowledge of the micro-credit loans for eco-toilets offered by XacBank (up to 7,000,000 MNT, at a monthly interest rate of 1.8-2.2 %) and willingness to pay if receiving such a loan. A second question was more precisely about willingness to pay by monthly installments during one year. In this context it has to be noted that both questions were not easy for respondents to answer since knowledge about micro-credits for eco-toilets is still not widespread in Mongolia. Only 30 % of respondents answered that they knew about this loan opportunity.

Making SuSan self-financing for infrastructures and service

There are possible business opportunities for organic fertilizer production in Mongolia (ACF, 2012). However, to establish the actual benefits and to quantify them in monetary terms from the companies involved remains a challenge. The results from the stakeholder interviews also showed that government and other stakeholders had shown keen interest in improving the situation of the Ger areas in terms of water, sanitation and hygiene, but very limited interest in the SuSan concept. On the other hand, several private companies showed business interest in managing the emptying services, installing eco-toilets and treatment of human feces through composting. These types of business possibilities should catalyze and trigger the process for self-financing mechanisms in the study area and in other parts of the country.

Towards corporate WASH responsibility

The idea of corporate social responsibility (CSR) is not new and many theories, definitions and characteristics of CSR are well documented in a range of business and management literature (see for instance, Aguilera et al., 2007; Dahlsrud, 2006; Smith, 2003; Lindgreen and Swaen, 2010). In addition, the concept of 'corporate environmental responsibility' (CER) has evolved from CSR in recent decades for improving the environmental impact of companies and other stakeholders (Kovacs, 2008; Zondorak, 1991). However, only very recently has it been addressed as a potential driver to solve global sanitary problems (Abeysuriya et al., 2007) and create finances for improving global water, sanitation and hygiene (WASH) conditions significantly. The results from the key informant interviews and stakeholder interviews showed that CSR is absent from the field of WASH in Mongolia. A department of corporate environmental responsibility at the Trade and Development Bank has just started recently to deal with the mining industry and making loans to companies dependent on an environmental assessment. Following the same logic, 'corporate WASH responsibility' can be considered as one of the important components of CSR in banking and non-banking sectors to raise awareness among institutions and communities for improving both the local and the global WASH situation.

Towards government subsidies

Qualitative interviews among the stakeholders revealed that there is in principle a budget allocation by companies (e.g. mining companies) for local residents in Mongolia which could be used for wider sanitary improvement and to replicate SuSan technologies and services. Improved sanitation and water in low-income countries yields an average of about 9 USD for every one dollar spent. This could encourage the Mongolian government, as any other, to reduce health-care costs and increase the population's productive days effectively (WSSCC, 2010). In Mongolia, the coverage of improved sanitation is 26.6% and of improved water supply is 39.2%. Progress during the last two decades has been very slow, so the country may not be able to meet the MDG target for water and sanitation by 2015 (UNDP, 2010). Although progress of improved water supply is a bit faster than improved sanitation coverage, water quality is still not ensured (Uddin et al., 2013c). However, the results from stakeholder interviews revealed that the Mongolian government recently showed great interest in actively supporting the sanitation sector in Ger areas. The Ulaanbaatar city municipality is working with UNICEF and the Mongolian Red Cross on ways to identify sanitation gaps and improved sanitation (and latrines in particular) in Mongolia. This kind of outreach and public support is a good indicator. The government has shown in the past that it is very supportive of environmental programmes especially in the Ger districts because it recognizes that they are a disaster in terms of infrastructure and public health. And if the problems of sanitation remain unaddressed then the consequences will get even worse. This could motivate the government to raise funds and provide subsidies for deploying SuSan technologies and services in the study area and other parts of the country.

Social capital towards generation of funds

Key informant interviews showed that social capital (bonding-bridging-linking such as neighborhood relationships), as described by (Pelling & High, 2005; Elgar et al., 2011; Franklin, 2005, is lacking in the peri-urban settlements of the Ger areas due to the historical nomadic life of the people. This may be one of the challenges to generating community funding mechanisms that should be applied to pay for SuSan technologies and services. This challenge can be overcome by using community-based activities and programs executed by various governmental and non-governmental organizations.

Improvement of the wellbeing of urban dwellers by enforcing environmental laws

In Mongolia, a series of environmental-protection laws has been recently adopted to provide a healthy environment and protect the lives of current and future generations. The Mongolian government introduced the principle of 'polluter pays' under the 'Law of Mongolia on Environmental Protection' to improve environmental conditions and reduce the possible health hazards caused by man-made environmental pollution. The water law states that 'a citizen, entity or organization that pollutes water shall be subject to water pollution compensation fees' (Aldrich and Melville, 2012; Sigel 2012; World Bank, 2013). However, still there is lack of implementation of these laws and the enforcement of regulations is unclear (UNDP, 2010). Environmental laws can also be applicable to residents who are polluting the environment through unimproved sanitation technologies (e.g. pit latrines or soak pits) and unhygienic practices (e.g. unplanned discharge of high-concentration greywater into the environment) (Uddin et al., 2013a). These laws may lead to cost reduction of decontaminating water and treating diseases caused that promote ecological sanitation approaches such as the SuSan concept, either through financial incentives or by taxing people and companies that still pollute the environment. Ultimately, a legal framework oriented towards protecting the urban environment, consolidated with a package of financial support to eco-friendly technologies and taxes on polluters, may be one the most powerful tools to scale up SuSan approaches.

Conclusions and recommendations

This study researches various options/perceptions for exploring funding sources at both community and institutional levels to scale up SuSan technologies in the study area and other parts of the country. Although there are potential benefits found from eco-toilets, the affordability to buy and willingness to pay is much lower than for installing a pit-latrine. There are micro-credit loans available for installing eco-toilets, but communities have negligible awareness and understanding of them.

It is recommended to further assess different potential options to overcome constraints connected with high initial up-front costs as well as with the running and maintenance costs. Additionally, the option of payment by installments could be explored. An assessment of healthcare costs and other hidden/opportunity costs would encourage advocating government agencies to provide subsidies for scaling up SuSan countrywide. Even though Mongolian health insurance covers basic treatment, water-borne diseases lead to financial costs for households in addition to personal constraints and discomfort. Micro-finance organizations, government subsidies and mining industries in Mongolia may be considered as potential sources of funding for replicating SuSan technologies and services. Building social capital among the Ger residents may also have added value to generate community funds for monitoring and maintaining the technologies and services at scale. A re-invented idea of 'Corporate WASH Responsibility' is highly recommended to explore in future studies. Enforcement of environmental laws and other related laws may also help reduce the costs associated with unsanitary/insufficient WASH facilities in the study area and other parts of the low and middle-income regions.

Acknowledgements

The authors would like to extend thanks to ACF Mongolia and ACF International France for their program and financial support.

References

ACF 2012 *Knowledge, attitude and practice survey on water, sanitation and hygiene of Ger areas in Ulaanbaatar, Mongolia,* Report of Comparison Results of KAP Surveys in 2009 and 2011, Action Contre la Faim, Ulaanbaatar: Mongolia.

ACF 2012 *Compost marketing study: Customer survey for soil amendments, Ulaanbaatar, Mongolia*, Action Contre la Faim, Ulaanbaatar, Mongolia.

AGUILERA, R. V., RUPP, D. E., WILLIAMS, C. A. and GANAPATHI, J. 2007 *Putting the S back in corporate social responsibility: A multilevel theory of social change in organizations*. Academy of Management Review Vol. 32, No 3, 836-863.

ABEYSURIA, K., MITCHEL, C. and WHITE, S. 2007 *Can corporate social responsibility resolve the sanitation question in developing Asia countries.* Ecological Economics Vol. 62, pp. 139-147.

ALDRICH, M. and MELVILLE, C. 2012 *Revision of environmental laws in Mongolia and its impact on the mining sector*. Hogan Lovells. Ulaanbaatar, Mongolia. Website: http://www.hoganlovells.com/files/Uploads/Documents/Mongolia_newsflash_-_Revision_of_environment_law_-_October_2012_1003877.pdf (accessed March 2014).

CALDIERON, J. and MILLER, R. 2010 *Residential satisfaction in the informal neighborhoods of Ulaanbaatar, Mongolia.* ARCC Journal, Vol. 7 No 1, pp. 12-18.

CALDIERON, J. M. 2013 *Ger districts in Ulaanbaatar, Mongolia: Housing and living condition surveys*, International Journal of Innovation and Applied Studies. Vol. 4, No 2, pp. 465-476.

ELGAR, E.J., DAVIS, C.G., WOHL, M.J., TRITES, S.J., ZELENSKI, J.M. and MARTIN, M.S. 2011 *Social capital, health and life satisfaction in 50 countries.* Health & Place Vol. 17, pp. 1044-1053.

FRANKLIN, J. 2005 *Women and social capital.* Families & Social Capital ESRC Research Group, London South Bank University: London, UK.

KOVACS, G. 2008 *Corporate environmental responsibility in the supply chain*, Journal of Cleaner Production Vol. 16, No 15, pp. 1571-1578.

DAHLSRUD, A. 2006 How corporate social responsibility is defined: an analysis of 37 definitions, *Corp. Soc. Responsib. Environ. Mgmt., Vol. 15, No 1, pp. 1-13.*

DAVAALKHAM, D., ENKHOYUN, T., TAKAHASHI, M., NAKAMURA, Y. and OKAMOTO, H. 2009 *Hepatitis A and E virus infections among children in Mongolia*, The American Journal of Tropical Medicine and Hygiene Vol. 8, No 2, pp. 248-51.

LINDGREEN, A. and SWAEN, V. 2010 *Corporate social responsibility,* International Journal of Management Review Vol. 12, No 1, pp. 1-7.

PELLING, M. and HIGH, C. 2005 *Understanding adaptation: what can social capital offer assessments of adaptive capacity?* Global Environmental Change Vol. 15, pp. 308-319.

SIGEL, K. 2012 *Urban water supply and sanitation in Mongolia: A description of the political, legal, and institutional framework*. UFZ Discussion Paper, Leipzig, Germany.

SMITH, N. C. 2003 *Corporate social responsibility: not whether, but how?* London Business School, London: UK.

UDDIN, S.M.N., MUHANDIKI, SAKAI, A., MAMUN, A. A. and HRIDI, S. M. 2014 *Socio-cultural acceptance of appropriate technology: identifying and prioritizing barriers for widespread use of the Urine Diversion Toilets in Rural Muslim Communities of Bangladesh,* Technology in Society Vol. 38C, pp. 32-39.

UDDIN, S.M.N., MUHANDIKI, V.S., FUKUDA, J., NAKAMURA, M. and SAKAI, A. 2012 *Assessment of Social Acceptance and Scope of Scaling Up Urine Diversion Dehydration Toilets in Kenya.* Journal of Water, Sanitation and Hygiene for Development Vol. 2, No 3, pp. 182-189.

UDDIN, S.M.N., LI, Z., MANG, HP., ULBRICH, T., SCHUBLER, A., RHEINSTEIN, E., and HUBA, E.M. 2013a Opportunities and challenges of greywater treatment and reuse in peri-urban Ger areas of Ulaanbaatar, Mongolia. *Proceedings of 11th IWA Conference on Small Water & Wastewater Systems and Sludge Management, 28-30 October, 2013.* Harbin, China.

UDDIN, S.M.N., LI, Z., MANG, H. HUBA, E.M. and LAPEGUE, J. 2013b A holistic approach to integrate safe water supply and sustainable sanitation system: a SWOT analysis. *International Conference on Water Research, 20-23 January 2013.* Singapore.

UDDIN, S.M.N., LI, Z., MANG, H. HUBA, E.M., LAPEGUE, J. and EYRARD, J. 2013c Sustainable sanitation for vulnerable peri-urban population in Mongolia: An introduction of a multi-lateral

cooperation project. *Proceedings of 12th JADE Conference, Japan Association of Drainage and Environment, 9 November 2013.* Tokyo, Japan.
UNDP 2010 *Governance, advocacy and leadership for water, sanitation and hygiene: Mongolia*. Country Sector Assessments, UNDP GoAL WaSH Program, Volume 2, New York, USA.
UN WATER 2013 Mongolia: UN-Water Country Brief. Website: http://www.unwater.org/downloads/WCB/finalpdf/MNG_pagebypage.pdf (accessed March 2013)
World Bank 2006 *Hygiene and sanitation situation report for Ger areas, Mongolia,* The World Bank, Ulaanbaatar, Mongolia.
World Bank 2009 *Study for financial and economic analysis of ecological sanitation in Sub-Saharan Africa.* Water and Sanitation Program-Africa, The World Bank, Nairobi: Kenya.
World Bank 2013 Environment in East Asia and Pacific: Mongolia environment. The World Bank, Website: http://go.worldbank.org/WS1HSEF2S0 (accessed March 2014).
WSSCC 2010 Sanitation financing. Website: http://www.wsscc.org/topics/sanitation/sanitation-financing (accessed March 2014).
ZONDORAK, V. A. 1991 *A new face in corporate environmental responsibility: the Valdez principles*. In 18 B. C. Envtl. Aff. L. Rev. 457.

Key Words: sustainable sanitation, finances, perceptions, stakeholders, communities.

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2. SOCIO-CULTURAL CAPITAL AND CORPORATE WASH RESPONSIBILITY: WAYS TOWARDS SUSTAINABLE WATER SUPPLY AND SANITATION

1st Specialist Conference on Municipal Water Management and Sanitation in Developing Countries-From Toilet to Source-Accelerating Uptake of Sustainable and Integrated Wastewater Management Solutions.
2-4 December 2014, AIT, Bangkok, Thailand

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Keywords: Social Capital; Corporate Responsibility; WASH.

The majority of projects in the field of water and conventional sanitation around the world receive funding from external sources from various donors and development agencies (Sahooly, 2003). The rate of project failure in the water and sanitation sector are high due to a range of factors such as lack of local participation in components of the projects and appropriate investment (McPherson and McGarry, 1987; Sandoval-Minero, 2005) from local to national levels. It has been suggested to implement policies such as cost recovery to meet Millennium Development Goals (MDGs) and to allow for clean water and sanitation (Mehta et al., 2005). Financial factors should be considered by governments to improve sanitary conditions, and to promote supply and maintenance of sanitation facilities and services (Arku et al., 2013). In light of this, socio-cultural capital (bonding-bridging-linking within societies such as neighbourhood relationships), as described by Pelling and High (2005), and corporate social responsibility (CSR) are interesting directions to consider for the sustainability of water supply and sanitation systems. Successful cooperation for long term mutual benefit depends on the cultivation of socio-cultural capital (Bridger and Luloff, 2001) and exploring CSR in societies. CSR is not new and many theories, definitions and characteristics of CSR are well documented in a range of business and management literature (see for instance, Aguilera et al., 2007; Dahlsrud, 2006; Smith, 2003; Lindgreen and Swaen, 2010). In addition, the concept of 'corporate environmental responsibility' (CER) has evolved from CSR to improve the environmental impact of companies and other stakeholders (Kovacs, 2008; Zondorak, 1991). However, only very recently has it been addressed as a potential driver to solve global sanitary problems (Abeysuriya et al., 2007) and create financial mechanisms to improve global water, sanitation and hygiene (WASH) conditions. The current study applied both qualitative and quantitative methods to explore both socio-cultural capital and CSR in peri-urban Ger areas (informal settlements with traditional yurts/tents) in Ulaanbaatar, Mongolia to assess the socio-cultural capital among the nomadic communities and to address existing corporate social responsibility towards financing sustainable water supply and sanitation programs.

A knowledge, attitude and practice (KAP) survey was conducted among the 210 households in the Ger areas in Ulaanbaatar, Mongolia in April 2014 to assess socio-cultural relationships with their neighbours, support received from each other during periods of need, and willingness to pay for improving the water supply and sanitation system. Moreover, a total of 20 key informants and institutional stakeholders from government and non-government organizations, community leaders, healthcare and hospitals, insurance and banks, service and business providers throughout the year of 2013 and 2014 were interviewed to assess existing financial sources, corporate social responsibility, future financing in the sector, willingness to provide finances and business opportunities for the sustainability of the water supply and sanitation system in Mongolia.

The results from the key informant and stakeholder interviews showed that CSR is absent from the field of WASH in Mongolia. The responsibility of government agencies such as the Water and Sanitation Regulatory Commission (WSRC) is to develop general pricing and tariff policies including licensing and regulations in the WASH sector. However, the current system of water supply does not have cost recovery, and 40% of the water is lost due to the low/lack of maintenance. A department of corporate environmental responsibility at the Trade and Development Bank started recently to deal with the mining industry and making loans to companies dependent on environmental assessments. Following the same logic, 'corporate WASH responsibility' can be considered as one of the important components of CSR in banking and non-banking private sectors to raise awareness among institutions and communities for improving both the local and the global WASH situation sustainably.

References

Abeysuria, K., Mitchel, C. and White, S. (2007) Can corporate social responsibility resolve the sanitation question in developing Asia countries. Ecological Economics, **62**, 139-147.

Aguilera, R.V., Rupp, D.E., Williams, C.A. and Ganapathi, J. (2007) Putting the S back in corporate social responsibility: A multilevel theory of social change in organizations. Academy of Management Review, **32** (3), 836-863.

Arku, F.S., Angmor, E.N. and Seddoh, J.E. (2013) Toilet is not a dirty word: close to meeting the MDGs for sanitation. Development in Practice, **23**(2), 184-195.

Bridger, J.C. and Luloff, A.E. (2001) Building the sustainable community: Is social capital the answer? Sociological Inquiry, **71**(4), 458-472.

Dahlsrud, A. (2006) How corporate social responsibility is defined: an analysis of 37 definitions, Corp. Soc. Responsib. Environ. Mgmt., **15**(1), 1-13.

Kovacs, G. (2008) Corporate environmental responsibility in the supply chain, Journal of Cleaner Production, **16**(15), 1571-1578.

Lindgreen, A. and Swaen, V. (2010) Corporate social responsibility, International Journal of Management Review, **12**(1), 1-7.

McPherson, H.J. and McGarry, M.G. (1987) User participation and implementation strategies in water and sanitation projects. International Journal of Water Resources Development, **3**(1), 23-30.

Mehta, M., Fugelsnes, T. and Virjee, K. (2005) Financing the Millennium Development Goals for water and sanitation: What will it take? International Journal of Water Resources Development, **21**(2), 239-252.

Sahooly, A. (2003) Public-private partnership in the water supply and sanitation sector: The experience of the Republic of Yemen. International Journal of Water Resources Development, **19** (2), 139-152.

Sandoval-Minero, R. (2005) Participation of the private sector in water and sanitation services: Assessment of Gunajuato, Mexico. International Journal of Water Resources Management, **21**(1), 181-197.

Smith, N.C. (2003) Corporate social responsibility: not whether, but how? London Business School, London: UK.

Zondorak, V. A. 1991 A new face in corporate environmental responsibility: the Valdez principles. In 18 B. C. Envtl. Aff. L. Rev. 457.

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1. EXPOSURE TO WASH-BORNE HAZARDS: A SCOPING STUDY ON PERI-URBAN GER AREAS IN ULAANBAATAR, MONGOLIA

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Contents lists available at ScienceDirect

Habitat International

journal homepage: www.elsevier.com/locate/habitatint

HABITAT INTERNATIONAL

ARTICLE INFO

Article history:
Available online

Keywords:
WASH
Hazards
Sustainable sanitation
Water kiosk
Peri-urban
Health

ABSTRACT

The present scoping study seeks to address the sources of water, sanitation, and hygiene (WASH) exposure of residents of peri-urban Ger areas of Ulaanbaatar, Mongolia. Field observations and semi-structured key informant interviews were carried out during 2012 and 2013 to assess the existing WASH situation in the peri-urban Ger areas of Ulaanbaatar, Mongolia. In addition, a knowledge, attitude, and practice (KAP) survey was conducted by *Action Contre la Faim* (ACF) Mongolia in 210 households to identify the sources of WASH-borne hazards in a statistically representative way. Moreover, the quality of drinking water was analyzed both at the household ($n = 210$) and water point (kiosk) ($n = 40$) levels to assess the risk of chemical and pathogenic contaminants. Both field observations and interviews revealed that the sanitary environment of the Ger residents is characterized by the lack of a drainage system, unimproved sanitation technology (e.g. unhygienic pit latrines and soak pits), unsafe water supply, and insufficient collection, transportation, and storage mechanisms. Poor infrastructure is associated with low standards of living. The transmission of WASH-borne disease (e.g. diarrhea, dysentery, hepatitis A) is the gravest consequence and source of hazards. The results from the water quality analysis demonstrate that Ger residents are more exposed to biological contamination of stored drinking water by *Escherichia coli* during the summer (May to August) than in the winter (November to February). During the winter, 36% of household storage containers were contaminated by *E. coli* at an average level of 12.5 *E. coli* per 100 ml, while, during the summer, 56% of household storage containers were contaminated at an average level of 50 *E. coli* per 100 ml. KAP surveys further reveal that the common practice of Ger residents to discharge greywater (with higher chemical oxygen demand) into pit latrines, soak-pits, yards, and streets likely causes environmental pollution and health hazards. Multifaceted WASH-borne exposure was addressed by the scoping study such that various WASH interventions could be planned for the study area and beyond. To tackle the above challenges and problems, a range of appropriate interventions and programs are recommended to reduce the exposure of WASH-borne hazards in the study area and other parts of the world — in both urban and peri-urban settings. The recommendations include: the development and implementation of a water safety plan (WSP), an effective monitoring system for collection, transportation and storage at both water kiosk and household levels, user training for correct use of water containers, effective coordination among stakeholders (including urban planners), development of a household greywater disposal system, and implementation of a functioning solid waste management system. Prior to taking these actions, a detailed study on the 'pollution load from peri-urban to urban' should be carried out to assess the WASH-borne vulnerability of both peri-urban and central urban population.

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http://dx.doi.org/10.1016/j.habitatint.2014.08.006
0197-3975/

Introduction

At present, water, sanitation, and hygiene (WASH) is a global concern and priority area in the international development sector (Dalton, Bendall, Ijaz, & Banks, 2008; Mara, 2003; UN, 2013). Although the Millennium Development Goals (MDGs) include improved drinking water supply, water quality and safety are still very precarious in many regions of the world. Globally, 748 million people still rely on unsafe drinking water sources such as rivers, streams, ponds, unprotected open wells, and poorly protected springs. In addition, even some populations who are using "improved" drinking water sources are not consuming safe water (UN, 2014). Improved sanitation facilities for one billion people need to be ensured by 2015, in order to meet the sanitation target set by the Millennium Development Goals (MDGs) (UN, 2013). In 2002, WASH-related deaths and disabilities occurred globally among children 14 years old and younger at rates of 25% and 22%, respectively (WHO, 2008b). Poor sanitation accounts for the death of a child every 20 s, including the 88% of deaths caused by diarrheal disease and insufficient access to sanitation. The United Nations estimates that good hygiene and a safe water supply could save 1.5 million children a year (UN WATER, 2013).

The safety and accessibility of drinking water are major concerns worldwide. Production and consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards increase both public health and environmental health hazards, particularly in low income countries (Craun, Hubbs, Frost, Calderon, & Via, 1998; Nelson & Murray, 2008; WHO, 2013). It has been evidenced that global incidence of WASH-borne illness, particularly cholera, has increased by 130% from 2000 to 2010 (UN, 2013). Oftentimes, WASH-borne illness results directly from the exclusion of the urban poor in national WASH policy, planning, and intervention processes. One of the root causes of this exclusion has been the long-standing inability of utility and city managers and their advisors to plan and implement water and sanitation systems, which respond to the realities faced by the urban poor (Evans, 2007). Both surface and groundwater sources can be polluted by lack of sanitation facilities, indiscriminate disposal of waste, and the lack of good governance surrounding the provision of sanitation services (Palamuleni, 2002). In many parts of the world, disparities in access to WASH solutions often stem from socioeconomic or geographic differences, such as 'urban vs. rural', 'urban vs. peri-urban', 'rich vs. poor', 'homeless vs. non-homeless' and 'majority vs. minority' (Rheingans, Cumming, Anderson, & Showalter, 2012; UN, 2014). In both urban and peri-urban settlements, including slums, provision of sanitation services from the government is absent or altogether ignored, particularly in low- and middle-income countries (Scott, Cotton, & Khan, 2013; UN, 2014; Winters, Karim, & Martawardaya, 2014). Mongolian peri-urban areas are no exception to this kind of attitude adopted by the government.

The present study was conducted in the peri-urban Ger areas (i.e. informal settlements) of Ulaanbaatar, Mongolia during the period of September 2012 to July 2013 under an ongoing research project jointly executed by *Action Contre la Faim* (ACF) Mongolia and University of Science and Technology Beijing and funded by ACF International in France. The paper predominantly focuses on discussing the main sources of exposure to WASH-borne hazards. The possible solutions/interventions presented herein aim to reduce the exposure to WASH-borne hazards in the study areas and can ideally be replicated in other parts of the world, especially in urban and peri-urban areas, to tackle the global challenges (Moe & Rheingans, 2006) in water, sanitation and health sectors.

WASH-borne hazards and exposure

Over the past few decades, 'hazards' have been addressed, defined and characterized in a wide array of fields, including climate, health, environment and disaster studies (see for instance, Dewailly, Poirier, & Meyer, 1986; Evans, Ribeiro, & Salmon, 2003; Kjellstrom et al., 2007; Riebsame, Diaz, Moses, & Price, 1986; Terblanche, 1991). CCOHS (2009) defines a hazard as 'any source of potential damage, harm or adverse health effects on something or someone under certain conditions at work'. In the context of disasters, Wisner, Gaillard, and Kelman (2012) refer to 'specific natural processes and events that are potentially harmful to people and their assets and disruptive of their activities (Wisner et al., 2012). Similarly, UNISDR (2009) considers that a hazards is ' a dangerous phenomenon, substance, human activity or condition that may cause the loss of life, injury, or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage'. In the particular context of WASH, hazards include 'harmful substances (physical/chemical/biological) that originate from the absence/lack/failure of water, sanitation and hygiene interventions/programs/policies and cause loss of life, disability, other health impacts, socio-economic loss, or environmental bane' (e.g. Hutton & Haller, 2004; Kulshrestha & Mittal, 2003; Montgomery & Elimelech, 2007; Pruss-Ustun, Kay, Fewtrell, & Bartram, 2004; Terblanche, 1991; WHO, 2008b).

On the other hand, 'exposure' includes "people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses" (UNISDR, 2009). Numerous pathways of exposures to both biological and chemical contaminants have been identified in freshwater and food, which may increase waterborne infections as well as fetal and infant death in many parts of the world — most notably low-income countries (Abhirosh, Sherin, Thomas, Hatha, & Abhilash, 2010; Milton et al., 2005; Montgomery & Elimelech, 2007; Pruss, Kay, Fewtrell, & Bartram, 2002; Rahman, Asaduzzaman, & Naidu, 2011; Suk, Murray, & Avakian, 2003). The exposure pathways include, for instance, air and water systems, soil, sewage, and food, among other indirect forms of contact. These studies are important; and greater efforts are needed to reduce exposure to both WASH and health hazards (Lioy et al., 2005; Steinemann, 2004). To this end, the exposure science should be considered widely to reduce or prevent exposures to WASH-borne hazards for all groups, without any disparities, and by adopting a bottom-up approach.

When public health and WASH are intertwined, comprehensive WASH-borne hazard analyses can be conducted. As early as the nineteenth century, John Snow (1855) defined water as a "vehicle of disease transmission". It is indeed said that drinking water is a major source of microbial pathogens in low-income countries, while poor WASH accounts for millions of deaths every year (Ashbolt, 2004). Lack of access to potable water, poor quality of water, absence of sanitation facilities, lack of hygiene practices, and environmental factors are all considered as possible causes of waterborne diseases due to microbiological and chemical hazards (Aiello, Coulborn, Perez, & Larson, 2008; Ako, Nkeng, & Takem, 2009; Pruss-Ustun et al., 2004; Terblanche, 1991). As a result, addressing WASH-borne hazards is urgently needed to protect affected populations from various kinds of chemical and pathogenic contaminants. Fig. 1 summarizes factors which significantly increase WASH-borne hazards. Lack of access to proper WASH facilities and lack of resources (e.g. income) likely reduce capacities to tackle WASH-borne hazards, while increasing exposure to WASH-borne hazards and threats. Alwang, Sigel, and Jorgensen (2001) addressed the poor and near-poor as vulnerable groups due to their inferior access to resources and limited abilities to respond to hazards.

WASH situation in Mongolia

Mongolia, a landlocked nation bordered by China and the Russian Federation, has an estimated population of 3.2 million (CIA, 2013). The country boasts the coldest capital city in the world with an annual mean temperature of −3.7 °C and a harsh climate with low precipitation (approximately 200 mm/year) (Altansukh, 2008; Hauck, 2008).

Ulaanbaatar, the capital of Mongolia, has a population of over one million people and is experiencing an influx of migrants from rural areas resulting in many environmental, health, and socio-economic problems. Forest fires, floods, waterborne disease, unsafe water supply, inadequate sanitation, insufficient heating, absence of suitable roads, high concentration of uranium in groundwater, wetlands and river pollution due to industrial and agricultural pollution, untreated wastewater from the city's sewage treatment plants, and heavy metal pollution in the soil (arsenic and lead) are amongst the greatest challenges faced in the capital (Altansukh, 2008; Asian Development Bank, 2010; Batjargal, Otgonjargal, Baek, & Yang, 2010; Itoh et al., 2011; Nriagu et al., 2012; Sigel, Altantuul, & Basandrorj, 2012; Uddin, Li, Mang, Huba, & Lapegue, 2014).

Mongolia, one of the world's fastest growing economies (BBC, 2014; The Diplomat, 2013; The Economist, 2013), is, unfortunately, not "on track" to meet the sanitation targets set by the Millennium Development Goals (MDGs) (UNESCAP, 2011; UNICEF & WHO, 2012). A majority of the population – particularly in the Ger areas of Mongolia (peri-urban unplanned informal settlements that surround the city) – employ unimproved and unhygienic sanitation technologies to solve sanitary problems, most notably unimproved pit latrines (Sigel et al., 2012; Uddin, Li, Mang, Huba, et al., 2014). In urban Mongolia, the coverage of piped and improved water supply is supposedly 100% (illustrating that Ger areas are not considered "urban" and highlighting the longstanding strategic issue of using the Joint Monitoring Program (JMP) as a baseline for peri-urban development projects). Sanitation coverage in urban Mongolia is 64%, which is considered improved, while the remaining 36% accounts for unimproved sanitation (UNICEF & WHO, 2012).

This study was conducted in the peri-urban Ger areas of Ulaanbaatar, Mongolia (Fig. 2). Much of the population in the capital and its surroundings inhabits Ger areas. Ger areas comprise over half of the total population of Ulaanbaatar and are increasing rapidly (i.e. "urban sprawl") (Sigel et al., 2012). Unlike their urban neighbors that occupy apartments and homes built on formal sites, Ger area residents live in felt tents or yurts ("Gers"). Recent research indicates that there is some modernization occurring in the Ger areas, mostly in terms of housing and food habits.

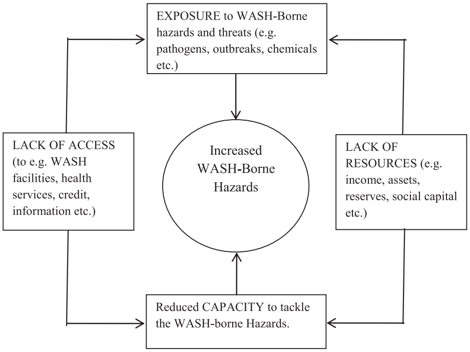

Fig. 1. Factors leading to increased WASH-borne hazards. Adopted from Wisner, 1996.

Materials and methods

Drinking water quality was analyzed to assess the chemical and pathogenic contamination to envisage the possible vulnerability of the health hazards of the Ger residents. A total of 250 water samples were collected by ACF Mongolia through random sampling, including from 210 households and 40 water kiosks from the Ger areas during the winter period of December 2012 and January 2013. Additionally, a similar quantity of samples was analyzed in the summer period of May and June 2013 to compare the seasonal state of water quality both at the household level and at water kiosks. All of the water samples were analyzed by the National Accredited Professional Inspection Central Laboratory of Ulaanbaatar in Mongolia. Three parameters were analyzed: biological *Escherichia coli*, chemical hardness, and pH, in order to identify drinking water contaminants and their sources. Furthermore, greywater generated from households was tested to ascertain chemical characteristics, which might have additional impacts on human health and environmental conditions in Ger areas (Uddin, Li, Mang, Ulbrich, et al., 2014).

In addition, research based on field observations was carried out by transect walks, which involved community members and key informants through the area from one side to other, observing, asking questions, and listening (Kar, 2005). Five transect walks were carried out in five different geographic areas with key community actors and ACF Mongolia WASH team members to characterize WASH and environmental conditions. The observations revealed implications of solid waste dumping, greywater discharge, toilet conditions, availability of water near toilets for handwashing, water collection systems, water storage systems at the household level, heating systems, and both indoor and outdoor air emissions.

In addition, five community-based representatives, five NGO officials, two doctors, three healthcare officers, and three university faculty members were chosen as key informants for interviews to ascertain the major sources of WASH-borne hazards in the Ger areas. Community-based leaders proved very knowledgeable about WASH-related issues, including health implications.

Fig. 2. Ger areas of Ulaanbaatar (Field Survey, Uddin, July 2013).

Fig. 3. Water kiosk, container, and trolley used for water collection and transportation in the Ger areas (Field Survey, Uddin, July 2012 and November 2013).

Representatives from ACF Mongolia, World Vision Mongolia, UNICEF Mongolia, ECO TV, and district health offices were considered key informants for a comprehensive diagnostic of the WASH situation in the area of interest and, moreover, to conceive of possible solutions to solve principal WASH-borne challenges. In addition, three faculty members from the Mongolian University of Science and Technology, Mongolian State University of Agriculture, and the National University of Mongolia were interviewed to inform proper solutions for reducing WASH-borne hazards in the study area.

A WASH-focused knowledge, attitude, and practice (KAP) survey, which serves as an educational diagnostic of the community, was also conducted by ACF Mongolia at 210 households in Ger areas at the end of 2012. Multiple choice questions where more than one answer could be chosen were asked to the respondents. The sites selected for the KAP survey are the Ger districts of Ulaanbaatar where the current ACF WASH program is being implemented. Intervention areas were selected based on several factors, such as population density, poverty level, and water and sanitation accessibility. The cluster sampling method was applied, due the large population size and scattered households in the intervention area. According to ACF & WHO sampling standards and methodology (Henderson & Sundaresan, 1982) — where a statistical accuracy of 10% precision is preferred — the total sample required was 210 households. Households were randomly selected for interviews in each residential cluster. The questions developed covered a range of topics related to domestic water, sanitation and hygiene practices, family health status, and waterborne disease transmission.

Moreover, an observational study and structured survey were carried out by ACF Mongolia with students and teachers from eights schools (three primary schools, three middle schools, and two high schools) to assess WASH conditions in schools. One hospital in the Ger area was likewise subjected to an observational study and semi-structured key informant interviews to gain further insight into hygiene issues and practices.

Water supply related hazards

Water supply in the Ger areas

Results from the KAP survey indicate that water kiosks (Fig. 3) account for the main source of water supply for both drinking and non-drinking purposes in the peri-urban Ger areas for the majority of respondents. Some water kiosks are connected to the central water supply network, while others are fed by water tank trucks managed by the Ulaanbaatar Water Supply and Sewage Authority (USUG). Other sources of water, such as unprotected private boreholes and springs, are also used by some of the respondents: 15.4% of respondents reported using private boreholes, while 2.5% of interviewees reported using spring water. The use of plastic containers is almost exclusively used for the transportation (94.3%) and storage (92.4%) of water.

Presently in Mongolia, coordination between stakeholders from the government and civil society is weak, especially with regards to solving environmental sanitation challenges in peri-urban settings. The present approach is centralized and functions at a very slow pace. The government aims to provide a centralized system for 40% of the population by 2015. There currently is no policy to encourage a decentralized system. In the Ger areas, water kiosks are the only way to access water for drinking, cooking, and cleaning purposes. The water kiosks can either be fed from a central water connection or by water tanks. Water in the Ger areas is mainly provided by approximately 550 public water kiosks, where the average water consumption is 10 L/person/day (World Bank, 2010).

Unsafe water supply and storage

The results from the water quality analysis show higher contamination in the summer than in the winter. However, the contamination in both seasons does not meet the Mongolian drinking water quality standard (MNS ISO 4697-1998: drinking water should not contain *E. coli* bacteria levels that exceed WHO 2008 guidelines for drinking water) (WHO, 2008a). The water quality analysis (Table 1) conducted in the winter illustrates that 36% of drinking water samples taken at the household level was contaminated by *E. coli* with low-to-high levels of health risks. The average number of *E. coli* in the contaminated drinking water samples was 12.5 ml per 100 ml, with a range of 1–52 ml. There were two water kiosks out of 40 total sampled that were found to be contaminated by *E. coli* during the winter. To show the contamination of households around the contaminated water kiosk, 6 samples were collected and tested, showing that the drinking water of all households was contaminated at levels as high as 31 *E. coli* per 100 ml.

On the other hand, summer analysis of the drinking water of similar households shows that over half of the samples were contaminated by *E. coli* with an average of 50 *E. coli*/100 ml of drinking water. There were five water kiosks found to be contaminated among the 40 samples, two of which were highly contaminated by *E. coli*: 120 and 189 *E. coli*/100 ml water. The sources of the above contamination at the household level may be due to the collection and transportation processes from the water kiosks using low quality containers. Water contamination during the summer is

Table 1
Contaminated drinking water by *E. coli* at the household level.

Season of sampling	Period of sampling	Contaminated households ($n = 210$) 10% precision	% Of households contaminated	Average number of *E. coli*	Range of *E. coli*
Winter	Dec 2012–Jan 2013	76	36	12.5	1–52
Summer	May–June 2013	117	55.71	50	1–404

Fig. 4. Unimproved and unhygienic pit latrines in the Ger Areas (Field Survey, Uddin, April 2012).

much higher than the winter, including at water kiosks. Water kiosk contamination might not only depend on the types of water supply (either piped or tank water supply), but also the maintenance of the pipes and tanks.

KAP survey results shows that 57% of the respondents among the surveyed households do not boil water before drinking, which may very well increase their risk of water-borne disease. Moreover, the majority of respondents use containers that are secondhand, unhygienic, and old for water collection and storage. 79.5% of respondents use secondhand containers to transport water, while 84.3% of respondent use secondhand containers to store water. These unsafe water supply, transportation, and storage practices increase the hazards of the Ger residents to waterborne disease.

Low water consumption and greywater production

Although the UN (2013) suggests that individuals have access to 20–50 L of water daily for drinking, cooking, and cleaning purposes, the average consumption of Ger residents is very low at 10 L/person/day (World Bank, 2010). KAP survey results show that the average consumption is 8 L/person/day, which drops to 4 L/person/day during the winter. There are several factors accounting for low consumption of water in the Ger areas, including distance of water kiosks from households, short period of daily distribution, consumption differences between the winter and summer months, low frequency of bathing outside the compound (public bath), irregular cloth washing, and reuse of water without treatment.

The results from the KAP survey illustrate that 51.4% of households have soak-pits in their compound to discharge greywater, while 40% of households pour greywater into their pit latrines. The rest of the households discharge greywater onto the roads, in yards, or in other places. Ger residents frequently discharge their greywater into pit latrines, soak-pits, yards, and on open streets, which causes immediate environmental pollution and health hazards due to high concentration of chemical agents in the greywater. In the warmer months, the same practices lead to even greater environmental degradation, as well as favorable conditions for vectors to breed (Uddin, Li, Mang, Ulbrich, et al., 2014; WHO, 2006).

Sanitation hazards

Unimproved sanitation technologies

A range of sanitation technologies that are not recognized as improved sanitation technologies, such as unimproved pit latrines (Fig. 4), soak pits for greywater discharge, and unplanned sites for solid waste disposal have been identified in the Ger areas. Over 80,000 pit latrines were estimated to solve the majority of sanitation problems, yet most of the technologies are unimproved and unhygienic due to the low maintenance, technological drawbacks, and poor quality. As a result, users are often exposed to contact with pathogens that result from the contamination of groundwater sources (Girard, 2009; Palamuleni, 2002).

The KAP survey illustrates that 96.7% of respondents use domestic and shared pit latrines, which are categorized as “unimproved sanitation facilities”. The rest of the respondents use public toilets, a neighbor's latrine, “ecosan” toilets, and/or open defecation. Common problems encountered with the current toilets are pit filling (43.1%), odor (41.1%), cold conditions (26.3%), flies (21.5%), and safety of use (17.2%) (15.3% of respondents said there were no problems).

No drainage system

During the rainy season, the lack of a proper drainage system results in frequent flooding. The problem is exacerbated by the fact that Ger residents often dispose of garbage in flat areas, which are often subject to the flooding. Exposure to waste-borne contaminants further exposes residents to pathogens. Moreover, the high concentration of household wastewater draining to yards, roads, and areas surrounding housing compounds also create health and environmental hazards for residents (Uddin, Li, Mang, Ulbrich, et al., 2014). A failure on the part of the government to invest in the infrastructural development of Ger areas makes these challenges even harder to combat.

Traditional heating system and environmental pollution

The Mongolian winter is very harsh with temperatures dropping to −40° C (Manaseki, 1993). Ger residents do not possess central heating and instead use traditional systems of coal and wood burning. Low quality coal burned for heating in the winter accounts for 77% of total air pollution, which has additional adverse health impacts (World Bank, 2009). The Ger residents dump ash from combustion outside (e.g. yards, streets), which may be a source of arsenic and other heavy metal contamination in the soil in Ulaanbaatar and its surrounding peri-urban settlements (Batjargal et al., 2010)

Unplanned solid waste management

Ulaanbaatar is facing multiple problems, due to an unplanned solid waste management system that is particularly pervasive in Ger areas. Average solid waste generation is 0.956 kg/capita/day, which is over four times that of the main city with predominantly tenement housing (Batsuuri, 2010). The city has been facing serious problems associated with solid waste output due to the increasing number of migrants moving to urban areas and their increasingly consumptive lifestyles (MNEC, 2011). Illegal dumpsites are a common feature in Ulaanbaatar, particularly in the Ger areas, due to the infrequent household collection, lack of central collection points, poor education of the Ger inhabitants, and very few landfills in urban and peri-urban settings (Altantuya, Zhang, & Li, 2012; The Asia Foundation, 2014). There are some open fields which have been considered as unplanned disposal sites; and these fields are highly hazardous for hundreds of scavengers (people who scavenge recyclable wastes) living near the areas (Altantuya et al., 2012).

In addition, coal ash deposition is a significant concern in the Ger areas where people use coal for heating their Ger houses. During the winter, around 50% of waste generated from ash which are deposited in the environment. These exposures pose severe environmental hazards, exposing residents to many toxic metals released from these ashes. There are several thermal power plants, which also use coal for heating households in the city. The coal ash contains various heavy metals including arsenic (As), which is a significant anthropogenic source of contamination in the environment (Pandey, Singh, Singh, Sing, & Yunus, 2011). In Ulaanbaatar, an average of 260–280 thousand tons of dry waste are produced a year. 40–50% of this waste goes to a dumpsite, while the rest is accumulated in the environment, such as in river basins, Ger areas, and illegal dumpsites. The major composition of the solid waste includes paper (13%), glass (6.5%), plastics (11%), other organic waste (30%), other inorganic waste (36.5%), household hazardous wastes (0.02%), and others (3.0%) (e.g. car parts, metal, healthcare wastes). However, there is no classification system or standard for urban waste. Most households, enterprises and industries including governmental organizations, dispose of waste without any classification (Altantuya et al., 2012; Serrona, Yu, & Che, 2010; Shinee, Gombojav, Nishimura, Hamajima, & Ito, 2008; WHO, 2005). The Master Plan for Solid Waste Management has been implemented by the Municipality of Ulaanbaatar since 2007 with technical support from Japan International Corporation Agency (JICA). In addition, solid waste processing and recycling factories are included in the Urban Development Master Plan 2030 (Ministry of Construction and Urban Development, 2013). However, the plan does not include the communities who are informally collecting and recycling waste, who should be protected from dangerous and poisonous wastes. There is still much need for an action plan and policies pertaining to: recycling solid waste for resource recovery, improved environmental and health protection, and the wellbeing of communities who informally collect waste. The key informant interviews show that the solid waste collection system is fairly irregular in the Ger areas, which causes waste to accumulate in the yard or roads and can affect the human and environmental health systems. Key informant interviews with doctors revealed that the hazardous WASH situation, particularly due to biological and chemical contaminants in surrounding peri-urban Ger and mountainous areas, may have potential to harm the population living in the central urban areas due to rainfall, flooding and runoff during the summer months.

Hygiene and wash-borne hazards

Unhygienic practices at home

KAP survey results show that 52.4% of respondents wash their hands after engaging in unsanitary activities, 36.4% after changing diapers, 27.7% before cooking, 23.3% before eating, and 20.9% after defecating. Among the respondents who wash their hands, 33.8% do not use soap, whereas 56.7% use soap during hand washing. Engaging in unhygienic practices significantly increases vulnerability to human health hazards. When respondents' were asked if water could transmit diseases, 52.4% replied yes, 15.7% replied no, and 31.9% replied that they did not know.

Unhygienic practices in schools

There were several challenges that were revealed from the study conducted in schools in the peri-urban settlements of Ulaanbaatar, including the lack of appropriate WASH facilities, unavailability of soap, and inadequate hygiene promotion among students. The survey results among the school students show that 59% of students do not wash their hands, 34% wash their hands with water only, and 5% wash with water and soap, bringing their own soap from their homes.

Unhygienic practices in hospitals

Hospitals are particularly sensitive areas where proper hygiene practice, safe water, and proper sanitation facilities should be considered to further reduce risk of infection. The results of the hospital study in the Ger areas revealed that no soap is provided for washing hands inside the hospital, including in bathrooms. A key informant interview with a doctor revealed that most of the patients affected by diarrhea and dysentery are children under five years of age, the majority of which visit the hospital frequently (once or twice in a month) for treatment. Public health data, particularly in Ger areas, is not available. National health statistics gathered at the district and national levels do not separate Ger areas, making comparisons between Ger areas and other urban areas difficult (GoM, 2011).

Ways forward to reduce WASH-borne hazards

There are various interventions and initiatives around the world that are considered effective ways to reduce WASH-related risks. Effective preventative measures are considered to be at the heart of proper risk management, with a focus on providing safe drinking water (Hrudey, Hrudey, & Polland, 2006). A systematic review has been done by Fewtrell et al. (2005); and all of the intervention studies were found to significantly reduce the risk of diarrheal illness with a similar degree of impact. Less *E. coli* contamination of stored water and a lower incidence of diarrhea were found in the households benefitting from 'point-of-use' water treatment versus households serving as controls (Quick et al., 1999). Some studies show that providing both toilets and safe water supply systems can reduce the incidence of cholera by as much as 76% (Azurin & Alvero, 1974). Aiello et al. (2008) shown that hand-hygiene practices alone can reduce the incidence of gastrointestinal disease by 31%, thereby illustrating the effectiveness of hand washing in preventing gastrointestinal illness. Likewise, Cairncross et al. (2010) show that hand washing with soap can reduce the risk of diarrhea up to 48%. Adequate practices of environmental sanitation can reduce incidences of pathogen-positive diarrhea among children by 40% (Baltazar et al., 1988). In addition, raising public awareness and conducting systematic monitoring are often recommended as ways to reduce exposure (Steinemann, 2004). Even when dealing with a good sanitation system, which isolates fecal matter from the human environment, other interventions must be simultaneously implemented to prevent other exposure pathways (Garrett et al., 2008; VanDerslice, Popkin, & Briscoe, 1994). For example, combined use of chlorinated stored water, latrines and rainwater may significantly decrease diarrheal risk (Garrett et al., 2008). All of the aforementioned findings are applicable to Mongolian Ger settlements and should be used by policymakers to inform WASH policies and reduce WASH-borne hazards.

Fig. 5 shows the link between sources of WASH-borne hazards and possible interventions and solutions that could be

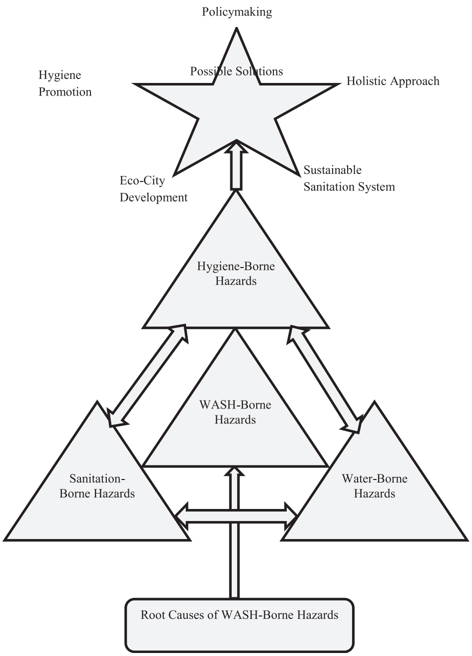

Fig. 5. WASH-borne hazards and possible solutions to reduce hazards.

implemented to reduce them. Strong WASH-related policy making and enforcement would greatly improve environmental health in Ger areas. A holistic/integrated approach to safe water supply and sustainable sanitation practices has the potential to prevent exposure to dangerous contaminants (Uddin, Li, Mang, Huba, et al., 2014). Various media and communication tools and techniques can be used to increase communities' awareness of good hygiene and sanitation practices to reduce exposure to WASH-borne hazards in households, hospitals, and schools. These initiatives will activate the process towards ecological urban development, which, in turn, may reduce WASH-borne hazards in Ger areas. Environmental regulation alone cannot ensure the prevention of hazards nor reduce exposures (Steinemann, 2004). However, a holistic approach to safe water supply and sustainable sanitation systems – coupled with the introduction of appropriate policies and regulations – may reduce WASH-borne hazards (SuSanA, 2014). Scaling up of sustainable sanitation technologies may reduce WASH-borne diseases significantly (Anand & Apul, 2014; Uddin, Li, Mang, & Lapegue, 2014; Uddin, Muhandiki, Fukuda, Nakamura, & Sakai, 2012). Proper sanitation and awareness campaigns are other essential components to encourage appropriate hygiene practices in the school, hospital, and household settings. Innovation in sustainable sanitation through resource/nutrient recovery from organic waste – including human waste – also contributes to preventing WASH-borne hazards. Finally, in order to be sustainable, sanitation systems have to be economically viable, socially acceptable, technically feasible, and eco-friendly (Uddin, Muhandiki, Sakai, Mamun, & Hridi, 2014).

The current study addresses multidimensional problems associated with WASH and exposure risks present in peri-urban areas of Ulaanbaatar, Mongolia. The study revealed that poor infrastructure in the peri-urban settlements is highly correlated with a low standard of living. The transmission of WASH-borne diseases is the gravest human health hazard the study area, which is likewise the case for many low- and middle-income countries in urban and peri-urban settings. Summer is a more hazardous season, as biological pathogens proliferate much faster in summer conditions, thus significantly increasing people's personal exposure levels. To tackle these challenges and problems, a range of appropriate interventions are recommended to reduce the exposure of WASH-borne hazards in the study area and other parts of the world with a comparable context. The development and implementation of a water safety plan (WSP) and effective monitoring system for collection, transportation and storage at both the water kiosk and household levels are essential to protecting water from both biological and chemical contaminants. Unprotected private boreholes and springs should also be considered in the WSP. The users of water containers should be oriented through awareness-building and educational activities on washing and hygiene practices for water collection and transportation from water kiosks and storage at the household level. Effective coordination among stakeholders, including urban planners, may be useful to tackling WASH-borne hazards in an integrated manner. An appropriate water kiosk operational monitoring system should be developed to supply water to communities for a longer period of time and during both summer and winter months. Household greywater disposal should also be planned so as to protect both human and environmental health from chemical and biological contaminants (Uddin, Li, Mang, Ulbrich, et al., 2014). Due to the absence of a drainage system, appropriate decentralized solutions are encouraged to avoid high costs associated with conventional sewage system implementation. An appropriate solid waste management system based on the 3R system (i.e. reduce, reuse and recycle) would improve environmental health in the study area and beyond. Moreover, improving the WASH situation in peri-urban Ger and mountainous areas will ultimately protect communities in the urban center of Ulaanbaatar from runoff water containing both biological and chemical contaminants. A detailed study on the 'peri-urban-to-urban' context is proposed to assess the WASH-borne pollution load/mobilization from peri-urban to central urban areas. More specifically, the study will shed light on waterborne pollutants' modes of action, as well as help to characterize the vulnerability of populations in both peri-urban and urban areas.

Acknowledgments

Support from different departments at ACF Mongolia and ACF France are acknowledged.

References

Abhirosh, C., Sherin, V., Thomas, A. P., Hatha, A. A. M., & Abhilash, P. C. (2010). Potential exposure risk associated with high prevalence and survival of indicator and pathogenic bacteria in the sediment of Vembanadu Lake, India. *Water Quality Exposure and Health, 2*, 105–113.

Aiello, A. E., Coulborn, R. M., Perez, V., & Larson, E. L. (2008). Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *American Journal of Public Health, 98*(8), 1372–1381.

Ako, A. A., Nkeng, G. E., & Takem, G. E. E. (2009). Water quality and occurrence of water-borne diseases in the Douala 4th District, Cameroon. *Water Science & Technology, 59*(12), 2321–2329.

Altansukh, O. (2008). *Surface water quality assessment and modeling: A case study in the Tuul River, Ulaanbaatar city, Mongolia* (Master's thesis). Enschede, The Netherlands: International Institute for Geo-Information Science and Earth Observation.

Altantuya, D., Zhang, Z., & Li, H. (2012). Municipal solid waste management of Mongolia: analysis on the solid waste treatment of Ulaanbaatar city. *Advances in Asian Social Science, 3*(3), 695–697.

Alwang, J., Sigel, P. B., & Jorgensen, S. L. (2001). Vulnerability: A view from different disciplines. In *Social protection discussion paper series*. Washington, D.C., USA: The World Bank.

Anand, C. K., & Apul, D. S. (2014). Composting toilets as a sustainable alternatives to urban sanitation – a review. *Waste Management, 34*, 329–343.

Ashbolt, N. J. (2004). Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology, 198*, 229–238.

Asian Development Bank. (2010). *Mongolia: Ulaanbaatar water and sanitation services and planning improvement*. Technical assistance report. Manila, Philippines: Asian Development Bank.

Azurin, J. C., & Alvero, M. (1974). Field evaluation of environmental sanitation measures against cholera. *Bulletin World Health Organization, 51*, 19–26.

Baltazar, J., Briscoe, J., Mesola, V., Moe, C., Solon, F., Vanderslice, J., et al. (1988). Can the case-control method be used to assess the impact of water supply and sanitation on diarrhea? A study in the Philippines. *Bulletin of the World Health Organization, 66*(5), 627–635.

Batjargal, T., Otgonjargal, E., Baek, K., & Yang, J. (2010). Assessment of metal contamination of soil in Ulaanbaatar, Mongolia. *Journal of Hazardous Materials, 184*(1–3), 872–876.

Batsuuri, N. (2010). *Implementation activities of 3R strategy in Mongolia*. Ministry of Environment Nature and Tourism of Mongolia, 2nd Meeting for 3R Forum, 4–6, October, 2010, Malaysia.

BBC. (2014). Mongolia profile. Website http://www.bbc.com/news/world-asia-pacific-15460525 Accessed June 2014.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C. H., et al. (2010). Water, sanitation and hygiene for the prevention of diarrhea. *International Journal of Epidemiology, 39*(Suppl. 1), 193–205.

CCOHS. (2009). *Hazard and risk*. Canadian Centre for Occupational Health and Safety. Available from http://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html Accessed February 2014.

CIA. (2013). The world factbook: Mongolia. Available from https://www.cia.gov/library/publications/the-world-factbook/geos/mg.html Accessed August 2013.

Craun, G. F., Hubbs, S. A., Frost, F., Calderon, R. L., & Via, S. H. (1998). Waterborne outbreaks of Cryptosporidiosis. *American Water Works Association, 90*(9), 81–91.

Dalton, H. R., Bendall, R., Ijaz, S., & Banks, M. (2008). Hepatitis E: an emerging infection in developed countries. *The Lancet Infectious Diseases, 8*(11), 698–709.

Dewailly, E., Poirier, C., & Meyer, F. M. (1986). Health hazards associated with windsurfing on polluted water. *American Journal of Public Health, 76*(6), 690–691.

Evans, B. (2007). *Understanding the urban poor's vulnerabilities in sanitation and water supply*. Financing Shelter, Water and Sanitation, Center for Sustainable Urban Development. Website http://www.indiawaterportal.org/sites/indiawaterportal.org/files/Financing_Shelter%2C_Water_%26_Sanitation_0.pdf Accessed September 2014.

Evans, M. R., Ribeiro, C. D., & Salmon, R. L. (2003). Hazards of healthy living: bottled water and salad vegetables as risk factors for Campylobacter infection. *Emerging Infectious Diseases, 9*(10), 1219–1225.

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., & Colford, J. M. (2005). Water, sanitation and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet Infectious Diseases, 5*(1), 42–52.

Garrett, V., Ogutu, P., Mabonga, P., Ombeki, S., Mwaki, A., Aluoch, G., et al. (2008). Diarrhoea prevention in a high-risk rural Kenyan population through point-of-use chlorination, safe water storage, sanitation, and rainwater harvesting. *Epidemiology & Infection, 136*, 1463–1471.

Girard, C. (2009). *Feasibility of pit-latrine emptying services, Ger areas, Ulaanbaatar, Mongolia* (Master's theses). School of Applied Science, Cranfield University, United Kingdom.

Government of Mongolia. (2011). *Health indicators*. Ulaanbaatar, Mongolia: State Implementing Agency of Health.

Hauck, M. (2008). Epiphytic lichens indicate recent increase in air pollution in the Mongolian Capital Ulaanbaatar. *The Lichenologist, 40*(2), 165–168.

Henderson, R. H., & Sundaresan, T. (1982). Cluster sampling to assess immunization coverage: a review of experience with a simplified method. *Bulletin of the World Health Organization, 60*(2), 253–260. Website http://whqlibdoc.who.int/bulletin/1982/Vol60-No2/bulletin_1982_60(2)_253-260.pdf Accessed July 2014.

Hrudey, S. E., Hrudey, E. J., & Polland, S. J. T. (2006). Risk management for assuring safe drinking water. *Environmental Risk Management – The State of the Art, 32*(8), 948–957.

Hutton, G., & Haller, L. (2004). *Evaluation of the costs and benefits of water and sanitation improvements at the global level*. Geneva: World Health Organization.

Itoh, M., Takemon, Y., Makabe, A., Yoshimizu, C., Koshzu, A., Ohte, N., et al. (2011). Evaluation of wastewater nitrogen transformation in a natural wetland (Ulaanbaatar, Mongolia) using dual-isotope analysis of nitrate. *Science of the Total Environment, 409*(8), 1530–1538.

Kar, K. (2005). *Practical guide to triggering community-led total sanitation (CLTS)*. Brighton, UK: Institute of Development Studies.

Kjellstrom, T., Friel, S., Dixon, J., Corvalan, C., Rehfuess, E., Campbell-Lendrum, D., et al. (2007). Urban environmental health hazards and health equity. *Journal of Urban Health: Bulletin of the New York Academy of Medicine, 84*(1), 86–97.

Kulshrestha, M., & Mittal, A. K. (2003). Diseases associated with poor water and sanitation: hazards, prevention, and solutions. *Reviews on Environmental Health, 18*(1), 33–50.

Lioy, P., Lebret, E., Spengler, J., Brauer, M., Buckley, T., Freeman, N., et al. (2005). Defining exposure science. *Journal of Exposure Analysis and Environmental Epidemiology, 15*, 463.

Manaseki, S. (1993). Mongolia: a health system in transition. *BMJ, 307*, 1609–1611.

Mara, D. D. (2003). Water, sanitation and hygiene for the health of developing nations. *Public Health, 117*, 452–456.

Milton, A. H., Smith, W., Rahman, B., Hasan, Z., Kulsum, U., Dear, K., et al. (2005). Chronic arsenic exposure and adverse pregnancy outcomes in Bangladesh. *Epidemiology, 16*(1), 82–86.

Ministry of Construction and Urban Development. (2013). Adjunct to the master plan to develop Ulaanbaatar city till 2020, development trend till 2030. Summary report. In *Urban city development master plan 2030* (Vol. IV). Ulaanbaatar, Mongolia.

MNEC. (2011). *Research report on waste management in Darkhan city*. Mongolian Nature and Environment Consortium. Website http://www.mnec.org.mn/Files/books/waste%20management%20in%20Darkhan%20city.pdf Accessed July 2014.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of Water and Health, 4*(1), 41–57.

Montgomery, M. A., & Elimelech, M. (2007). Water and sanitation in developing countries: including health in the equation – millions suffer from preventable illness and die every year. *Environmental Science & Technology, American Chemical Society*, 17–24.

Nelson, K. L., & Murray, A. (2008). Sanitation for unserved population: technologies, implementation challenges and opportunities. *Annual Review of Environment and Resources, 33*, 119–151.

Nriagu, J., Nam, D., Ayanwola, T. A., Din,h, H., Erdenechimeg, E., Ochir, C., et al. (2012). High levels of uranium in groundwater of Ulaanbaatar, Mongolia. *Science of the Total Environment, 414*, 722–726.

Palamuleni, L. G. (2002). Effect of sanitation facilities, domestic solid waste disposal and hygiene practices on water quality in Malawi's urban poor areas: a case study of South Lunzu Township in the city Blantyre. *Physics and Chemistry of the Earth, Parts A/B/C, 27*(11–22), 845–850.

Pandey, V. C., Singh, J. S., Singh, R. P., Sing, N., & Yunus, M. (2011). Arsenic hazards in coal fly ash and its fate in Indian scenario. *Resources, Conservation and Recycling, 55*(9–10), 819–835.

Pruss, A., Kay, D., Fewtrell, L., & Bartram, J. (2002). Estimating the burden of disease from water, sanitation and hygiene at global level. *Environmental Health Perspectives, 110*(5), 537–542.

Pruss-Ustun, A., Kay, D., Fewtrell, L., & Bartram, J. (2004). Unsafe water, sanitation and hygiene. In M. Ezzati, A. D. Lopez, A. Rodgers, & C. J. L. Murray (Eds.), *Comparative quantification of health risks: Global and regional burden of disease attributable to selected major risk factors*. Geneva: World Health Organization.

Quick, R. E., Venczel, L. V., Mintz, E. D., Soleto, L., Aparicio, J., Gironaz, M., et al. (1999). Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. *Epidemiology and Infection, 122*(01), 83–90.

Rahman, M. M., Asaduzzaman, M., & Naidu, R. (2011). Arsenic exposure from rice and water sources in the Noakhali district of Bangladesh. *Water Quality, Exposure and Health, 3*, 1–10.

Rheingans, R., Cumming, O., Anderson, J., & Showalter, J. (2012). *Estimating inequalities in sanitation-related disease burden and estimating the potential impacts of pro-poor targeting*. Research report, 49. Website http://r4d.dfid.gov.uk/PDF/Outputs/sanitation/EquityResearchReport.pdf Accessed July 2014.

Riebsame, W. E., Diaz, H. F., Moses, T., & Price, M. (1986). The social burden of weather and climate hazards. *American Meteorological Society, 67*(11), 1378–1388.

Scott, P., Cotton, A., & Khan, M. S. (2013). Tenure security and household investment decisions for urban sanitation: the case of Dakar, Senegal. *Habitat International, 40*, 58–64.

Serrona, K. R., Yu, J., & Che, J. (2010). Managing wastes in Asia: looking at the perspectives of China, Mongolia and the Philippines. In E. S. Kumar (Ed.), *Waste management* (p. 232).

Shinee, E., Gombojav, E., Nishimura, A., Hamajima, N., & Ito, K. (2008). Healthcare waste management in the capital city of Mongolia. *Waste Management, 28*, 435–441.

Sigel, S., Altantuul, K., & Basandrorj, D. (2012). Household needs and demand for improve water supply and sanitation in peri-urban ger areas: the case of Darkhan, Mongolia. *Environmental Earth Sciences, 65*, 1561–1566.

Snow, J. (1855, reprinted 1936). *On the mode of communication of cholera*. New York: Harvard University Press. In Webb, P., & Harinarayan, A. (1999). A measure of uncertainty: a nature of vulnerability and its relationship to malnutrition. *Disasters, 23*(4), 292–305.

Steinemann, A. (2004). Human exposure, health hazards, and environmental regulations. *Environmental Impact Assessment Review, 24*, 695–710.

Suk, W. A., Murray, K., & Avakian, M. D. (2003). Environmental hazards to children's health in the modern world. *Mutation Research, 544*, 235–242.
SuSanA. (2014). *Introduction to sustainable sanitation*. Sustainable Sanitation Alliance. Website http://susana.org/lang-en/sustainable-sanitation Accessed February 2014.
Terblanche, A. P. S. (1991). Health hazards of nitrate in drinking water. *Water SA, 17*(1), 77–82.
The Asia Foundation. (2014). Improving access to information on waste management in Mongolia. Website http://asiafoundation.org/in-asia/2014/04/30/photo-blog-improving-access-to-information-on-waste-management-in-mongolia/ Accessed July 2014.
The Diplomat. (2013). Mongolia's economic boom. Website http://thediplomat.com/2013/01/the-monglias-economic-boom/ Accessed July 2014.
The Economist. (2013). The fastest growing-economies in 2013: speed in not everything. Website http://www.economist.com/blogs/theworldin2013/2013/01/fastest-growing-economies-2013(Accessed July 2014.
Uddin, S. M. N., Li, Z., Mang, H., Huba, E. M., & Lapegue, J. (2014). A strengths, weaknesses, opportunities and threats analysis on integrating safe water supply and sustainable sanitation systems. *Journal of Water, Sanitation and Hygiene for Development, 4*(3), 437–448.
Uddin, S. M. N., Li, Z., Mang, H., & Lapegue, J. (2014). Sustainable sanitation towards eco-city development. In *Second symposium on urban mining*.
Uddin, S. M. N., Li, Z., Mang, H. P., Ulbrich, T., Schubler, A., Rheinstein, E., et al. (2014). Opportunities and challenges of greywater treatment and reuse in Mongolia: lessons learnt from piloted systems. *Journal of Water Reuse and Desalination, 4*(3), 182–193.
Uddin, S. M. N., Muhandiki, V. S., Fukuda, J., Nakamura, M., & Sakai, A. (2012). Assessment of social acceptance and scope of scaling up urine diversion dehydration toilets in Kenya. *Journal of Water, Sanitation and Hygiene for Development, 2*(3), 182–189.
Uddin, S. M. N., Muhandiki, Sakai, A., Mamun, A. A., & Hridi, S. M. (2014). Socio-cultural acceptance of appropriate technology: identifying and prioritizing barriers for widespread use of the urine diversion toilets in rural Muslim communities of Bangladesh. *Technology in Society, 38C*, 32–39.
UNESCAP. (2011). *Statistical yearbook for Asia and the Pacific*. Thailand: United Nations.
UNICEF, & WHO. (2012). *Progress on drinking water and sanitation*. New York, USA: Joint Monitoring Program for Water and Sanitation.
UNISDR. (2009). *Terminology on disaster risk reduction*. Geneva: Switzerland.
United Nations. (2013). *The millennium development goals report*. New York: United Nations.
United Nations. (2014). *The millennium development goals report*. New York: United Nations.
United Nations WATER. (2013). *Drinking water, sanitation and hygiene*. Website http://www.unwater.org/statistics_san.html Accessed August 2013.
VanDerslice, J., Popkin, B., & Briscoe, J. (1994). Drinking-water quality, sanitation, and breast-feeding: their interactive effects on infant health. *Bulletin of the World Health Organization, 72*(4), 589–601.
Winters, M. S., Karim, A. G., & Martawardaya, B. (2014). Public service provisions under conditions of insufficient citizen demand: insights from the urban sanitation sector in Indonesia. *World Development, 60*, 31–42.
Wisner, B. (1996). The geography of vulnerability. In J. Uitto, & J. Schneider (Eds.), *Preparing for the big one in Tokyo: Urban earthquake risk management* (pp. 20–33). Tokyo: United Nations University and INCEDE. In Wisner, B. (1998). Marginality and vulnerability: why the homeless of Tokyo don't 'count' in disaster preparations. *Applied Geography, 18*(1), 25–33.
Wisner, B., Gaillard, J. C., & Kelman, I. (2012). Framing disaster: theories and stories seeking to understand hazards, vulnerability and risk. In B. Wisner, J. C. Gaillard, & I. Kelman (Eds.), *Handbook of hazards and disaster risk reduction* (pp. 18–33). London: Routledge.
World Bank. (2009). *Asia sustainable and alternative energy program, Mongolia: Heating in poor, peri-urban Ger areas if Ulaanbaatar*. Washington, DC, USA: The World Bank Group.
World Bank. (2010). *Managing urban expansion in Mongolia: Best practices in scenario-based urban planning*. Washington, D.C.: The World Bank.
World Health Organization. (2005). *Mongolia: environmental health country profile*. Ulaanbaatar, Mongolia: World Health Organization. Website http://environment-health.asia/fileupload/MongoliaEHCP14205.pdf Accessed July 2014.
World Health Organization. (2006). Policy and regulation aspects. In *Guidelines for the safe use of wastewater, excreta and greywater* (Vol. 1). Geneva: Switzerland.
World Health Organization. (2008a). Recommendations (3rd ed). In *Guidelines for drinking-water quality, incorporating 1st and 2nd addenda* (3rd ed), (Vol. 1). Geneva.
World Health Organization. (2008b). *Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health*. Geneva.
World Health Organization. (2013). *Health topics: drinking-water*. Available from http://www.who.int/topics/drinking_water/en/ Accessed August 2013.

2. SUSTAINABLE SANITATION SOLUTIONS FOR PERI-URBAN MONGOLIA: WAYS TO REDUCE WASH-BORNE HAZARDS AND VULNERABILITY

The 2nd IWA Malaysia Young Water Professionals Conference 2015, 17-20 March 2015, Kuala Lumpur, Malaysia.

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Abstract

Hazard is defined as 'a dangerous phenomenon, substance, human activity or condition that may cause the loss of life, injury, or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage'. In the particular context of water, sanitation and hygiene (WASH), hazards include 'harmful substances (physical/chemical/biological) that originate from the absence/lack/failure of WASH interventions/programs/policies and cause loss of life, disability, other health impacts, socio-economic loss, or environmental bane'. On the other hand, vulnerability is defined as 'the risks or hazards for human beings either physically or mentally by natural events or through anthropogenic activities'. Therefore, WASH-borne hazards may play the leading role to increase the vulnerability of the affected communities to loss of life and disabilities. This study was carried out in the peri-urban Ger areas (the areas where people live in traditional yurt/felt tent) of Ulaanbaatar, Mongolia to evaluate various interventions on sustainable sanitation which may have potentiality to reduce the WASH-borne hazards and vulnerability in the study area. A range of sustainable sanitation technologies (e.g. eco-toilets) and services (e.g. emptying services) were designed, constructed and monitored to assess the feasibility and replicability of the technologies and services in the study area. The results from the drinking water and greywater quality analysis demonstrated that Ger residents are highly exposed to both biological and chemical contamination due to the unhygienic water containers to transport and store water, unplanned discharge of high concentrated greywater (COD- app. 50,000 mg/L) to the environment, lack of hygiene practices such as hand washing which may cause both environmental pollution and health hazards. The results also shown that eco-toilets may improve the health and environmental situation than any other existing unimproved sanitation technologies in the study area, composting human feces through greenhouse and semi-contained composting facility may enhance to treat human feces and recover nutrients for agro-production and other horticultural application. Greywater treatment through greenhouse and ice-block units seem technically and socially more feasible and acceptable than underground unit to fulfil partial demand of water in the study area and to protect from health and environmental hazards. It is recommended to test various options in holistic/integrated way to improve the global sanitary condition and to reduce WASH-borne hazards and vulnerability.

Key Words: Sustainable sanitation; hazards, vulnerability, WASH, peri-urban.

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1. NIGHT SOIL COMPOSTING AS A COMMON APPROACH TO SUSTAINABLE SANITATION. A REVIEW.

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Abstract: As the world population increases, also the trend for food demand, urbanization, and waste generation (night soil) increases; this has posed greater societal, economical, health and environmental detriments to the populace. Most of the people are blind of useful nutrients contained in night soil; they only perceive it as waste to be cast away. Ecological sanitation (eco-san) as a concept has adopted composting as commonly, economically and environmentally sustainable approach in solving night soil (human excreta) indiscriminately discharge. Composting process involves biological decomposition and stabilization of organic matter by microorganisms to produce humus-like product. Composting as one of the options of treating night soil under sustainable sanitation, not only to recycle the nutrients alone, but also to address health implication and environmental pollution that has claimed lives especially among the children. Most of night soil is treated by composting to produce fecal compost, but the acceptance of this concept in totality is still a bottleneck due to its threat, especially among the faecophobic societies. Nevertheless, these barriers can be penetrated through proper composting to sanitize night soil and also to increase public awareness of its nutrient contents/potentials to boost food production for sustainable development.

Keywords: acceptability, composting, night soil, sustainable sanitation

1. INTRODUCTION

The exploitation of fossil fuel, phosphorus mining, unplanned urbanization and linear flow of nutrients contained in night soil (human excreta) are quite unsustainable, so the need for sustainable alternatives becomes imperative to fully recycle the nutrients contained in both feces and urine. Sustainable sanitation focuses on how night soil is handled from generation to disposal/treatment; this involves the feasibility and acceptance of technology used by users to improve their health status and reduces environment pollution [Katukiza et al., 2012]. According to World Commission on Environment and Development (WCED) [1987] that states “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

In many parts of the world especially developing countries, the lack of adequate water supply and basic sanitation is the most vital issue concerning sustainability [Sigel et al., 2012]. According to a Joint Monitoring Programme (JMP) conducted by WHO/UNICEF [2010], about 2.6 billion i.e. 40% of the world population do not use improved sanitation, with large number in Southern/Eastern Asia and Sub-Sahara Africa; where open defecation is widely practiced, this posed tremendous hazards to health and caused environmental damage and pollution. If the trend continues without proactive measures, it’s projected that by 2020-30, additional 2 billion people will be demanding for basic sanitation especially in developing countries [Esrey et al., 2001 ; Langereraber, and Muellegger, 2005]. Also, estimated that at every 20 seconds, this scourge leads to the death of a child less than five years of age, due to exposure to the related diseases such as diarrhoeal, typhoid, cholera, ascaris, dracunculiasis, hookworm, schistosomiasis and trachoma [WHO/UNICEF, 2006; Mara et al., 2010]. Particularly, diarrhoeal contributes heavily to child mortality and morbidity in low-income countries [Mara et al., 2010], which can be significantly prevented by proper and improved night soil disposal.

Managing night soil has been categorized into off-site systems (flush and discharge model) and on-site systems (drop and store model). Apart from their shortcomings such as: groundwater contamination; bad odour; flies and mosquitoes breeding; scarcities of land and water; operation and maintenance cost; and diseases transmission, these two systems have considered night soil as wastes rather than resources to be conserved and recycled to replenish the nutrients and organic contents of the soil. Therefore, a proactive and sustainable approach has to be developed, which addresses environmental and public health issues and guarantees economic feasibility along with nutrient recovery and reuse as bio-fertilizer. The combination of these factors is possible in an approach called "ecological sanitation" (eco-san) [Drangert, 1998; Esrey et al., 2001; Winblad and Simpson-Hébert, 2004].

Several approaches have been used and adopted in disposing/treating night soil such as: indiscriminate discharge into open canals and waterways; composting; incineration; landfilling; storage; aerobic and anaerobic digestion; ammonia-based treatment; urea; urine-diversion and Aquatron [Vinnerås, 2007; Ottoson, et al., 2008]. Thermal composting proves to be most common, low cost and reliable treatment that renders night soil safe, hygienic, innocuous and made it possible for recycling without detriment to the environment [Vinnerås, et al., 2003; WHO, 2006]. Vinnerås [2007] is of the view that, addition of urea is the most efficient night soil treatment, due to high presence of ammonia that not only acts as fertilizer but also inhibits the re-growth of pathogens; albeit, urea leads to the risk of ammonia volatization with an offensive smell [Ottoson, et al., 2008].

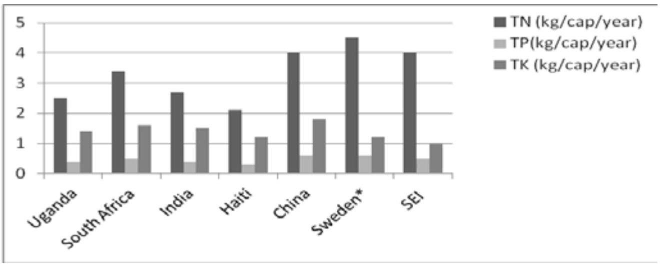
Composting as a sustainable sanitation approach has been widely used in managing and treating night soil especially for developing countries due to its accessibility, low environmental pollution, low cost of operation and maintenance and significant pathogens reduction [Winblad and Simpson-Hébert, 2004]. This process has long been practiced for many centuries ago; it was reported that Chinese has long history of millennia in co-composting of human waste and crop residues [McGarry, 1976].

The objective of this study was to review relevant information on sustainability and applicability of night soil through composting process and its affecting factors, both the potentials and threats in it, and societal acceptability for sustainable development.

2. NIGHT SOIL COMPOSITION

Night soil is a genteelism used for human excreta that is used as soil condiment i.e. humanure, which consist of both feces and urine [Maurya, 2012; UN-HABITAT, 2008; Esrey et al., 2001]. This is readily available in every community as free fertilizer, which can be harnessed for food production [Heinonen-Tanski and Wijk-Sijbesma, 2005]. Most of the nutrients are contained in urine with approximately 88% of N and 67% of P, while feces contain about 12% of N and 33% of P [Jönsson et al., 2004]. The higher nutrients in urine can be directly used on crops without storage for household consumption [WHO, 2006].

The estimated total nutrients excreted per capital in different countries are shown in Fig. 1; these differences are based on physiological nature of people, climate, diet compositions and digestibility. In night soil, feces contain most of the pathogens that need to be sanitized before application [Feachem et al., 1983; Vinnerås, et al., 2003; WHO, 2006]. According to Feachem et al. [1983], the equivalent pathogens contained in one gram of fresh feces of an infected person are about 10^6-10^8 bacterial pathogens; 10^6 viral pathogens; 10^4 protozoan cysts or oocysts and 10–10^4 helminth eggs. By contrast, urine is normally sterilized in urine bladder in the human body, but not totally sterile [Heinonen-Tanski and Wijk-Sijbesma, 2005], contains less pathogen that can be rendered safe on storage within short period of time, unless its cross contaminated with feces [Schönning and Stenström, 2004].



Source: [Jönsson and Vinnerås, 2004; Stockholm Environment Institute (SEI), 2005] and from Drangert [1998].*

Figure 1. Estimated of total nutrients (NPK) excreted per capital in different countries.

2.1 COMPOSTING OF NIGHT SOIL

Composting process is a bio-oxidative and controlled process that involves humidification, mineralization and stabilization of organic matter by microorganisms in order to produce a stable, free of pathogens humus-like product that can be beneficially applied to soil. Under favourable conditions, microorganisms decompose organic matter and transform into carbon dioxide (CO_2), heat, water (H_2O) and humus-like product [Diaz, et at., 1993; Haug, 1993; Rynk et al., 1992]. It is very hard to compost night soil alone due to its low C/N ratio and high moisture, so, co-composting with organic matter used as bulking agents becomes imperative. Co-composting has been carried out by different researchers [Vinnerås, et al., 2003; Kone´, et al., 2007; Niwagaba, et al., 2009 ; Ronteltap et al., 2009], which has been found to the most common and economical way of recycling both the nutrients and organic matter to the soil**.**

2.2 FACTORS AFFECTING NIGHT SOIL COMPOSTING.

Several studies have been conducted on the physicochemical factors such as: pH, particle size, moisture, temperature, oxygen concentration, ammonia, solar radiation/UVlight and nutrient balance etc, which affect biodegradation, degree of stability and maturity, and microbial growth of night soil compost [Schönning and Stenström, 2004; Kakimoto and Funamizu, 2007; Hotta and Funamizu, 2007].

2.2.1 TEMPERATURE

Temperature is one of the major factors that not only influences the microbial growth within the compost but also affect the rate and period of decomposition [Lopez Zavala et al. 2004]. In terms of biodegradation of organic matter, Bai and Wang [2011] achieved 73.5 and 68% reduction of organic matter at both thermophilic (60°C) and mesophilic (35°C) respectivley, though at different period of time. This indicated that, a mutured compost reduces in weight, volume, odur, destroy plant and animal pathogens [Epstein, 1997].

According to Lopez Zavala et al. [2004], the optimum temperature for efective biodegradability of night soil is nearly to 60°C, they reported that, at higher temperature such as 70°C, there was reduction of enzymatic activities that consequently led to low biodegradation. Also in the same trend, Miller [1992] observed that the most favourable condition for maximizing biodegredation is in the of range of 52-60°C. Above 60°C, it was observed that microbial growth or activity and ligni degredation will be decresed [Strom, 1985]. There was no detection of pathogen indicators such as total coliform or E. coli and *Salmonella spp.* within 3-6 days of composting as the temperature rises within 50-55°C [Grewal, et al., 2006; Niwagaba, et al., 2009], while in 7 days, E. coli was reduced at 55°C from 10^6 to below 10^2 CFU/g-wet [Hanajima, et al., 2006].

Vinnerås, et al. [2003] observed that, there is possibility to achieve 12 $\log_{10}$ inactivation of pathogens using mathematical method during thermal composting with sufficient insulation, this was above the 6 $\log_{10}$ reduction guidelines set by WHO [2006]. If only the center of compost reached higher temperature, turning and mixing will become imperative to ensure all other parts of compost are sanitized, though the turning frequency at 10 days interval and at 3 days interval did not influence helminth eggs removal efficiency [Kone´, et al., 2007].

2.2.2 MOISTURE

In order to produce matured compost, moisture content is one of the most critical factors to be considered. The optimum moisture content for adequate decomposition and microbial activities ranges between 40-60% [Haug, 1993; Epstein, 1997]. Night soil composting moisture was controlled at 55-65% [Hotta and Funamizu, 2007]; at 60% [Bai and Wang, 2011]. Nevertheless, composting of dairy cattle feces with easily digestible organic waste was successfully conducted in the bench-scale composter with high moisture content of 78% [Hanajima, et al., 2006]. As observed by Lens et al. [2004], composting process with more than 60% moisture leads to anaerobic and below 20% will cause the microbial activities to stop. So, moisture content must be critically observed to avoid water-logged of the compost, which prevents the flow of oxygen within the compost and consequently leads to anaerobic with foul smell. Moisture content decreases as temperature increases in the compost, therefore, additional water needs to be added during active compost to offset the loss.

2.2.3 AERATION

Proper aeration is essential in maintaining uniform temperation and moisture contents throughout the compost during composting process. Aeration provides oxygen required by the microorganisms to cause degredation, aslo to remove excess heat, waste gases and reduce moisture. [Rynk et al., 1992]. Aeration rate is observed to be the most essential factor that determines successful composting [Diaz et al., 2002]. When aeration is not enough for microbial activities, this can lead to anaerobic conditions due to the lack of oxygen, while excessive aeration can increase costs and slow down the composting process, water and ammonia losses. Aeration can be performed either manually or mechanically. Excessive aeration should be avoided in order not to dry compost pile that consequently leads to slowing down of microbial activities.

2.2.4 C/N RATIO

For every living organism, there must adequate supply of nutrients for metabolism. The nutrients supplied are in form of C/N ratio that deals with relative ratio of amount of carbon and nitrogen in the compost or soil. This ratio is important because without sufficient number of carbon in compost to balance the nitrogen, such compost cannot support the microbial activity for proper biodegradation. Carbon supplies energy and growth, while nitrogen provides protein used for building protoplasm and reproduction. Many researchers have concluded that the preferred C/N ratio for proper decomposition of any compost is within the range of 25-30:1[Haug, 1993; Rynk et al., 1992], above this range, the decomposition process slow with little rise in temperature, while below the range, nitrogen loss inform of ammonia volitization which is great environmental concern. The main reason for nitrogen loss during composting is the conversion of ammonium nitrogen (NH_4^+-N) to ammonia gas (NH_3) [Diaz, et at., 1993; Haug, 1993].

3. SOCIAL ACCEPTABILITY OF NIGHT SOIL

Though, its general societal norm that every individual does not like the odor and stigma attached to night soil handling, consequently, the awareness and limited knowledge on night soil's potentials are major constraints. Therefore, to sensitize people on sustainable sanitation alternatives, usage and acceptability has proven to be bottleneck, due to behavioural and psychosocially related problems of night soil handling, ranging from ribald humor to disgust [UN-HABITAT, 2008; Rosenquist, 2005].

The opportunities in night soil have been apprehended, harnessed and applied as a fertilizer not only in China for centuries but also some other Asian countries especially South East Asia, albeit lots of enteric diseases that are predominant among the users [Mackie Jensen et al., 2008]. Chinese as a fecophilic society are familiar with the concept of applying night soil on their farms. In the early 1990s in China, about 90% of untreated night soil was consumed by agriculture in rural areas [Black and Fawcett, 2008]. Also, Korean people are aware of benefit and value of applying night soil in agriculture to the extent of having a proverb that states "You can always give away a bowl of rice, but never a bag of compost" [Lee, 2000]. In the same trend, more than 50% of night soil collected in Japan is returned to agriculture [Drangert, 1998]. The applications of night soil are mainly due to its availability, nutrient contents and also serves as waste management.

In contrast, fecophobic societies especially in Hinduism and south of Sahara in Africa have considered touching of night soil as a taboo, malodorous and unclean due to socio-cultural and religious beliefs [Winblad and Simpson-Hébert, 2004]. Taboo is one of the major constraints that hinder the acceptability of night soil due to sociocultural attitudes [Black and Fawcett, 2008). According to WHO [2006], "Sociocultural factors are fundamental for sustainability", in spite of well designed, protective and hygienic measures taken to sanitize night soil and greywater, the efforts can still be abortive, if people's orientation, perceptions, norms and attitude have not changed towards the acceptance and application. This implies that, a successful research involves stakeholders and users to actively participate in planning and decision making; this gives a profound opportunity and sense of belongings to the common people. [Zurbrügg and Tilley, 2009].

The acceptance of eco-san concept that includes night soil application among the Muslims communities has been so narrow due to strong religious prohibition of direct or indirect contact with night soil; these psychological and religious barriers have inhibited the fertilizer value for the people [Nawab, et al., 2006]. Also, in North West Frontier Province in Pakistan, a study was conducted by Drangert and Nawab [2011], they reported that, according to Islamic doctrine, night soil and wastewater have been considered as impure (*najas*), which can be rendered safe and useful through advance treatment that is capable of removing the impurities such as taste, color and smell.

Contrary to this religious view, are the people of Ghana especially Manya krobo district people that are enthusiastically accepted and used night soil without taboo, cultural and religious barrier [Cofie, et al., 2010]. In addition, the Vietnamese people are actively engaged in farm production, it was reported that about 94% of 471 household surveyed used composted night soil with no smell as organic fertilizer [Mackie Jensen et al., 2008]. This shows that people's orientation and perceptions can be changed on acceptability especially when they realized the potential benefits and required nutrients contained in night soil for sustainable development.

3.1 OPPORTUNITIES DERIVED FROM NIGHT SOIL APPLICATION

Maurya [2012] asked a question that, should night soil be regarded as waste? When there are lots of benefits and opportunities to be derived for sustainability. The degree of awareness and acceptance varies in different cultures and tribes. In some societies, night soil has not been seen as waste, rather it is considered as valuable resources [Winblad and Simpson-Hébert, 2004]. In order to maximize these opportunities contained in night soil, the concepts and orientation of linear flow of nutrients have to be changed to close-loop. The new sanitation approach as the best approach has been identified and selected to counteract the linear flow of these nutrients, which can be used as fertilizer and soil conditioner upon adequate treatment [Winker et al., 2009]. Night soil users have given good recommendations not only in terms of organic quality and quantity of nutrients but also the yield of the crop production that provided Manya krobo district people three times of net income than non-users [Cofie, et al., 2010].

The trend of chemical fertilizers usages is unsustainable and its availability in future is quite uncertain, apart from given soil its chemical requirement, there is no organic matter supply to the soil. It is observed that the depletion of life span of global phosphorus reserves is somewhere around 60 to 130 years [Steen, 1998], with expected global peak in its production by 2030 [Cordell et al., 2009]. This future threat on food production can be mitigated, if other sources of phosphorus such as: animal manure, night soil and wastewater can be fully harnessed. On yearly basis, more than 200 million tones of night soil are indiscriminately discharged to the environment without collection [UNDP, 2008], If these are properly collected, 22% of the global phosphorus demand could be derived from night soil [Mihelcic, et al., 2011], while 33% of nitrogen could be recovered [WHO, 2006]. Urine blindness has to be overcome because urine alone can provide more than 50% of phosphorus required to fertilize cereal crops [Drangert, 1998]. Furthermore, considering the high cost of chemical fertilizers that prevents many people especially poor communities to afford [Cofie, et al., 2010], Fig. 2 depicts various opportunities that could be derived from night soil compost application in accordance with [UN-HABITAT, 2008].

Figure 2. Opportunities from Night soil application

3.2 THREATS IN NIGHT SOIL APPLICATION

The major threats in night soil are enteric diseases transmission due to pathogenic bacteria, virus, protozoans and helminthes, especially helminthes (ascari eggs) that are highly resistance to environmental conditions [Haug, 1993; Sidhu and Toze, 2009]. These have hindered the acceptability and applicability of night soil, unless the loop of disease transmission chain broken either by thermal composting, storage or ammonia-based treatment [Vinnerås, 2007]. The untreated discharge of night soil into rivers has caused loss of biodiversity, detriment to aquatic lives, social welfare and economic development of the people. The presence of faecal coliforms, total coliforms, faecal *enterococci* and helminth eggs in contaminated water has been used as pathogens indicators, coliforms are not that difficult to remove during thermal composting except ascaris eggs that need longer time, which when reduced to 1 ascaris egg/g TS, it can be used as reliable indicator that all human pathogens are destroyed [Kone´, et al., 2007; Sidhu and Toze, 2009]. However, once the appropriate measures and techniques to treat these pathogens are observed, it can be used for crop production [Winker, 2009]. Besides, in terms of the nutrients lost, it was estimated that on yearly basis, 50% of the global phosphorus extracted, lost to the environment either by runoff or erosion from cropland, which has led to eutrophication [Liu et al., 2008].

4. CONCLUSIONS

The waste “night soil” from our body has to be properly collected and treated to avoid nuisance in the environment. Also, this indiscriminate discharge has to be viewed with the perspective of resources rather than waste. Eco-san concept adopts composting process as an approach of treating organic waste including night soil as sustainable sanitation in terms of improving water and sanitary condition, protect environment pollution, prevent health hazards and ecosystem degradation. This composting approach is feasible and profitable especially for low income earners in developing countries, in comparison with other means of waste disposals such as incineration and landfilling. It recycles and utilizes the free nutrients in night soil, mainly to close the gap between sanitation and food production, also to substantially reduce the amount of waste transported to landfill. However, the major threat in night soil is availability of pathogens that has claimed lives especially among the children. From literature, it is observed that night soil can be commonly treated and sanitized by thermal composting within the range of 55-60°C.

Conclusively, acceptance of the usage of night soil in different societies differs due to socio-cultural and religious beliefs. This can be penetrated, based on the technical know-how and awareness about the valuable nutrients and economic benefits for sustainability, which can be derived from its application.

REFERENCES

BAI, F., and WANG, X. 2011. Effect on Biodegration of Organic Matter and Change of Biomass in Aerobic Composting of Human Feces from Tempreture. 2011 International Conference on Environmental and Agriculture Engineering. vol.15. © (2011) IACSIT Press, Singapore.

Black, M. and Fawcett, B. 2008. The Last Taboo: Opening the Door on the Global Sanitation Crisis. Earthscan, UK and USA, pp 254.

Cofie, O. , Adeoti, A., Nkansah-Boadu, F., Awuah, E. 2010. Farmers perception and economic benefits of excreta use in southern Ghana. Resources, Conservation and Recycling 55, 161–166.

Cordell, D., Drangert, J.O., and White, S., 2009. The story of phosphorus: global food security and food for thought. Global Environ. Change 19, 292–305.

Diaz, L.F., Savage, G.M., Eggerth, L.L., & Golueke, C.G. 1993. Composting and recycling municipal solid waste. Boca Raton, Florida: Lewis Publishers & CRC Press, Inc.

Diaz, M.J., Madejon, E., Lopez, F., Lopez, R., Cabrera, F., 2002. Optimization of the rate vinasse/grape marc for co-composting process. Process Biochem. 37, 1143–1150.

Drangert J.O. 1998. Fighting the urine blindness to provide more sanitation options. Water SA, 24(2), 157-164.

Drangert, J.O., Nawab, B. 2011. A cultural–spatial analysis of excreting, recirculation of human excreta and health-The case of North West Frontier Province, Pakistan. Health & Place, 17, 57–66.

Epstein, E. 1997. The Science of Composting. Technomic Publ. Co., Inc., Lancaster, Pennsylvania.

Esrey, S., Andersson, I., Hillers, A. and Sawyer, R. 2001. Closing the Loop: Ecological Sanitation for Food Security. Publications on Water Resources No. 18, First edition. Swedish International Development Corporation Agency (SIDA), Mexico.

Feachem R.G., Bradley D.J., Garelick H, Mara D.D. 1983. Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. John Wiley and Sons, Published for the World Bank by John Wiley and Sons, pp. 326.

Grewal, S.K., Rajeev, S., Sreevatsan, S., Michel, F.C., 2006. Persistence of Mycobacterium avium subsp paratuberculosis and other zoonotic pathogens during simulated composting, manure packing and liquid storage of dairy manure. Appl. Environ. Microbiol. 72 (1), 565–574.

Hanajima, D., Kuroda, K., Fukumoto, Y., Haga, K. 2006. Effect of addition of organic waste on reduction of Escherichia coli during cattle feces composting under high-moisture condition. Bioresource Technology, 97, 1626–1630.

Haug, R.T. 1993. The Practical Handbook of Compost Engineering. Lewis Publishers, Boca Raton, Ann Arbor, London, Tokyo, pp. 717.

Hotta, S., and Funamizu, N. 2007. Biodegradability of fecal nitrogen in composting process. Bioresource Technology, 98 (17), 3412–3414.

Jönsson, H. and Vinnerås, B. 2004. Adapting the nutrient content of urine and feces in different countries using FAO and Swedish data. In: Ecosan – Closing the loop. Proceedings of the 2nd international symposium on ecological sanitation, incorporating the 1st IWA specialist group conference on sustainable sanitation, 7th-11th April 2003, Lübeck, Germany. Pp 623-626. – In: Jönsson et al. (2004).

Jönsson, H., Stintzing, A. R., Vinnerås, B. and Salomon, E. 2004. Guidelines on the Use of Urine and Feces in Crop Production. Report 2004-2. EcoSanRes Publications Series. Stockholm Environment Institute, Sweden. www.ecosanres.org. (Accessed 11 Jan. 2013).

Kakimoto, T. and Funamizu, N. 2007. Factors affecting the degradation of amoxicillin in composting toilet. Chemosphere, 66, 2219–2224.

Katukiza, A.Y. Ronteltap, M.., Niwagaba, C.B. Foppen, J.W.A., Kansiime, F., Lens, P.N.L. 2012. Sustainable sanitation technology options for urban slums. Biotechnology Advances, 30(5), 964-978.

Kone´, D., Cofie, O., Zurbrgg, C., Gallizzi, K., Moser, D., Drescher, S., and Strauss, M. 2007. Helminth eggs inactivation efficiency by faecal sludge dewatering and co-composting in tropical climates. Water Research, 41, 4397 – 4402.

Langereraber, G. & Muellegger, E. 2005. Ecological sanitation – a way to solve global sanitation problems? Environment International 31, 433–444.

Lee, D.B. 2000. The dream of the nature-orientated toilette "Dickan". Seoul, South Korea. In: Lüthi C., Panesar, A., Schütze, T., Norström, A., McConville, J., Parkinson, J., Saywell, D and Ingle, R. 2011. Sustainable Sanitation in cities -A framework for action. Sustainable Sanitation Alliance (SuSanA), Eschborn, Germany, pp. 169.

Lens, P., Hamelers, B., Hoitink, H., Bidlingmaier, W. 2004. Resource Recovery and Reuse in Organic Solid Waste Management, IWA Publishing eds. ISBN: 184339054.

Liu, Y., Villalba, G., Ayres, R.U., Schroder, H., 2008. Global phosphorus flows and environmental impacts from a consumption perspective. J. Ind. Ecol. 12 (2), 229–247.

Lopez Zavala, M.A., Funamizu, N., and Takakuwa, T. 2004. Temperature effect on aerobic biodegradation of feces using sawdust as a matrix. Water Research, 38, 2406–2416.

Mackie Jensen, P.K., Phuc, P.D., Knudsen, L.G., Dalsgaard, A., Konradsen, F., 2008. Hygiene versus fertiliser: The use of human excreta in agriculture – A Vietnamese example. International Journal of Hygiene and Environmental Health, 211, 432-439.

McGarry, M.G. (1976). The Taboo Resource: The use of human excreta in Chinese agriculture. The Ecologist 6, pp. 4.

Mara D., Lane J., Scott B., Trouba D. 2010. Sanitation and Health. PLoS Med 7(11): 1-7.

Maurya, N.S. 2012. Is human excreta a waste? International Journal of Environmental Technology and Management, 15 (3), 325-332.

Mihelcic, J. R., Fry, L.M., Shaw, R. 2011. Global potential of phosphorus recovery from human urine and feces. Chemosphere, 84, 832–839.

Miller, F.C., 1992. Composting as a process based on the control of ecologically selective factors. In: Metting, F.B., Jr. (Ed.), Soil Microbial Ecology, Applications in Agricultural and Environmental Management. Marcel Dekker, Inc., New York, pp. 515–544.

Nawab, B., Nyborg, I.L.P., Esser, K.B and Jenssen, P.D. 2006. Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan. Journal of Environmental Psychology, 26, 236–246.

Niwagaba, C., Nalubega, M., Vinnerås, B., Sundberg, C. and Jönsson, H. 2009. Substrate composition and moisture in composting source-separated human feces and food waste. Environmental Technology, 30(5), 487-497.

Ottoson, J., Nordin, A., von Rosen, D., Vinnera˚s, B. 2008. Salmonella reduction in manure by the addition of urea and ammonia. Bioresource Technology, 99, 1610–1615.

Rosenquist D. L. E. 2005. A psychosocial analysis of the human-sanitation nexus. Journal of Environ Psychology, 25, 335–346.

Rynk, R., van de Kamp, M., Willson, G.B., Singley, M.E., Richard, T.L., Kolega, J.L., Gouin, F.R., Laliberty, L., Jr., Kay, D., Murphy, D.W., Hoitink, H.A.J., and Brinton, W.F. 1992. On-farm composting handbook, Natural Resource, Agriculturae and Engineering Service, Cornell University, Ithaca, New York. 14853-570. pp. 204.

Sidhu, J.P.S. and Toze, S.G. 2009. Human pathogens and their indicators in biosolids: A literature review. Environment International, 35, 187–201.

Schönning, C. and Stenström, T.A. 2004. Guidelines for the Safe Use of Urine and Feces in Ecological Sanitation. Report 2004-1. EcoSanRes, SEI, Stockholm www.ecosanres.org. (Accessed 11 Oct. 2012).

SEI. 2005. Sustainable Pathway to Attain Millenium Devlopment Goals: Accessing the Key Roal of Water, Energy and Sanitation. SEI, pp. 103.

Sigel, K., Altantuul, K., and Basandorj, D. 2012. Household needs and demand for improved water supply and sanitation in peri-urban ger areas: the case of Darkhan, Mongolia. Environ. Earth Sci., 65, 1561–1566.

Steen, I. 1998. Phosphorus recovery in the 21st Century: Management of a non-renewable resource. Phosphorus & Potassium Journal, 217, 25-31. Also available at: http://www.nhm.ac.uk/mineralogy/phos/P&K217/steen/html. (Accessed 29, Jan., 2013).

Strom, P. 1985. Effect of temperature on bacterial species diversity in thermophilic solid-waste composting. Appl. Environ. Microbiol. 50, 899–905.

UNDP. (2008). United Nation Development Programme on Ecological sanitation. http://www.undp.org/water/initiatives/ecol. html (Accessed 27 Feb., 2012).

UN-Habitat, 2008. Global Atlas of Excreta, Wastewater Sludge, and Biosolids Management: Moving forward the sustainable and welcome uses of a global resource. United Nations Human Settlements Programme. Nairobi 00100, Kenya, pp. 632.

Vinnerås B., Björklund,A., and Jönsson, H. 2003. Thermal composting of faecal matter as treatment and possible disinfection method–laboratory-scale and pilot-scale studies, Bioresource Technology, 88 (1), 47–54.

Vinnerås, B. 2007. Comparison of composting, storage and urea treatment for sanitizing of faecal matter and manure. Bioresource Technology 98, 3317–3321.

Winblad U. and Simpson-Hébert M. 2004. Ecological sanitation – revised and enlarged edition. SEI, Stockholm, Sweden. pp 147. www.ecosanres.org. (Accessed 11 August 2012).

WHO. 2006. Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 4. Excreta and Grey Water Use in Agriculture, World Health Organization (WHO), Geneva, pp. 204.

WHO/UNICEF, 2006. Meeting the MDG Drinking Water and Sanitation Target. The urban and Rural Challenge of the Decade. WHO & UNICEF (JMP). WHO, Switzerland, pp. 47.

WHO/UNICEF, 2010. Joint Monitoring Programme (JMP) for Water Supply and Sanitation. Progress on Sanitation and Drinking Water: 2010 Update. Geneva and New York: World Health Organization and United Nations Children's Fund, 2010, pp. 60.

Winker, M., Vinnerås B., Muskolus A., Arnold U., Clemens J. 2009. Fertiliser products from new sanitation systems: Their potential values and risks. Bioresource Technology, 100, 4090–4096.

World Commission on Environment and Development (WCED) (1987). Our common future. Oxford: Oxford University Press. pp. 43.

Zurbrügg, C. and Tilley, E. 2009. A system perspective in sanitation – Human waste from cradle to grave and reincarnation. Desalination, 248, 410–417

2. CO-COMPOSTING OF FECAL MATTER IN MONGOLIA USING TWO DIFFERENT TECHNOLOGIES

Ibrahim Babatunde Mahmood, Zifu Li, Sayed Mohammad Nazim Uddin, Heinz-Peter Mang and Jörn Germer

ABSTRACT

Sanitation is one of the most pressing issues faced by the population in the peri-urban Ger areas of Ulaanbaatar, Mongolia. Poorly constructed pit latrines have caused environmental, socioeconomic and health problems especially Hepatitis A, among the residents, which is predominant among children less than 5 years old. This research aimed to investigate the feasibility of co-composting fecal matter with different recipes using two different technologies, i.e. composting facility and greenhouse (GH) technology. All the trials conducted met the international sanitary requirements for compost, i.e. World Health Organization (50 °C $\geq$ 1 week). Conclusively, GH technology with the addition of food waste allowed the temperature to increase up to 70 °C, which proved to be a better option for co-composting of fecal matter under specific local conditions.

Key words | co-composting, composting facility, eco-toilets, fecal matter, greenhouse, sanitation

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INTRODUCTION

Inadequate sanitation is a global challenge that affects people's daily lives and standards of living, most especially in developing countries across the globe. At the end of 2011, about 2.5 billion (10^9), i.e. approximately 40% of the world population, was still lacking basic sanitation and had no access to improved sanitation facilities (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation 2013). The lack of inadequate water supply and basic sanitation is the most vital issue concerning sustainable development, most especially in developing countries (Sigel *et al.* 2012).

This research was conducted in Ulaanbaatar (UB), the capital city of Mongolia, which is known to be the coldest capital city in the world. Mongolia is the most sparsely populated country in the world with a population of 2.74 million inhabitants (National Statistic Office of Mongolia 2010). The majority of the people living in Ger areas (60% of UB's population) are served with poorly constructed simple pit latrines as means of excreta disposal (Sigel *et al.* 2012). The usage of simple pit latrine leads to surface and groundwater contamination, which has caused a severe health hazard, most especially Hepatitis A, among the people of the area (Basandorj & Altanzagas 2007). The epidemic of Hepatitis A has covered up to 92% of the total related Hepatitis diseases in Mongolia, which is seven times more than the international average (World Bank 2004).

The composting process as a sustainable sanitation approach has been widely used in managing and treating human excreta, especially in developing countries, due to its accessibility, low environmental pollution, low cost of operation and maintenance as well as significant pathogens reduction (Esrey *et al.* 2001). It is a controlled biological process that involves aerobic microorganisms in breaking down and converting organic material into a biologically stable product called 'compost' (Said-Pullicino *et al.* 2007). Co-composting of excreta with organic matter (OM) used as bulking agents has been carried out by different researchers. However, little research has been conducted on the effect of

doi: 10.2166/washdev.2014.079

technologies and different recipes used in fecal composting for sustainability.

The aim of this research work was to sustainably solve the sanitation problems faced by the people in Ger areas, by determining the feasibility of co-composting fecal matter with different recipes via composting facility (CF) and greenhouse (GH) technology.

MATERIALS AND METHODS

Composting site

The composting activities took place at a particular site that is located at the outskirts of UB. Two facilities, CF and GH, were constructed on the site by Action Contre la Faim (ACF) Mongolia. Figure 1(a) and 1(b) shows the schematic diagrams of the CF, with the arrangement of four bins that represent the first four trials as shown in Figure 1(b), while the fifth trial was later conducted in the GH facility.

Feedstock

The fecal matter used in these trials was collected in a container beneath the toilet's superstructure and manually emptied at 3-month intervals. The co-composting materials (feedstock) used as carbon sources were wood chips, sawdust, straw and food waste. Preliminary activities such as sorting, shredding (1–5 cm) and separations were conducted before mixing with fecal matter. The C/N ratio of each trial was approximately 30:1.

Analytical methods

The following analytical parameters for effective composting were conducted in Mongolia State University of Agriculture. Moisture content (MC), total solid and total carbon (TC) were determined before mixing as shown in Table 1 in accordance with American Public Health Association standard methods (Greenberg *et al.* 1992). pH (1:10 w/v compost:water extract) was measured with a hand-held pH meter (HANNA HI9125N, Italy), while total nitrogen (TN) was analyzed by the Kjeldahl method (Novozamsky *et al.* 1983). The process stability on CO_2/O_2 was monitored by biogas analyzer (Geotech-Biogas 5000, UK) to check the aeration level in the piles.

Trials (1–4) were conducted in the CF, while Trial 5 was conducted in the GH. The physicochemical properties of the recipes in the five trials are given in Table 2.

Experimental setup and design

Composting facility

Four 660 L of waste bins were used as reactors as shown in Figure 1(b). Each bin was fully covered with 150 mm thick Styrofoam to minimize the heat lost. On top of each bin, a ventilation pipe of 10 cm diameter discharges the toxic

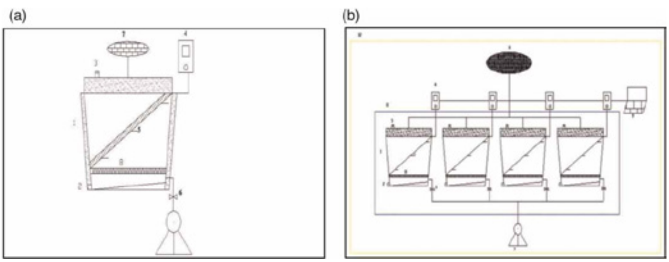

Figure 1 | (a) Composting facility reactor. (1) compost bin; (2) leachate collection; (3) CO_2/O_2 determination; (4) data logger; (5) temperature probe; (6) control valve; (7) exhaust ventilation pipe; (8) perforated plate; (9) air pump. (b) Four reactors in the composting room.

Table 1 | Physicochemical properties of the recipes used

Feedstock	MC (%)	DM (kg)	TC (%) (dm)	TN (%) (dm)
Feces	87.0	26.0	48.5	4.5
Sawdust	8.0	32.0	55	0.1
Straw	7.7	9.7	51	0.6
Wood chips	13.0	24.9	54	0.15
Food waste	78.5	3.7	29.7	0.8

DM, dry matter; dm, dry matter; MC, moisture content; TC, total carbon; TN, total nitrogen.

Table 2 | Physicochemical properties of mixed compost structure material

Serial number	Trials in CF and GH	Feedstock	Mixing ratio (v/v)	MC (%)	TC (%) (dm)	TN (%) (dm)
1	Trial 1[a]	Feces	1	87.0	48.5	4.5
		Sawdust	1	8.0	55	0.1
		Straw	1	7.7	51	0.6
2	Trial 2[a]	Feces	1	87.0	48.5	4.5
		Woodchips	1	13.0	54	0.15
		Straw	1	7.7	51	0.6
3	Trial 3[a]	Feces	1	87.0	48.5	4.5
		Sawdust	1	8.0	55	0.1
		Woodchips	1	13.0	54	0.15
4	Trial 4[a]	Feces	1	87.0	48.5	4.5
		Sawdust	1.5	8.0	55	0.1
5	Trial 5[b]	Feces	1	87.0	48.5	4.5
		Sawdust	1	8.0	55	0.1
		Straw	1	7.7	51	0.6
		Food waste	1	78.5	29.7	0.8

dm, dry matter; MC, moisture content; TC, total carbon; TN, total nitrogen.
[a]Trial conducted in composting facility (CF).
[b]Trial conducted using GH technology.

gases and odor out of the room. The perforated boards for carrier plates were placed 10 cm from the base of the reactors to support the composting bed and ensure uniform aeration. The compost pile temperatures were monitored hourly with data loggers that were placed diagonally inside the bins to determine the temperature at the top, core and bottom of the piles.

Ventilation systems across the piles were intermittently supplied and maintained (30 minutes off and 30 minutes on with the help of a stop clock) at 0.5 L kg/ minutes (dm) from the bottom of each reactor. Turning was manual with pitchfork on a weekly basis to allow every part of the pile to be exposed to heat for pathogens destruction.

Greenhouse technology

The objective of the second type of trial was to define the feasibility of the composting process using GH technology. Passive aeration was adopted to distribute ambient air evenly across the pile, which diffuses through the bored blocks and slanted planks that were placed against the wall. The composting pile was stacked to a volume of about 1.2 m^3, which was 80% of the inner volume of the slot. For this trial, a data logger was placed horizontally at the center of the pile and the average temperatures were recorded. The turning was conducted fortnightly, not only to reduce the stress of the labor but also to minimize ammonia volatilization.

RESULTS AND DISCUSSION

Composting facility

Temperature variations against composting time are shown in Figure 2(a)–2(e). The ambient temperature ranged from 18–24 °C, which shows no significant influence on the process. As composting began, the thermophilic phase (>50 °C) was reached within 3 days for Trial 1, 2 and 3, as shown in Figure 2(a)–2(c), respectively. This could be understood to be a result of the co-substrates used in the first three trials, i.e. woodchips or straw, which provided spaces within the piles for evenly distributed aeration. The rapid increase in temperature also indicated that the available OM and nitrogenous compound decomposed gradually and were utilized by microorganisms. Only Trial 4 reached the stage (>50 °C) after a week of composting as shown in Figure 2(d).

The rapid increase in temperature corresponds to the observation made by Haug (1993) that the thermophilic phase (>45 °C) must be reached within hours or days in a well monitored composting process. The maximum temperatures reached in Figure 2(a)–2(d) were 60.6, 63.0, 60.1 and 64.2 °C, respectively. Also, the periods of temperatures that were maintained above 55 °C were 11, 15, 10 and 16 days as shown in Figure 2(a)–2(d), respectively.

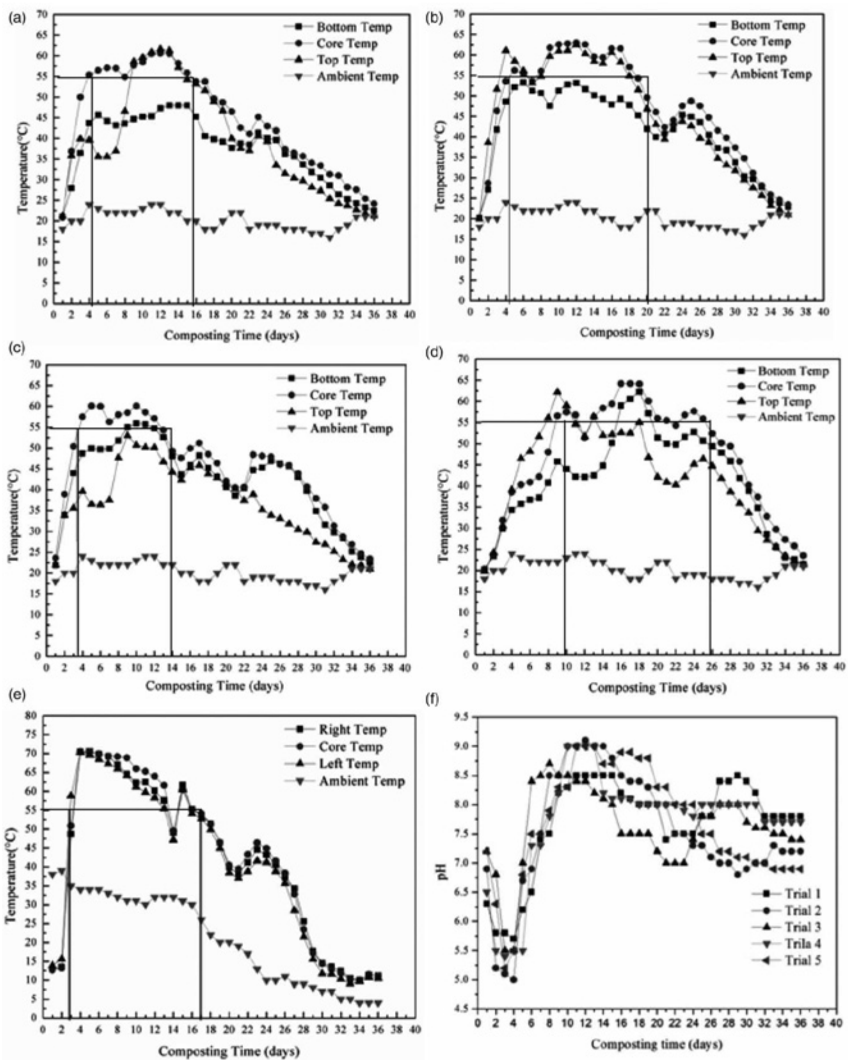

Figure 2 | (a) Temperature variation and composting time in time Trial 1 (F + SD + ST). (b) Temperature variation and composting in Trial 2 (F + W + ST). (c) Temperature variation and composting time in Trial 3 (F + SD + W). (d) Temperature variation and composting time in Trial 4 (F + SD). (e) Temperature variation and composting time in Trial 5 (F + SD + ST + F). (f) pH against composting time in all the trials. F, feces; SD, sawdust; ST, straw; W, woodchips; F, food waste.

Furthermore, in the case of Trial 4, which took 1 week to reach the thermophilic phase, the delay was probably caused as a result of there being no larger particles to create more space for adequate aeration, and also, the fact that the sawdust used was from pine trees that contain high acidity level and lignin content, which are not easily digestible by the microorganisms. After the active phase of the process, microbial activities decreased as a result of the decrease in OM and thereby led to a decrease in temperatures to ambient on 36th day.

Turning ensures pathogens die off throughout the entire mass of compost. For every weekly turning, there was a slight increase in the temperatures across all the piles. If only the center of the piles reach thermophilic phase, turning becomes imperative to ensure all parts of the piles are well sanitized. In accordance with most international standards on compost guidelines, all of the four trials met the sanitation requirements, such as the Canada standard (55 °C for 3 days, In-vessel; 3 days, aerated static pile; 15 days, Windrow) (CCME 2005), United States standard (55 °C for 5 days, In-vessel; 15 days, Windrow) (U.S. Environmental Protection Agency 1993) and WHO (50 °C $\geq$ 1 week) (WHO 2006).

Greenhouse technology

In this trial, sensors were placed horizontally at the center of the pile and temperatures were logged as shown in Figure 2(e). The ambient temperature inside the GH dropped from 39 to 4 °C as there was a corresponding drop of outside temperature from 15 to −20 °C, respectively, at the end of the trial. At the fourth day of the composting process, the temperature reached 70 °C; this high temperature could either be influenced by the ambient temperature of the GH or the easily digestible carbon source that was added, i.e. food waste. Also, such a high temperature within a few days could be a result of monitored pH and moisture content; arrangement of the pile's structure for adequate aeration and available nutrients during the process. The temperatures above 55 and 65 °C were maintained for 2 weeks and 8 days, respectively, which satisfies all the sanitation requirements including the German standard. After 2 weeks of composting with declining temperature, the pile was turned to ensure other parts were exposed to high temperature. After turning, the temperature rose back to 65 °C and gradually fell as the outside temperature dropped below 0 °C. The sufficient high temperatures obtained in this trial were in line with observations made by Germer *et al.* (2010) that mixing of food waste into feces provides easily digestible carbon to the microbes and thus maintained a high temperature for a longer period of time.

pH

pH is one of the chemical parameters that affects the composting process (Haug 1993), i.e. it affects the growth response of microbial activities. The microbial decomposition began after the piles were formed, and a gradual increase in temperature was observed. At the initial stage of the process, pH dropped from 6.8 ± 0.5 to 5.0 across all the trials, as shown in Figure 2(f). This was due to the bio-oxidative action of the microorganisms, i.e. formation of volatile fatty acids and carbonic acid, which could lower the pH of the piles, thereby increasing the growth of fungi and degradation of lignocelluloses substance.

When the acidification phase was over and the intermediate metabolites were mineralized, i.e. degradation of organic acid compounds, pH tended to increase with increasing temperature during the thermophilic phase, which led to ammonia volatilization. In all the trials, the measured pH values across the piles ranged from 5.0 to 9.2. High ammonia volatilization was observed in all the trials, which could be a result of the high concentration of nitrogen contained in Mongolians' urine, weekly turning of the piles, or mineralization of organic nitrogen. However, as observed by Haug (1993), for optimum decomposition and mineralization by microbial activities, pH should be within the range of 5.5–8.5. Therefore, since on the last day of the process the pH values ranged from 6.9 to 7.7, this showed that all the pH values at the end of the experiments were within the suggested optimum range.

Potential application of fecal compost

On a yearly basis, more than 200 million tons of human excreta are indiscriminately discharged into the environment without proper collection and treatment (UNDP 2008). According to research findings, if these tons of fecal matter are properly collected, 22% of the global phosphorus demand could be derived from fecal matter (Mihelcic *et al.* 2011), while 33% of the nitrogen could be recovered (WHO 2006).

Fecal compost is applied as an organic amendment to improve the physical, chemical and biological properties of the soil. The perception of fecal matter application is gradually changing, especially in developing countries such as China and some other Asian countries (Mackie Jensen *et al.* 2008). However, applying fecal compost on soil to boost food production is still unacceptable among some residents of the studied areas (ACF document not published). This is not because some people do not realize the potential in fecal compost but because having a quality assurance on the final products (i.e. free from pathogens) is a major concern. Consequently, this has narrowed the acceptance and willingness-to-pay for the compost, and hence it hinders its marketability.

CONCLUSIONS

These trials focused on how to solve peri-urban sanitation problems holistically in a sustainable way. To maintain high temperature, there is need for an easily digestible carbon source like food waste which can maintain the thermophilic phase of the process for a longer period. The GH was used not only to replace the CF based on economic aspects but also to harness the natural heat generated inside the structure, and to extend the period of the composting cycle (twice) within a year. The temperature increased up to 70 °C in GH as a result of the technology used, the easily digestible carbon that was added, and the arrangement of the slot for proper aeration across the pile.

RECOMMENDATIONS

There is a need for strong social marketing in order to break the barrier of sociocultural beliefs and taboos that are associated with fecal compost and urine application. People need to change their perceptions toward fecal matter; it should be viewed as a valuable resource, not as waste to be discarded.

ACKNOWLEDGEMENT

These research findings were conducted under a PhD research project that was fully financed and supported by Action Contre la Faim (ACF) France, in collaboration with the University of Science and Technology Beijing (USTB), China.

REFERENCES

Basandorj, D. & Altanzagas, B. 2007 Current situation and key problems on water supply and sanitation in Mongolia. In: *Strategic Technology, 2007. IFOST 2007. International Forum*, 3–6 October 2007, *Ulaanbaatar, Mongolia*, IEEE, pp. 166–168.

CCME 2005 *Guidelines for Compost Quality*. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

Esrey, S., Andersson, I., Hillers, A. & Sawyer, R. 2001 *Closing the Loop: Ecological Sanitation for Food Security. Publications on Water Resources No. 18*. 1st edn. Swedish International Development Corporation Agency, Mexico.

Germer, J., Boh, M. Y., Schoeffler, M. & Amoah, P. 2010 Temperature and deactivation of microbial faecal indicators during small scale co-composting of faecal matter. *Waste Management* **30** (2), 185–191.

Greenberg, A. E., Clesceri, L. S. & Eaton, A. D. 1992 *Standard Methods for the Examination of Water and Wastewater*. APHA-AWWA-WPCF, Washington, DC.

Haug, R. T. 1993 *The Practical Handbook of Compost Engineering*. Lewis Publishers, Boca Raton, Ann Arbor.

Mackie Jensen, P. K., Phuc, P. D., Knudsen, L. G., Dalsgaard, A. & Konradsen, F. 2008 Hygiene versus fertiliser: the use of human excreta in agriculture – a Vietnamese example. *International Journal of Hygiene and Environmental Health* **211**, 432–439.

Mihelcic, J. R., Fry, L. M. & Shaw, R. 2011 Global potential of phosphorus recovery from human urine and feces. *Chemosphere* **84** (6), 832–839.

National Statistic Office of Mongolia 2010 *Mongolia Statistical Yearbook*. NSO Press, Ulaanbaatar.

Novozamsky, I., Houba, V. J. G., Eck, R. V. & Vark, W. V. 1983 A novel digestion technique for multi-element plant analyses. *Communications in Soil Science and Plant Analysis* **14**, 239–248.

Said-Pullicino, D., Erriquens, F. & Gigliotti, G. 2007 Changes in the chemical characteristics of water-extractable organic matter during composting and their influence on compost stability and maturity. *Bioresource Technology* **98** (9), 1822–1831.

Sigel, S., Altantuul, K. & Basandrorj, D. 2012 Household needs and demand for improved water supply and sanitation in

peri-urban ger areas: the case of Dharkhan, Mongolia. *Environmental Earth Sciences* **65**, 1561–1566.
UNDP 2008 United Nations Development Programme on Ecological Sanitation. http://esa.un.org/iys/docs/un%sanitation%brochure.pdf (accessed 20 November 2013).
U.S. Environmental Protection Agency 1993 *Standards for the Use or Disposal of Sewage Sludge (40 Code of Federal Regulations Part 503)*. U.S. Environmental Protection Agency, Washington, DC.
WHO 2006 *Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 4: Excreta and Greywater Use in Agriculture*. WHO, Geneva.
WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation 2013 *Progress on Sanitation and Drinking Water. 2013 Update*. WHO Press, Switzerland.
World Bank 2004 *Environmental Challenges of Urban Development: Mongolia Environment Monitor*. World Bank Press, Washington, DC.

First received 4 May 2014; accepted in revised form 12 October 2014. Available online 19 November 2014

3. WATER, SANITATION AND HYGIENE SERVICES BEYOND 2015: IMPROVING ACCESS AND SUSTAINABILITY

TRADITIONAL CLOSED-LOOP SANITATION SYSTEMS IN PERI-URBAN AND RURAL AFGHANISTAN: A SWOT ANALYSIS

38th WEDC International Conference, Loughborough University, UK, 2015

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BRIEFING PAPER

The closed-loop-sanitation-system (CLSS), or sustainable sanitation system, has accelerated in recent years and been successfully implemented in many parts of the world. This study explored the strengths, weaknesses, opportunities, and threats (SWOT) of the traditional CLSS (T-CLSS) in both peri-urban and rural contexts within three different provinces in Afghanistan, the first study of its kind in this country. Participatory research tools such as transect walks, focus group discussions, and interactive workshops have been applied to assess the SWOT components of T- CLSS. The results show that T-CLSS is practiced historically in both peri-urban and rural areas by different generations using local and traditional knowledge, skills and technologies. Socio-cultural acceptance of the system is considered as one of the strengths in both rural and peri-urban areas. It is highly recommended that the feasibility of improved CLSS be assessed and implemented in the light of the T-CLSS system.

Introduction

The closed-loop-sanitation-system (CLSS) or sustainable sanitation system has been successfully implemented in many parts of the world with systematic means (improved technical and non-technical) in both cold and temperate regions. The principles of this system are to improve the overall water, sanitation and hygiene (WASH), health and environmental situation and to recover resources/nutrients from organic waste streams, particularly from human faeces (Esrey et al., 2001; Uddin et al., 2012; Uddin et al., 2014a, b, c; Uddin et al., 2015).

In Afghanistan, including in urban centres like Kabul and Kandahar, human excreta from dry toilets is applied directly to the agricultural fields without any specific treatment (Patinet, 2012). No systematic research can be found in either scientific or grey literature exploring the existing situation of this traditional practice in both peri-urban and rural contexts and evaluating the efficiency, relevance and sustainability of this kind of traditional closed-loop-sanitation-system (T-CLSS). This study was therefore conducted in Afghanistan in Action Contre La Faim (ACF) Afghanistan's programme intervention areas to examine the strengths, weaknesses, opportunities and threats of the existing T-CLSS with the objective of improving design and plans for future developmental programmes. It may help to improve the existing system in terms of safety, risk reduction for both environment and humans, productivity, market and job creation based on each local context. It can also contribute to finding a sustainable and efficient way of addressing the huge problem of excreta disposal and management in big, often poorly structured, urban centres.

Materials and Methods

Study Area

This study was conducted during the period of January and February 2015 in five different villages across three provinces in Afghanistan (Table 1) where ACF Afghanistan runs WASH, food security and livelihoods, and nutrition programmes. This study was one of the components of the objectives concerning the scope of replicating improved CLSS (Uddin et al., 2015) and knowledge dissemination from the Mongolian research project jointly executed by ACF Mongolia and University of Science and Technology Beijing and funded by ACF International France.

Table 1. Study locations and demographic information

Village, District and Province	No. of Families	Population	No. of Toilets	Type of Toilet (Traditional)
Yousuf Bangi, District 13, Kabul (Peri-urban)	328	2,624	328	Vault with urine diversion
Tangi-e-Yaqub, Dar-e-Suf Bala, Samangan (Rural)	244	1,500	200	Vault
Chobaki Payan, Dar-e-Suf Payan, Samangan (Rural)	250	1,500	250	Vault
Mashi wa Nigeri, Dehdadi, Balkh (Rural)	1000	7,000	1,000	Vault
Deh Hassan, Khulam, Balkh (Rural)	220	1,087	40	Vault

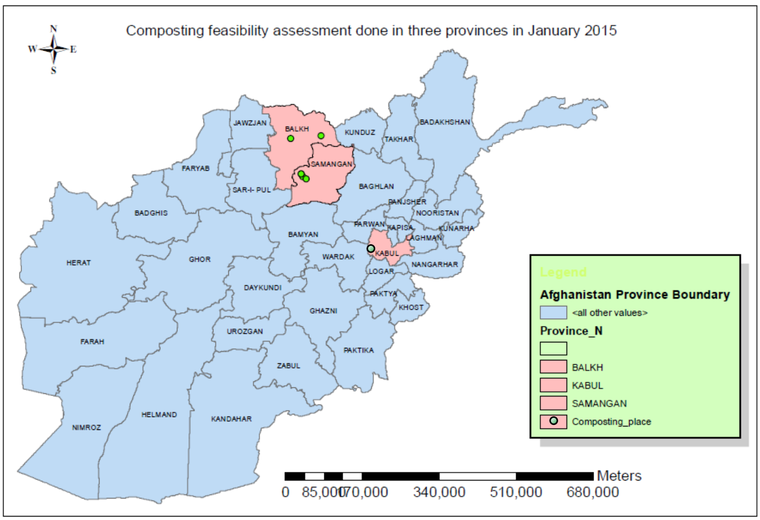


Figure 1. Study locations

Strengths, weaknesses, opportunities and threats analysis

This study applies SWOT as a research tool in the study area. Qualitative field investigations, such as transect walk, focus group discussions (FGDs), and interactive workshops were conducted to address the components of the SWOT analysis.

Transect Walk

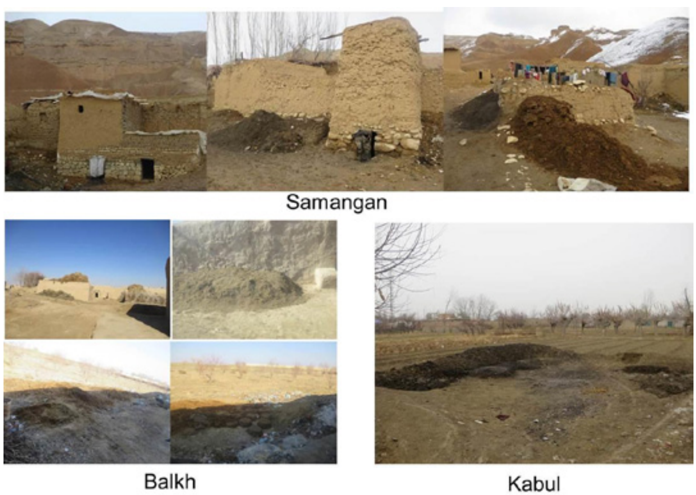
Five transect walks were chosen for visual observations in five villages to identify the compost locations, land application of the compost, their technological interventions, toilet situation, and transportation of faecal matter to the land. Photographs were taken during the transect walks to provide image-based scenarios of the T-CLSS for analysis.

Focus group discussion

Five focus group discussions (FGD) were organised in five villages to assess the existing situation and address the key SWOT components. Farmers, community leaders, elders, the mullah (religious leader), teachers, community development counsel (CDC) members and other villagers were the participants of these focus groups. Each FGD consisted of 10-20 people (primarily men, who are mainly responsible for T-CLSS activities) for spontaneous discussions on previously designed open questions based on T-CLSS in their areas. ACF WASH and FSL (food security and livelihood) team members communicated with the participants to support the principal investigator in translating and facilitating the whole discussion. All FGDs were recorded using audio recorders and analysed by double-checking afterwards.

Interactive workshops

Small (10 ACF participants) and large (25 participants including other stakeholders) interactive workshops (IWs) were organised (e.g. Skapetis and Gerzina, 2012). Open questions were asked during the IWs based on the research objectives of getting to know the overall SWOT components and validating the information collected from the fields. The information were presented in tabular format to the comparative scenarios of the SWOT components for both peri-urban and rural areas.



Photograph 1. T-CLSS practices in three different provinces

Results and discussions

Existing T-CLSS situation

Most of the toilets in the peri-urban context are urine-diverting vault toilets, and in rural areas all of the toilets are traditional vault toilets without urine diversion. Most of the toilets in the peri-urban area are emptied by local farmers who apply faecal compost to their land, and in rural areas toilets are emptied by each household and also applied to their own land for agro-productions. In most cases, faecal matter is transported by either donkey, horse or humans (particularly adult men). The marketing system for selling the agro-products in the local markets was seen only in peri-urban areas. In the case of rural areas, farmers consumed the agricultural products produced by faecal compost themselves.

Strengths

Table 1 shows the SWOT components of the T-CLSS in both peri-urban and rural contexts in Afghanistan. Results from FGDs and IWs for the peri-urban area of Kabul and rural areas reveal several T-CLSS strengths. One of the major strengths is the socio-cultural acceptability of the system over hundreds of years, particularly the positive approach to dealing with faecal matter and consuming the agro-products produced by faecal compost, rarely seen in many other parts of the world, especially in the contexts of peri-urban settlements (e.g. Mongolia) (Uddin et al., 2015) and in Muslim communities in Pakistan (Nawab et al., 2006). In peri-urban area, a total number of 58 farmers have been running the system throughout the year by collecting faecal matter from traditional urine-diverting vault toilets in the village and also from outside villages to fulfil the demand for agricultural productions and of local markets. The majority of farmers are not interested in using chemical fertilizers due to the negative impacts on their land and prefer organic compost, particularly the fertilizers produced by faecal matter. Between 300-500 Afghani/ 5-9 USD is paid by households to the farmers for each emptying operation, which represents another strength, with the establishment of businesses at the local level. In rural areas, most villagers have their own land where they can apply traditional faecal compost to close the loop of traditional sanitation system. The farmers and communities are in favour with improving the existing system. However, they were not being able to improve the system due to lack of technical knowledge and availability of funding.

Weaknesses

Several weaknesses were found (Table 1) during the FGDs and IWs in both peri-urban and rural areas. Little/no funding and lack of capacity (technical and non-technical) were found to be the major weaknesses in both rural and peri-urban contexts. Not a single co-operative exists in either area for developing and running the systems properly and generating local funds. In Afghanistan, no policy or regulation exists on human faeces composting or its application, which can be also considered as a weakness for T-CLSS. The existing system needs a long time (average of 1 year) to mature the compost and for application. There is no application during the winter, and it has been also revealed that the composting process was not done properly before application in both peri-urban and rural areas. It may increase the risks of faecal contaminations of both soil and streams where they get drinking water and product agricultural products. In peri-urban area some farmers still face land scarcity for continuing agricultural production by the faecal compost. On the other hand, communities in rural area have sufficient lands for their production.

Opportunities

There was a list of opportunities identified during the FGDs and IWs. Good quality agro-products can be produced by faecal compost in both peri-urban and rural areas. There are some business and job opportunities created due to the existing system, particularly in the peri-urban context. Results also show that the urine separation system might be possible to introduce in rural areas to reduce the load of work and to decrease the heavy dilation and mixing of urine and faces, as currently there is no urine separating toilet system in the rural areas. The evidence from existing system may catalyse to advocate government and related stakeholders for improving the system and to reduce the T-CLSS-borne risks and hazards.

Threats

There were very few threats raised in both peri-urban and rural areas. One of the major threats is the health and environmental risks of the T-CLSS transmitting water-borne diseases and environmental contaminations. There was strong possibility of contamination of the streams alongside the villages in rural areas where almost everyone collects water for drinking and other purposes. Unsafe handling of faecal matters during emptying, collection, transportation, and application presents the potential risk of infections and contamination of food and the environment. Application of chemical fertilizers was also considered as one of the threats, particularly in rural areas due to insufficient and incorrect organic and faecal compost.

Table 1. SWOT on T-CLSS in peri-urban and rural Afghanistan

Peri-Urban	Rural
Strengths	
• Socio-cultural acceptance of faecal matter application. • A good number of farmers using this system. • Demand of marketable products produced by faecal matter both in local and city central markets.	• Socio-cultural acceptance of faecal matter application. • Almost every household has been using the existing system for hundreds of years. • People are interested in improving the system.
• Non-interest in chemical fertilizers. • Existing historical system; introducing a completely new system, rather than improving the existing system, is not required at the moment. • Higher production by T-CLSS than low-quality chemical fertilizers. • Farmers' interest in improving the system. • Availability of agricultural land among farmers. • Customers know the faecal matter products. • Faecal matter is available in sufficient quantity and they also receive money from the community.	• Most of the people have their own farming land where they can apply faecal compost. • A new pit system has been introduced during the last two years. • Equal production compared with chemical fertilizers. • Interested in coordinating with NGOs/institutions. • Interest in creating co-operatives among the farmers using the system.
Weaknesses	
• Lack of funding and capacity to improve the system. • Lack of policy and regulation. • Lack of skilled human resources and lack of technical knowledge on the system. • Lack of technology innovation. • Little/no support/subsidies/actions from central or local government. • No farmer co-operatives exist in the area and they are not organised for the existing system. • Not enough production based on demand. • Some farmers still face land scarcity.	• Traditional compost is not sufficiently available. • The existing system takes more time (almost 1/2 year) to build up the compost. • No cooperatives, no interest in a large group to manage faecal composting. • Lack of funding and capacity to improve the system. • Lack of policy and regulation. • Lack of skilled human resources and lack of technical knowledge on the system. • Lack of technology innovation. • Little/no support/subsidies/actions from both central and local government and NGOs to improve the system. • No application during winter.
Opportunity	
• Job and business creation through existing system marketing and technology innovation. • Interest in creating co-operatives among the farmers using the system. • Production of good quality ago-products by using the existing system rather than chemical fertilizers. • Advocacy for clear regulation and policy interventions by the government. • Development of traditional and improved CLSS. • Application of urine for agro-production. • Income generation.	• Production of good quality ago-products by using the existing system rather than chemical fertilizers. • Advocacy for clear regulation and policy interventions by the government and NGOs. • Development of the traditional system into improved CLSS. • Possibility of improving soil fertility. • Urine-separation system can be developed for land application. • Income generation.
Threats	
• Health risks due to transmitting infectious agents and pathogens during traditional CLSS. • Environmental threat (especially to aquifers). • Climatic condition. • Complaints in neighbourhoods due to the bad smell in the areas concerned. • Land will be decreased because of migration from rural areas to Kabul city. • Future plan for septic tanks due to modernisation can impact household budgets.	• The streams where they collect water might be affected by this system. • Health risks due to transmitting infectious agents and pathogens during traditional CLSS. • Climatic condition. • Application of chemical fertilizers.

Conclusions

Participatory research tools have been used to analyse the SWOT components for the T-CLSS in peri-urban and rural Afghanistan. The results show that T-CLSS is socio-culturally acceptable in both rural and peri-urban areas of Afghanistan and it can be considered as one of the strengths for future improvement and replication of the system. There are opportunities and interests to develop new system and improve the existing system to reduce the threats of improper dealing with human feces. Therefore, it is highly recommended that the feasibility of improved CLSS be assessed, taking into account the T-CLSS in terms of its socio-technical, economical and institutional aspects. As the overall quality of soil in Afghanistan is poor in terms of low organic content, unavailability of nutrients, higher pH and calcium carbonate, and low water-holding capacity (UCDAVIS, 2013), faecal compost might improve the quality of soil if properly produced and applied. Alternatively, it might be possible to apply urine after separation to the agricultural fields, an option that might need to be explored with proper scientific and social research.

Acknowledgements

Support from ACF France, ACF Mongolia and ACF Afghanistan is gratefully acknowledged.

References

Esrey, S. A., Andersson, I., Hillers, A. and Sawyer, R. (2001) *Closing the loop: ecological sanitation for food security.* Publications on Water Resources No. 18, Swedish International Development Corporation Agency, Mexico.

Patinet, J. (2012) Dry toilets in urban crises: the case of Kabul, 4th International Dry Toilet Conference, 22-24 August, 2012, Finland.

Nawab, B., Nyborg, I.L.P., Esser, K. B. and Jenssen, P. D. (2006) Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan, Vol. 26, No. 3, pp. 236-246.

UCDAVIS (2013) Afghan agriculture - soils. Website: http://afghanag.ucdavis.edu/natural-resource-management/soil-topics (accessed February 2015).

Uddin, S.M.N., Li, Z., Ibrahim, M. B., Lapegue, J., Adamowski, JF., Donati, P. F., Huba, EM, Mang, HP., Avirmed, B. and Cheng, S. (2015) *Perspective evaluation of 'Closed-loop-sanitation-system' in a country with cold climate: a case from Ulaanbaatar, Mongolia.* Environment and Urbanization. (In Press).

Uddin, S.M.N., Li, Z., Mang, H. Huba, E.M., and Lapegue, J. (2014a) *A strengths, weaknesses, opportunities and threats analysis on integrating safe water supply and sustainable sanitation systems.* Journal of Water, Sanitation and Hygiene for Development, Vol. 4, No. 3, pp. 437-448.

Uddin, S.M.N., Muhandiki, and Sakai, A., Mamun, A. A., and Hridi, S. M. (2014b) *Socio-cultural acceptance of appropriate technology: identifying and prioritizing barriers for widespread use of the Urine Diversion Toilets in Rural Muslim Communities of Bangladesh.* Technology in Society, Vol. 38, No. C, pp. 32-39.

Uddin, S.M.N., Li, Z., Gaillard, J. C., Tedoff, P.F., Lapegue, J, Mang, H.P., Huba, E.M. Kummel, O., and Rheinstein, E. (2014c) *Exposure to WASH-borne hazards: A scoping study on peri-urban Ger areas in Ulaanbaatar, Mongolia.* Habitat International, Vol. 44, pp. 403-411.

Uddin, S.M.N., Muhandiki, V.S. Fukuda, J. Nakamura, M. and Sakai, A. (2012) *Assessment of Social Acceptance and Scope of Scaling Up Urine Diversion Dehydration Toilets in Kenya*. Journal of Water, Sanitation and Hygiene for Development, Vol. 2, No. 3, pp. 182-189.

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1. OPPORTUNITIES AND CHALLENGES FOR GREYWATER TREATMENT AND REUSE IN MONGOLIA: LESSONS LEARNT FROM PILOTED SYSTEMS

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ABSTRACT

In Mongolia, as worldwide, communities are challenged by water scarcity, depletion and pollution. Greywater treatment and reuse could partially meet water demand and help protect the environment and health. In March 2010, greywater from six randomly sampled households in the Ger areas of Ulaanbaatar, Mongolia, was analyzed followed by the development of three innovative treatment systems: an underground (UG-), greenhouse (GH-) and ice-hole greywater treatment unit (IH-GWTU). The UG- and GH-GWTU were implemented to identify opportunities and challenges for future investments in greywater treatment and reuse. Users' and non-users' perceptions, and business opportunities, were assessed. Laboratory analysis showed a high chemical oxygen demand (6,072–12,144 mg/l), N-NH_4^+ (183.7–322.6 mg/l), PO_4^- (12.6–88.2 mg/l) and total suspended solids (880–3,200 mg/l) – values exceeding the WHO guidelines and much higher than in any other country: low water consumption combined with traditional diet might be major reasons. Odourless and colourless water after treatment in a UG-GWTU lead to more acceptance than a GH-GWTU. Business opportunities include the use of treated water for irrigation, considering WHO and national standards. Further research focuses on seasonality of installation, technical shortcomings, maintenance, biological quality control and user training.

Key words | Ger area, greywater treatment, groundwater pollution, peri-urban areas, reuse, water scarcity

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INTRODUCTION

Global water stress and scarcity, depletion and pollution in high, middle and low income countries have been addressed in many studies (see for instance, Postel 2000; Exall *et al.* 2006). A growing number of contaminants are entering water bodies due to anthropogenic activities (Montgomery & Elimelech 2007), which may dramatically reduce the amount of potable water on earth. Greywater definitions and characteristics are well documented in a range of studies (see for instance, Jeppesen 1996; Ghaitidak & Yadav 2013); treatment and reuse can be one potential option to solve the problem of reuse for different purposes which are the source of a large portion (50–80%) of domestic wastewater generation (Li *et al.* 2003; Abusam 2008). Jeppesen (1996) revealed that 30–50% water can be saved at household level, if all greywater is reused after some sort of treatment. Various alternative treatments and solutions are proposed to control the physical, chemical and microbial risks of reusing greywater, as well as for non-potable use in both industrial and non-industrial sectors (Li *et al.* 2009; Chen *et al.* 2013a, 2013b). During the past decades greywater has dramatically gained attention for treatment and reuse in countries with different climatic patterns (including cold regions) in order to tackle water shortage, minimize health hazards, conserve the environment and

doi: 10.2166/wrd.2014.008

reduce environmental risks (Jeppesen 1996; Jenssen *et al.* 2005; Domenech & Sauri 2010). There might be various challenges to treat and reuse greywater in various climatic zones (see for instance, Exall *et al.* 2006). To fulfil the global water demand and to secure and ensure a safe water supply, a range of alternatives are needed to treat and reuse recyclable water in terms of numerous factors such as economic viability, technological suitability and adaptability, socio-cultural acceptability, political stability and institutional capability.

Mongolia, where this study was conducted, claims the coldest capital in the world, with an annual mean temperature of $-3.7\,^{\circ}$C (Hauck 2008). The country has one of the lowest rates of access to improved sanitation and major parts of the population rely on only very poor quality water (UNICEF 2010). The country faces numerous natural disasters such as drought, heavy rainfall, flood, snow and storms, and extreme cold and heat (Batimaa *et al.* 2010), which without doubt have a great impact on water resources, either directly or indirectly. Ulaanbaatar, the capital of Mongolia, has a population of over one million and is experiencing many environmental, health and socio-economic problems (World Bank 2010; Nriagu *et al.* 2012). Sixty percent of the total population of Ulaanbaatar reside in peri-urban informal settlements, called Ger areas. A lack of safe water supply and unimproved sanitation have been found to be the key issues in the Ger areas of Mongolia where simple, unimproved and unventilated pit latrines (UNICEF 2010; World Bank 2010; Sigel *et al.* 2012) and soak pits are generally used for on-site sanitation and household greywater, resulting in unhygienic living conditions. Water in the Ger areas is mainly provided by over 550 public water kiosks where the average water consumption is 10 litres/person/day (l/p/d) (World Bank 2010).

Mongolia is one of the 60 countries in the world with limited water resources, significantly lower than the world average (Batimaa *et al.* 2010). Additionally, both surface water, for example the Tuul River, and groundwater quality is degrading due to numerous anthropogenic activities (Batsaikhan *et al.* 2011; Nriagu *et al.* 2012). It has been projected by the CSIRO-Mk2b model of the Tuul River that water resources will decrease by up to 25% by 2080 due to climate change impact (Batimaa *et al.* 2010). Limited capacity in water resources and their treatment, and the limited sewerage system have been identified as major constraints for increased demand in future (World Bank 2010). Moreover, Mongolian water resources are under threat of climate change and rapid urbanization with over 50% of the population facing challenges to obtain access to clean water (Batimaa *et al.* 2010). Surface water is iced for over half the year during the long winter and underground water is polluted by uranium in some areas of Ulaanbaatar (Nriagu *et al.* 2012). Protection of existing water resources is urgently required, such as treatment and reuse of greywater for non-potable purposes at the household level, in order to cope with water demand and to overcome (to some extent) water-related challenges in the future. This study is the only study on household level greywater treatment and reuse in Mongolia in the literature, and was conducted jointly by a team from the University of Science and Technology Beijing (USTB) with the field cooperation of Action Contre la Faim (ACF) Mongolia, funded by ACF International under a research project on 'sustainable sanitation for the vulnerable peri-urban population in Ulaanbaatar, Mongolia' since 2011 in the Ger area of Ulaanbaatar. It identifies possible opportunities and challenges for treatment of greywater and the ensuing reuse options. The perceptions of both users and non-users on greywater treatment and reuse were assessed for the future acceptability and scale up of the technology.

MATERIAL AND METHODS

Study area and site selection

The study area was made up of the peri-urban Ger areas, informal and unplanned settlements, which surround Ulaanbaatar City in Mongolia. Figure 1 shows the study area map.

From 17 pre-selected sites, 13 sites were evaluated as potential sites for the installation of model greywater treatment units (GWTU) based on several criteria, for instance, availability of space, people's interest, technological suitability and opportunity to reuse the treated greywater on or nearby the compound. Some households were already participating in the water, sanitation and hygiene programme of ACF Mongolia. Other sites were visited by request of the owners who contacted ACF staff during an

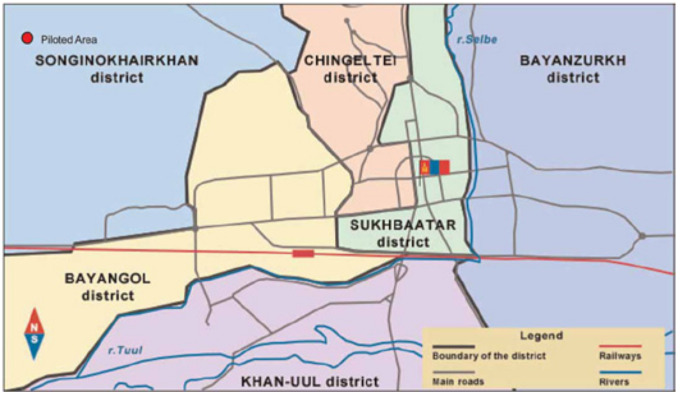

Figure 1 | Ulaanbaatar city and study area.

information session in the community. The most suitable compounds were selected from those sites to pilot two of the proposed greywater treatment units. The following criteria were applied to 'scout' potential GWTU sites for on-site greywater treatment: (1) activities that require water usage thus providing opportunities for reuse of treated greywater; (2) compounds with a number of trees, already installed greenhouses and/or gardens. While on-site treatment of greywater generates a reasonable amount of water for reuse, off-site treatment of greywater – based on the collected amount of greywater from several households – requires large-scale reuse opportunities such as in tree nurseries, on agricultural farms or golf courses.

Sample collection and laboratory analysis

The USTB team distributed six barrels, each of 60 litre volume, to collect greywater samples from six randomly sampled households in the Ulaanbaatar Ger area. The analysis was carried out at the USTB laboratory in Beijing, China, in March 2010 to get to know the characteristics of household greywater in the Ger areas. The methodology of analysis followed the relevant ISO standard. The samples from this mixed household greywater contained hand-washing, kitchen and laundry greywater. Each of the six sampled households collected its mixed greywater for one entire day in the 60 litre bin. Table 1 shows the samples collected from the six households.

Model development and piloting

Three different concepts and technical models of greywater treatment were developed by USTB and ACF Mongolia considering the high concentration of greywater and extreme cold climatic conditions. These concepts and models include an underground greywater treatment unit (UG-GWTU), a greenhouse greywater treatment unit (GH-GWTU), and an ice-hole greywater treatment unit (IH-GWTU) (Figure 2). Two of them were applied at

Table 1 | Socio-economic data of Ger area households who supplied the greywater samples

Barrel Number	Number of Children	Number of Family members	Washing Machine	Volume of Greywater Sample (litres)	Laundry Water Included
1	4	10	Yes	30	Yes
2	4	7	Yes	20	No
3	2	5	Yes	30	No
4	2	4	Yes	20	No
5	2	5	Yes	20	No
6	3	11	Yes	40	No

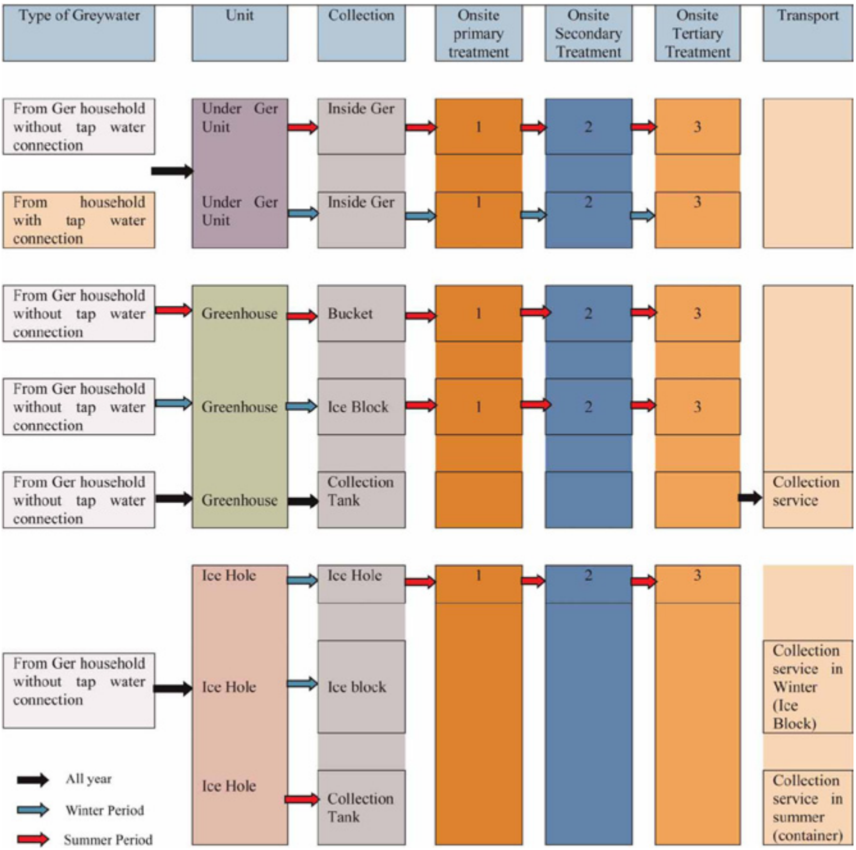

Figure 2 | Flow diagram of the three greywater systems (*Source:* Adopted from Schüßler 2011).

pilot scale in 2011 in Ger households to identify opportunities and challenges for future investments in greywater treatment and reuse options in the Mongolian context. The household owners, where the two units were piloted, and the concerned ACF staff were trained to carry out the piloting, operation and maintenance of the treatment units. The household owners were the key stakeholders and responsible for running the units to obtain more practical knowledge in the operation and maintenance of the units. The three models are described below.

Underground greywater treatment unit

Greywater is poured into a sink inside the Ger or the house. Below the sink a fat trap with screen is installed to retain fat and impurities. The screened greywater flows into a septic tank, which is located in an insulated chamber under the Ger or the house. Remaining fat and solid particles are retained. The pre-treated water leaves the septic tank towards a secondary treatment step, which is a vertical flow filter or an anaerobic filter. For the tertiary treatment step a slow sand filter, vertical flow filter or an anaerobic filter is recommended. A storage tank collects the treated effluent water, which could then be used for irrigation. As an option, a percolation bed could be installed below the chamber to recharge groundwater during wintertime when the treated water cannot be used or stored on site. The fact that the chamber is located under the Ger or house leads to positive temperatures inside the chamber throughout the whole year, and prevents the treatment unit from freezing during winter. Effluent water can be used for irrigation in summer; during winter the effluent water could be stored in the form of ice; so a huge amount of water will be on hand in springtime. It is also part of the pilot phase to empower GWTU users to handle the different treatment techniques: as the composition of the greywater is not 100% specified, the maintenance activities and intervals cannot as yet be specified in detail. From time to time, users of GWTU have to take sludge out of the septic tank and sand filter. Sludge can be taken to an on-site sludge drying bed where it is dried. Sludge could also be co-composted in an on-site compost pile.

Greenhouse greywater treatment unit

Greywater is supplied into the inlet of the treatment unit, where screening also takes place. The next step is a septic tank where solids and floating fat particles settle. After this pre-treatment in the septic tank, the greywater receives a secondary treatment in a vertical flow constructed wetland or an anaerobic filter. For the tertiary treatment, a slow sand filter is constructed. At the end of the treatment process, a tank is recommended for collection and storage of the effluent water, which can be used for irrigation. During winter it is not possible to achieve permanently positive temperatures inside the passive solar greenhouse so treatment is not possible. Therefore, it is recommended to store the raw greywater on site in the form of ice for 4 months (from December to March). When temperatures inside the greenhouse climb above 0 °C, greywater ice blocks are placed in the treatment unit where they melt and the liquefied greywater can be treated as described above. Effluent water can be used for irrigation.

An inside green house unit could be chosen if the soil is rocky thus making it difficult to dig. If the soil consists of gravel or scissile rock, the site might be considered for the construction of either an underground or an ice-hole unit design. Information about soil characteristics could be obtained by asking about the depth and the year of installation of the currently used pit latrine. Also, for winter greenhouse construction options, it is necessary to know the compound's West-East axis. Winter greenhouse construction may require changing the fence in order to minimize any shadow effect.

Ice-hole greywater treatment unit

The frozen greywater is brought to an insulated chamber which is installed underground, designed to receive a calculated amount of frozen greywater throughout the winter months. When outside temperatures climbs above 0 °C, the ice blocks are supplied to a treatment unit. The greywater melts and can be treated. The ice blocks inside the insulated chamber stay frozen until summer. During summer months, liquid greywater is applied directly to the treatment unit. The unit provides for an optional three-step treatment: (1) a septic tank for primary treatment; (2) a vertical flow constructed wetland or an anaerobic filter for secondary treatment; and (optional) (3) a slow sand filter for tertiary treatment. A collection and storage tank or pond is recommended to keep the effluent water for irrigation. Table 2 shows the hydraulic loading of major components of the three greywater treatment units.

Project evaluation

The project was evaluated by a team comprising USTB with the coordination of ACF Mongolia during the period of November and December 2012, in order to assess experiences and perceptions of users regarding both treatment units and reuse of greywater. Various business options and scopes for treated greywater utilization were also considered for future marketing of reusable greywater.

Questionnaires for semi-structured interviews were developed for the users of greywater, key informants and stakeholders to obtain data for this evaluation. An observational

Table 2 | Hydraulic loading of the major components of each treatment unit

Treatment unit	Component	Hydraulic loading	Unit
UG-GWTU	Grease Trap	Daily flow	60 l/d
		Retention time	0.5 d
	Septic Tank	Retention time	5 d
	Aerobic Filter	Max. loading/m^2	0.4 m^3
	Slow Sand Filter	Max. loading/m^2	0.4 m^3
GH-GWTU	Septic Tank	Daily flow	60 l/d
		Retention time	5 d
	Anaerobic Filter	Max. flow at peak hours	5 l/d
	Slow Sand Filter	Max. loading/m^2	0.4 m^3
IH-GWTU	Septic Tank	Daily flow	119.4 l/h
		Retention time	5 d
	Distribution Chamber	Times of loading	5 times/d
	Constructed Wetlands	Max. flow at peak hours	23.9 l/h
	Collection Chamber	Daily flow	119.4 l/d
		Size of chamber	119.4 l/d

investigation was undertaken to identify current problems in Ger areas regarding the related issues of greywater disposal systems, sanitary infrastructure and drainage systems. The results from the Knowledge, Attitude and Practice (KAP) household survey, conducted by ACF Mongolia at the end of 2012 within 210 households in the Ger areas were used as supplementary information about the opinions of both users and non-users on greywater issues. The cluster sampling method was applied, due to the large population size and scattered households in the intervention area, under which a statistical accuracy of 10% precision was preferred. Households were randomly selected for the survey in each residential cluster. Additionally, a market survey was carried out to assess various kinds of products of soap and detergents, which are used by the Ger area residents.

RESULTS AND DISCUSSION

Current situation

The results from the KAP survey among the households of the Ger areas show that 51.4% households have a soak-pit in their compound to discharge greywater and 40% of households pour greywater into their pit latrines. The other households discharge greywater onto the roads, in the yard or in other places. The practice of Ger residents for discharging their greywater into pit latrines, soak-pits, yards and on the open streets causes immediate environmental pollution and health hazards to the Ger inhabitants. The reasons for not having any disposal facility are the lack of space, rocky ground, limited time and human resources to deal with greywater and shallow groundwater. Field observation confirmed that there is no drainage system where greywater can be disposed of for any kind of treatment in the Ger areas. The Ger areas were not connected to any centralized or decentralized sewer system, a fact that forces them to practise uncontrolled greywater disposal to the environment. Public bath houses are equipped with contingency wastewater tanks that are emptied when full; the private operator of the bath house bears the cost for this service.

Disposal of greywater inside or outside the compound is a very common practice. Reason for this behaviour is the fact that in winter the greywater freezes in the pit latrine or soak pit and considerably reduces the effective volume of the pit. Therefore households pour greywater in the compound or on the street, causing considerable ice hazards. As people maintain the same attitude in the warmer months this may considerably degrade the environment and provide favourable conditions for vectors to breed (WHO 2006).

Greywater characteristics

The laboratory analysis shows (Table 3) a high concentration of chemical oxygen demand (COD) (range from 6,072 to 12,144 mg/l), N-NH_4^+ (range from 183.7–322.6 mg/l), PO_4^+ (range from 12.6–88.2 mg/l) and total suspended

Table 3 | Test results of greywater from six randomly sampled households

Sample	COD (mg/l)	N-NH_4^+ (mg/l)	PO_4^+ (mg/l)	pH	TSS (mg/l)
1	11,334	322.6	88.2	6.23	1,280
2	6,072	183.7	16.2	5.29	1,720
3	12,144	205.4	18.6	6.00	3,200
4	7,286	195.6	12.6	5.56	880
5	6,882	282.9	52.2	6.02	1,720
6	6,477	289.5	49.4	6.38	1,300

solids (TSS) (range from 880to 3,200 mg/l) which are much higher than in any other country (Li *et al*. 2003; Ghaitidak & Yadav 2013). The values are much higher than the values mentioned in the WHO (2006) guidelines (e.g. COD is 366 mg/l, TSS is 162 mg/l and N-NH_4^+ [1.7]mg/l). In addition, the average greywater generation in the Ger area households was 4 l/p/d with an average range of water consumption of 8–10 l/p/d (World Bank 2010). The greywater generation is much lower in the Ger areas than in other countries, such as 66 l/p/d in Jordan and 70 l/p/d in Germany (see, for instance, Li *et al*. 2003; Palmquist & Hanaeus 2005; Ghaitidak & Yadav 2013).

The results from the KAP survey among the residents of the Ger areas confirm that over 90% of households practise the intensive use of detergents for washing their clothes, dishes and other utensils. This non-point source of pollution may increase the potential risks of both underground and surface water contamination which leads to possible health hazards in the Ger areas of Ulaanbaatar (Carpenter *et al*. 1998; Batsaikhan *et al*. 2011). Moreover, this practice may threaten the water supply security (Wu & Chen 2013) in the study area. Limited water consumption (8 l/p/d during winter), same water usage for different purposes, higher/intensive usage of chemical detergents, diet and cooking methods that contain much fat, milk and oil, and modern lifestyle may be the major factors of this high concentration of greywater parameters in the Ger area. Some of these factors were also considered by Ghaitidak & Yadav (2013) as being highly influential on the characteristics of greywater.

The concentration of COD in mg/l has a correlation to the total amount of greywater per person, which is 4 l/d. This value confirms the assumption that about 40–50% of the freshwater delivered is available as greywater in the study area. The high phosphate content in sample No. 1 is due to the washing powder used for laundry purposes. Considering laundry services, one family could produce a fertilizer value of up to 1 kg of phosphate annually from nutrients contained in the greywater.

A market survey was carried out by Schüßler (2011) and showed that in Mongolia the major products of the soap and detergent industry include soaps, laundry detergents, dishwashing detergents, household-cleaning products, hair cleaning products and toothpaste. Laundry detergents account for 40% of the overall market, while soap accounts for 20% and dishwashing detergent for 15%. Laundry detergents come in powder as well as liquid form and may contain bleach additives or colour brighteners. Dishwashing detergents come in powder, liquid, gel and tablet form. Soap comes in bars or liquid form. These characteristics of chemical washing products may have a great influence on the high values of the chemical characteristics of greywater.

Currently the Mongolian government does not have rules or regulations in place that require listing ingredients of detergents on the label of the products. But the authorities that could take a lead in this field are already in place, among them being the General Agency for Specialized Inspection, the Centre of Standardization and Measurement, the Unfair Competition Regulatory Authority, the NGO Consumer Foundation, and the Mongolia Customs Agency.

Suggested greywater treatment units

Various types of greywater treatment systems have been addressed (Ghaitidak & Yadav 2013), which have been developed and piloted in many low, middle and high income countries. For this study, several facts were considered to establish sustainable and affordable greywater treatment systems in the Ger areas at household level. These include the cold weather: temperatures drop under $-40\,^{\circ}$C, freezing soil down to a 3.5 m depth during the months of November through to May (6–7 months per year) and no sewer connection, neither in the compounds nor in the streets in the near future. The greywater treatment units were developed based on the requirements to be convenient for maintenance, economically feasible and affordable for low income Ger residents, and technologically suitable under extremely cold climatic conditions. Additionally, the availability of construction materials for each greywater treatment unit (GWTU) was considered in order to facilitate its replication.

Underground greywater treatment unit

Field investigation revealed that some households have a storage chamber under their Ger or house where they keep vegetables during winter to protect them from freezing. These storage rooms maintain temperatures above freezing point. This space might reduce the cost of excavation for the installation of an UG-GWTU. The fact that the chamber is located under the residence leads to temperatures always above zero inside the chamber, and the GWTU could continuously operate throughout the year without any effect from cold temperatures.

Greenhouse greywater treatment unit

The GH-GWTU was identified as the technology option with the most advantages. However, this treatment option combined with an above ground storage tank was evaluated as not being practicable. The unit for a house with water connection seems to be practicable, but building a constructed wetland of 4 m depth causes concerns. The proposed GH-GWTU to treat greywater was modified according to the experience of the NGO GERES with passive solar greenhouses in Mongolia.

For any off-site treatment (greywater is not treated at the source of origin but 'centralized' in an indoor greenhouse unit) a collection service is requested to transport greywater from several households to the treatment unit. Part of the pilot phase is also to empower GWTU users to handle the different treatment techniques: as the composition of the greywater is not 100% specified, the maintenance activities and intervals could also not yet be specified in detail. From time to time users of GWTU have to remove sludge from the septic tank and sand filter. Sludge could be brought to an on-site sludge drying bed. Sludge could also be composted in an on-site compost pile. Fat can be burned on site together with solid waste (currently a common practice, although not really recommended) or could be used as fuel for the oven inside the Ger, if the stove is suitable and no liquid fat can drop out.

Piloting and evaluating the GWTUs

UG-GWTU

The summer period for construction is very short in Mongolia (June–October) and all types of construction have to be completed within this period. The UG-GWTU was set up for piloting during that period in 2011. The results from interviews with users show that the system was running without any problems for the first two months and then it was running slower until it clogged completely. The slow sand filter was identified as the component with the biggest blockage due to the high grease and fat content of the greywater. In October 2011, the UG-GWTU was dismantled and removed by the owner of the house. The chamber is currently being used as a storage room. The chamber underneath the house was warm enough to keep the water unfrozen even during the month of November when the temperature outside was recorded as $-39\,^{\circ}$C. Above that, smell and odour were mentioned to be intense from the system, but only towards the end of the operation of the system. No maintenance was applied except for removing grease two or three times per month, and cleaning the sink twice a month. The fat and grease were disposed of with the household garbage. Sludge was not recovered. To overcome the clogging, chemicals were applied, but no improvement resulted from that intervention due to lack of information about the adequate maintenance measures, as well as inadequate handling guidelines.

GH-GWTU

At the end of summer 2011 the installation of the GH-GWTU was completed by ACF. The system was running for around 1 month, but after 2 weeks it started to become clogged due to heavy grease and fat content. After 4 weeks the gravel filter and the slow sand filter were overflowing. The system was cleaned and emptied shortly after by the user, and then stopped running. Both filters were described to have a thick layer of sludge on top. In the end, water was overflowing from the system and a very strong smell developed. Even with the additional aeration that was installed afterwards, the smell was described to be so intense that it could be noted in the Ger next to the greenhouse. The owner decided finally to dismantle the unit. It should be mentioned that the owner was not provided with guidelines on maintenance apart from washing the gravel in the case of blocking. On clogging, the user cleaned the system, but even after this the outcome was described as unsatisfactory. The remaining grease and sludge was disposed of with the household garbage. The user expressed the view that the frequent cleaning of the unit (e.g. washing the gravel, etc.) was regarded critically since it takes a lot of work and time and involves a lot of effort.

The treatment capacity of both UG-GWTU and GH-GWTU is 60 litres/day. The average daily production of greywater is 20 litres/household which leads to an annual production to 7,300 litres/household. The systems are feasible in terms of greywater production at household levels. As the UG-GWTU can run throughout the year, there is no need to store the greywater during the winter period. However, greywater needs to be stored for the GH-GWTU during the extreme winter/freezing period.

Perceptions of users and non-users

The perceptions of greywater treatment and reuse options, except for some maintenance and technological issues, were well understood by 100% of users of greywater. Based on the physical characteristics of the treated greywater, the UG-GWTU was more acceptable than the GH-GWTU, because of the odourless and colourless water from the UG-GWTU. Although the users of GH-GWTU did irrigate the treated greywater to their vegetable plots and produce lettuce, cucumber and tomatoes, it did not meet with user satisfaction due to its strong odour and yellow colour. However, all users generally accepted the treated greywater from both units, which indicates that improved models could be scaled up to meet part of the water demand in the Ger areas. Business opportunities were assessed including the application of treated greywater as irrigation water for gardening (which is in great demand from the Ger residents), for other horticultural applications and many more.

KAP survey results (Figure 3) show that the perception of greywater reuse among non-users was well accepted by almost 50% of the respondents. They had a willingness to use the treated greywater and to consume agro-commodities produced with it. One third of respondents

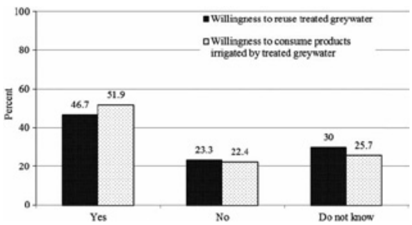

Figure 3 | Non-users' willingness to reuse treated greywater.

did not have any knowledge at all of greywater treatment and reuse issues. The rest of the respondents had a negative approach to this issue. As greywater treatment and reuse is completely new for Ger residents, low awareness and knowledge levels, and social acceptance are still challenges for scaling up of the technology. Additionally, the survey results show that most respondents had a very low awareness level of the greywater treatment and reuse issue, organic food consumption, use of bio-degradable detergents and other environmental issues.

Opportunities and challenges for greywater treatment and reuse

There are a range of opportunities and challenges for treating and reusing greywater in the Mongolian context, and these are listed in Figure 4. Maintenance problems were identified as one of the challenges in both the United States and Australia where 60–80% of 'on-site domestic wastewater treatment plants' were not maintained sufficiently (Jeppesen 1996). This study also addressed several challenges regarding the period of installation, technical shortcomings and maintenance. These challenges, which need to be further researched, include clogging of the systems, strong odour from the treatment units, lack of maintenance, unskilled human resources, lack of user guidelines, lack of ultimate disposal of fat and grease produced from the units, and lack of sludge removal. Local socio-economic and climate conditions pose additional challenges, which obviously are not yet completely answered by the piloted models, such as the temperature dropping under $-40\,^{\circ}C$, freezing soil down to 3.5 m depth for up to 8 months per year, low income, and a low level of technical skills for operation and maintenance.

The way forward

Further technical modifications of the piloted models and detailed and specific training of the users should make the technology fit in to the socio-economic and ecological context. Regarding the GH-GWTU, the design would benefit from adjustments such as introducing a grease trap as a pre-treatment, a ventilated system for gas/odour evacuation, replacement of the metal barrel with plastic or pre-fabricated

Opportunities

Technological

- Independent design at household level.
- Tackle future water crisis and meet future water demand to some extent.
- Decentralized so no need to connect with expensive conventional system.

Operation and Maintenance

- Human resources development.
- Increased skills, knowledge and awareness.
- Reduction in freshwater use in gardening and other landscaping.
- Low operating cost and affordable.

Social

- Current acceptance will enhance future scale up and acceptability of the technology.

Economic

- Save the cost of constructing centralized systems.
- Material business.
- Local available materials can be used.
- Possible business options in future.

Institutional

- Institutional engagement.
- Networking and coordination.
- Research and development.

Challenges

Technological

- Clogging of the systems.
- Strong odour from the units.

Operation and Maintenance

- Lack of maintenance.
- Unskilled/low level of technical skilled human resources.
- Lack of user guidelines.
- Lack of ultimate disposal of fat and grease produced from the units.
- Lack of sludge removal.

Climatic

- Temperature drop under -40°C.
- Freezing soil down to 3.5m depth for 6 to 7 months per year.

Social

- Low awareness on this issue.
- Social acceptance of all Ger residents.

Economic

- Low income people.
- Low interest from Government.

Institutional

- Low capacity, low training skill.
- No policy.
- Low political willingness.

Figure 4 | Opportunities and challenges for greywater treatment and reuse in Mongolia.

barrels, and pipes to allow overflow. Furthermore, the system needs to be maintained and cleaned frequently for effective operation. The greywater from the Ger areas is known to be highly concentrated since it is used repeatedly and traditional food contains a lot of fat. For this reason it is strongly recommended to have a two chamber grease trap installed before releasing the water into the septic tank. To overcome the effect of the cold climate on the treatment processes and efficiency, greywater only needs to be stored in front of the system for the GH-GWTU. The UG-GWTU can run throughout the year for treatment without any impact from cold temperatures. As both water consumption and production are low in the study area, the treatment capacity of both systems is feasible and it is recommended to store greywater for GH-GWTU during the extreme winter and treat the frozen greywater as soon as the temperatures move above freezing. Compared to the UG-GWTU, the GH-GWTU is easy accessible and it is suggested that the GH-GWTU be used as a pilot again with adjustment. The IH-GWTU which has been briefly described above can be considered in the Ger area context during winter when greywater freezes. Both the upgraded GH-GWTU and the IH-GWTU would be feasible in the study area and beyond.

Other technological options such as 4-in-1 biogas systems, willow wastewater treatment facilities and septic tanks with perforated pipe soil filters may also offer a high potential for adaptation to Ger area conditions. As the period for construction is very short in Mongolia (4–6 months in a year), it is proposed that the planning and design be done before that period. A laboratory analysis after treatment is suggested to assess the potential and suitability of the greywater treatment technology, and to reuse them in various sectors according to international standards of greywater reuse.

An overall approach foresees that the design of the GWTU should be in line with the desired effluent quality for the intended pathway, disposal or reuse. In the case of Mongolia, there are as yet no regulations for the use of reclaimed water. Since official standards for reuse for irrigation are not yet established, treated greywater should meet the standards provided by the WHO guidelines (WHO 2006). A legal framework or guidelines on greywater can be supported based on the complete piloting of the proposed GWTUs in future. In addition, a high level of advocacy tools concerning pollution and preservation of resources in relation to future greywater treatment and reuse should be developed to involve the government as an active role player at policy level. There are no policies or guidelines at present in Mongolia on the greywater treatment and reuse option due to a lack of political willingness. This study and the proposed piloting would therefore trigger policy making on this issue. Additionally, there might be the possibility of up scaling the household level GWTUs to get rid of greywater in non-connected Ger areas, which might prevent the environmental pollution and health hazards associated with greywater produced and discharged there contribute to the global knowledge of the sector on the management and reuse of greywater in cold climate conditions.

ACKNOWLEDGEMENT

Support from ACF France and ACF Mongolia is acknowledged.

REFERENCES

Abusam, A. 2008 Reuse of greywater in Kuwait. *International Journal of Environmental Studies* **65**, 103–108.

Batimaa, P., Myagmarjav, B., Batnasan, N., Jadambaa, N. & Khishigsuren, P. 2010 *Urban Water Vulnerability to Climate Change in Mongolia*. Water Authority, Ulaanbaatar, Mongolia.

Batsaikhan, N., Woo, N. C. & Nemer, B. 2011 Groundwater quality & sustainability in Ulaanbaatar, the fast growing Capital of Mongolia. American Geophysical Union, Fall Meeting 2011, The Smithsonian/NASA Astrophysics Data System. http://adsabs.harvard.edu/abs/2011AGUFM.H33C1334B (accessed June 2013).

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N. & Smith, V. H. 1998 Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Application* **8**, 559–568.

Chen, Z., Ngo, H. H. & Guo, W. S. 2013a Risk control in recycled water schemes. *Critical Reviews in Environmental Science and Technology* **43**, 2439–2510.

Chen, Z., Ngo, H. H. & Guo, W. 2013b A critical review on the end uses of recycled water. *Critical Reviews in Environmental Science and Technology* **43**, 1446–1516.

Domenech, L. & Sauri, D. 2010 Socio-technical transitions in water contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. *Resources, Conservation and Recycling* **55**, 53–62.

Exall, K., Marsalek, J. & Schaefer, K. 2006 Water reuse in Canada: opportunities and Challenges. In: *Integrated Urban Water Management* (Hlavinek *et al.* eds). Springer, The Netherlands, pp. 253–262.

Ghaitidak, D. M. & Yadav, K. D. 2013 Characteristics and treatment of greywater – a review. *Environmental Science and Pollution Research* **20**, 2795–2809.

Hauck, M. 2008 Epiphytic lichens indicate recent increase in air pollution in the Mongolian Capital Ulaanbaatar. *The Lichenologist* **40**, 165–168.

Jenssen, P. D., Maehlum, T., Krogstad, T. & Vrale, L. 2005 High performance constructed wetlands for cold climates. *Journal of Environmental Science and Health* **40**, 1343–1353.

Jeppesen, B. 1996 Domestic greywater re-use: Australia's challenge for the future. *Desalination* **106**, 311–315.

Li, F., Wichmann, K. & Otterpohl, R. 2009 Review of the technological approaches for greywater treatment and reuses. *Science of the Total Environment* **407**, 3439–3449.

Li, Z., Gulyas, H., Jahn, M., Gajurel, D. R. & Otterpohl, R. 2003 Greywater treatment by constructed wetlands in combination with TiO_2-based photocatalytic oxidation for suburban and rural areas without sewer system. *Water Science and Technology* **48** (11), 101–106.

Montgomery, M. A. & Elimelech, M. 2007 Water and sanitation in developing countries including health in the equation. *Environmental Science and Technology* **41**, 17–24.

Nriagu, J., Nam, D., Ayanwola, T. A., Dinh, H., Erdenechimeg, E., Ochir, C. & Bolormaa, T. 2012 High levels of uranium in groundwater of Ulaanbaatar, Mongolia. *Science of the Total Environment* **414**, 722–726.

Palmquist, H. & Hanaeus, J. 2005 Hazardous substances in separately collected grey- and blackwater from ordinary Swedish households. *Science of the Total Environment* **348**, 151–163.

Postel, S. L. 2000 Entering an era of water scarcity: The challenges ahead. *Ecological Application* **10**, 941–948.

Schüßler, A. 2011 Greywater treatment units in Ger settlements in Ulaanbaatar, Mongolia. Work Report on Phase 1, Specific Activities: Greywater Handling & Treatment, University of Science and Technology Beijing, China.

Sigel, S., Altantuul, K. & Basandrorj, D. 2012 Household needs and demand for improved water supply and sanitation in peri-urban Ger areas: the case of Dharkhan, Mongolia. *Environmental Earth Sciences* **65**, 1561–1566.

UNICEF 2010 *Country Office Annual Report: Mongolia*. UNICEF, Ulaanbaatar, Mongolia.

WHO 2006 *Guidelines for the safe use of wastewater, excreta and greywater*. Volume IV: Excreta and greywater use in agriculture. World Health Organization, Geneva, Switzerland.

World Bank 2010 *Managing Urban Expansion in Mongolia: Best Practices in Scenario-Based Urban Planning*. The World Bank, Washington, DC.

Wu, Y. & Chen, J. 2013 Investigating the effects of point source and nonpoint source pollution on the water quality of East River (Dongjiang) in South China. *Ecological Indicators* **32**, 294–304.

First received 30 January 2014; accepted in revised form 13 March 2014. Available online 12 May 2014

2. HOUSEHOLD GREYWATER TREATMENT IN PERI-URBAN NOMADIC COMMUNITIES: FEASIBILITY OF A 'GREENHOUSE SYSTEM' IN ULAANBAATAR, MONGOLIA

The 12th IWA Conference on Small Water & Wastewater Systems & 4th Specialized Conference on Resources Orientated Sanitation, November 2-4, 2014, Muscat, Sultanate of Oman

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Abstract

Studies are limited in the grey and scientific literature or in policy documents which focus on greywater treatment and reuse options for nomadic societies. This is especially so in areas which experience long winters, and where people consume liquids other than water. To the authors' knowledge, no study has been successfully conducted on household greywater treatment dealing with high concentration of chemicals (e.g. chemical oxygen demand up to 49969 mg/L) akin to the quality of many untreated industrial effluents and where the nomadic lifestyle or pastoralism is considered a high influential factor on greywater production, composition, and characterization. The current study aims to fill this gap. In Ulaanbaatar, Mongolia, an upgraded greenhouse greywater treatment unit (GH-GWTU) was designed and constructed during the summer (June-September) of 2013 to assess the technical feasibility, and up-scaling capability of the system at the household or community level. Chemical and biological test results indicated that most parameters (e.g. PO_4^-, NO_2^-, NH_4^+) had a high removal rate of up to 98%. Moreover, the greenhouse may extend the treatment period up to eight months (May to December) due to its ambient temperature. In Mongolia, greywater treatment and reuse is a novel concept for both communities and government as there is no standard and guidelines for greywater reuse. The study has shown that GH-GWTU might be a potential technology to significantly reduce the chemicals and biological agents from greywater in Mongolian Ger area context. It can be replicable both at household and community scale according to resources available for system operation and maintenance. Although the removal rate of both chemical and biological agents in the treated water was satisfactory, system improvement and further treatment are needed to address the treated greywater for proper field application and to reduce the greywater-borne hazards and vulnerability to residents. Like many other countries, Mongolia will face serious water scarcities in the near future. Therefore, various options of greywater treatment and reuse should be considered for meeting the future water demand in the study area and other parts of the country.

Keywords: Greywater treatment; Ger area; water scarcity; greenhouse.

Introduction

Mongolian water resources are under threat due to rapid urbanization, overexploitation of water for irrigated agriculture, increased mining activities, lack of proper policies and water resource management systems, climate change (Batimaa et al. 2011; Priess et al., 2011; Malsy et al., 2012), and point and non-point sources of pollution (Ning, 2002; Shih, 2005; Hofmann et al., 2010). Since 2003, the number of dried up streams, lakes and springs has increased by 30%. In addition, surface water is not available for 6-8 months of the year due to freezing temperatures that can reach -40^{o} C in extreme cases (Uddin et al., 2014a; UN WATER 2013). 82% of the country's water withdrawal comes from aquifer extraction, which is increasingly causing high stress on the future availability of groundwater supplies. Only 13% of water is consumed by municipalities from the total yearly withdrawal of water and the substantial remainder is allocated for industry, crop irrigation, livestock cleaning and watering, and cooling of thermoelectric plants (UN WATER 2013).

Sixty percent of the urban population and 78% of the total population reside in the Ger (yurt/tent) areas in Mongolia where they adapt traditional dwellings to the urban environment (Dore and Nagpal, 2006). Ulaanbaatar, the capital of Mongolia, has a population of over one million, and has faced step-wise migration in recent years due to a range of human induced and natural problems. The majority of poor nomads reside in the city peri-urban informal settlements (Uddin et al., 2014a).

Meanwhile, 44.6% of the total population does have access to improved water sources. Wide inequalities exist between the two dwellers (Ger and apartment) in terms of access to heat, electricity, water, sanitation and communication (Dore and Nagpal, 2006). Although municipalities (e.g. in Ulaanbaatar) have central water supply and sewage systems for residents, the peri-urban Ger areas, where over 60% of urban population inhabit, are completely disconnected from the central water supply and sewage systems (Uddin et al., 2014a; Uddin et al, 2014b). Residents of the Ger areas collect water from various water points (water kiosks) during both favorable and unfavorable weather conditions, with consumption around 8-10 litters/person/day compared to apartment residents who consume between 240 and 450 liters/person/day (Dore and Nagpal, 2006). As a result, in Ger areas, less greywater is produced (4-5 litters/person/day). The water contains high chemical and biological contaminants at household levels, which may Ger residents to be exposed to environmental and health hazards (Uddin et al., 2014a). Indeed, the greywater production in the Ger areas is much lower than other high and low income countries in the world (WHO, 2006). The public health and environmental issues related to non-treated greywater reuse is addressed in several studies (see for instance, Gross et al., 2005; Maimon et al., 2010; Travis et al., 2010) and include changes of soil properties and toxicity to biota due to accumulation of salts, surfactants and boron, phosphorus, oil and grease. To overcome these challenges, a range of alternative solutions are needed to treat household greywater for reuse, to protect the environment and health of residents, as well as to reduce risks and hazards due to unplanned greywater discharge to the environment (Uddin et al., 2014c).

There are very limited studies that can be found in both grey and scientific literature and policy documents which focus on greywater (the water released from kitchen, bathroom, washing machine and so on except toilet water) treatment and reuse options for nomadic societies (Dallas et al, 1998; Dalahmeh et al., 2009). This is especially the case in nomadic societies in areas with long winters where liquids other than water are consumed, such as fermented milk, horse milk, and milk tea. Indeed no study has been conducted on household greywater dealing with high concentration of chemicals akin to quality of many untreated industrial effluents. Greywater treatment and reuse remains a novel concept for Mongolian nomadic communities, especially for the residents of peri-urban Ger areas of Ulaanbaatar and government agencies and non-government organizations. Although previous authors (Uddin et al., 2014a) faced a range of challenges in two pilot prototypes, an upgraded greenhouse greywater treatment unit (GH-GWTU) was designed, constructed and monitored during the period of June and September of 2013 at household level in the Ger areas of Ulaanbaatar, Mongolia. This unit aimed to overcome past technical and socio-cultural challenges and assess the technical feasibility of up-scaling the system at household or community level.

Materials and Methods

Study Area

The study was conducted in the peri-urban Ger District of Songinokhaikhan in Ulaanbaatar, Mongolia (Uddin et al., 2014a). The Songinokhairkhan district was established in 1994. It is1200.6 km^2 and is subdivided into 32 administrative units-sub-districts or khoroos. By January 2013, there were a population of 261, 917 inhabitants. The district is a major producer of wheat flour, bread, meat and milk products. These products are supplied both within the district and other parts of the country. The main economic sectors include milk and dairy products, meat and meat products, pig and chicken farming and greenhouse farming enterprises. The majority of people (around 93%) in the area collect water from water kiosks (infoMongolia.com; UNDP, 2009) for drinking and other purposes.

Figure 1 Map of Mongolia.

Experimental Setup

After reviewing various technological options, three models (underground greywater treatment unit-UG-GWTU, greenhouse greywater treatment unit-GH-GWTU and ice-hole greywater treatment unit-IH-GWTU) of greywater treatment units were developed. UG-GWTU and GH-GWTU were piloted during the first phase of the research project executed by the University of Science and Technology Beijing and Action Contre la Faim Mongolia, funded by ACF International France (Uddin et al., 2014a). In the current study, a greenhouse greywater treatment unit (GH-GWTU) (Figure 2 & Figure 3) was upgraded and adjusted based on previous evaluation and technical shortcomings described in Uddin et al., 2014a.

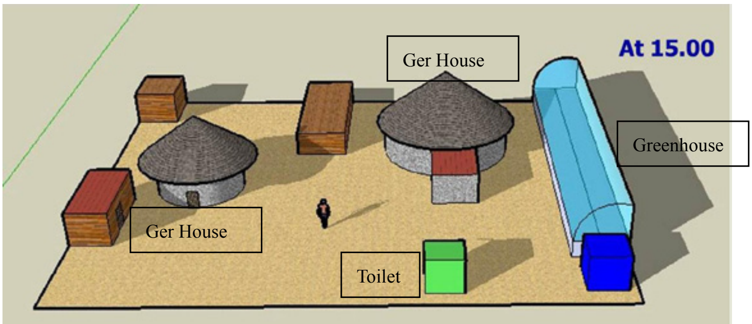

Figure 2 Schematic diagram of a Ger compound and the location of GH-GWTU.

The major components of the system include two grease traps, two septic tanks, three anaerobic gravel filters, one slow sand filter and an effluent tank. The household members were requested to dispose greywater manually in the system. The system was monitored and the water quality was tested at the National Accredited Central Laboratory under Ministry of Environment and Green Development Mongolia. Different chemical and biological parameters were analyzed for greywater from five different sections of the GH-GWTU. The sections include Septic Tank 1(influent), Septic Tank 2, Anaerobic Filtration 1, Slow Sand Filter and Effluent Tank. The chemical and biological parameters include Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), NH_4, NO_2^-, NO_3^-, PO_4^-, and Total *E-coli*. As there is no standard in Mongolia on greywater treatment and reuse, we evaluated system performance with the discharge standard of pollutants for municipal wastewater treatment plant of neighboring country China (SEPA, 2002). In addition, the available parameters of pollutants and their environmental discharge standard of industrial effluent in Mongolia were also evaluated (JICA, 2010). Lastly, temperature data was collected manually during the sampling period to assess any effect on the treatment process.

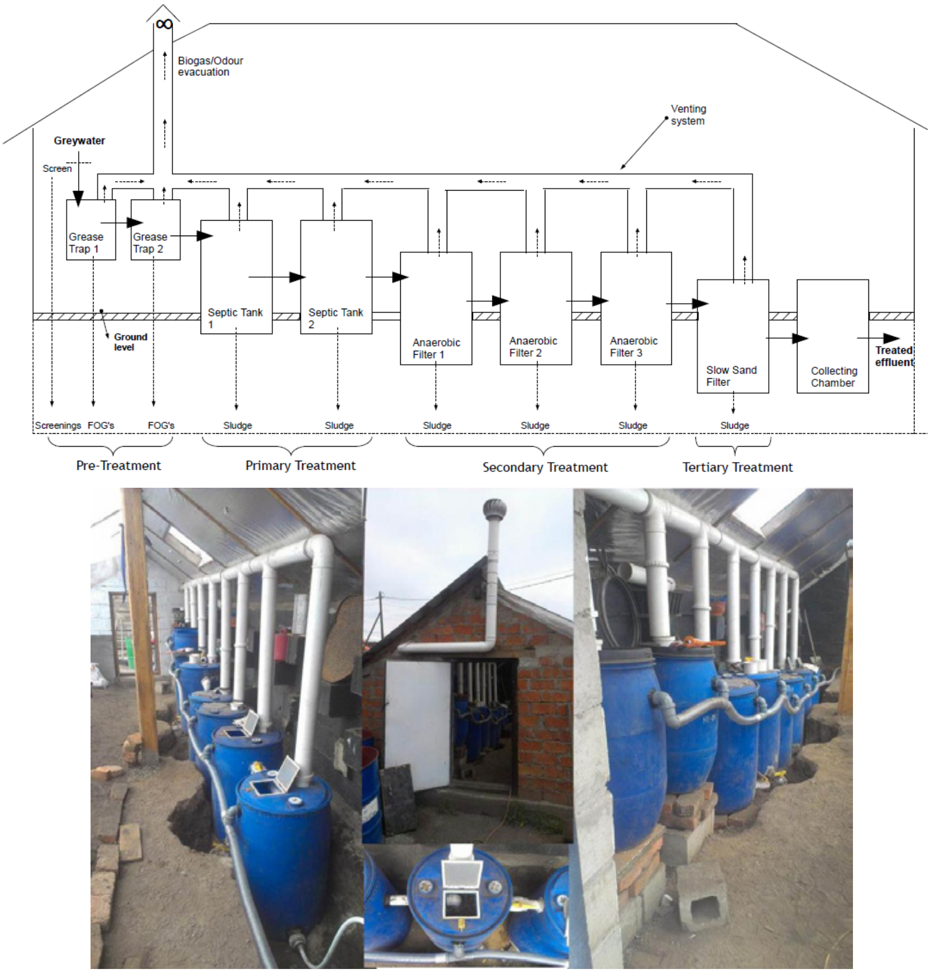

Figure 3 Flow Diagram (above) and photo (below) of Greenhouse Greywater Treatment Unit (Photo Credit to S.M.N. Uddin, July 2013)

Major Design Adjustments

The design components and the concepts are the same as those described in the previous pilot system (see Uddin et al., 2014a). However, the current system is an upgraded version with major adjustments. The following adjustments have been made for the upgraded system in order to overcome previous technical shortcomings (e.g. system clogging, overflowing, bad odor, absence of fat and grease trap, heavy corrosion) and for the ease of operation and maintenance.

To avoid the clogging and over flowing the Ø of pipes and fittings have been increased. The previous design consisted of two Slow Sand Filters (SSF) whereas the current design included only one SSF to increase the efficiency of the treatment and to reduce the retention time due to the low greywater production at household level. Initially there was no grease trap to screen the fats and grease from the greywater. However, two grease traps were installed in the current system as pre-treatment to avoid rapid clogging of the unit. Introduction of a venting system for bio-gas/odor evacuation, as the previous system experienced extreme odor by the household members near the system. Metal barrels were replaced with plastic barrels to avoid heavy corrosion; Proper overflow was permitted to prevent system flooding through the introduction of a side pipeline. The current design also introduced access points through the entirety of the system for easy inspection, maintenance and monitoring. An adequate slope has been maintained to allow smooth water flow from the top to the bottom of the system. The size of the sludge outlet has been increased to avoid system clogging. A wrap drainage pipe from the SSF has been also introduced towards easy overflow the system.

Results and Discussions

Characteristics of greywater and influent

The greywater of the Ger households has been already analyzed and characterized by Uddin et al. (2014a) and ACF/USTB (2010). From these studies, very high concentration of chemical parameters were found, which are higher than the industrial wastewater effluent of many other countries (e.g. India) (Rajkumar and Palanivelu, 2004). The analysis carried out by the Water Supply and Sewage Authority (USUG) Laboratory of Mongolia (Table 1) illustrates the concentration of chemical parameters, particularly the chemical oxygen demand (COD). The parameters measured from a majority of household samples were substantially higher than the COD and total suspended solids (TSS) of effluent from different industries such as dairy mills and pineapple industries (Rajeshwari et al., 2000; Rajkumar and Palanivelu, 2004; Musa and Ahmad, 2010). Three sources of greywater were sampled: hand washing in a sink, kitchen water-use, and laundry water-use. The effluent parameters from these sources included a COD of 35-49969 mg/L; a pH of 3-10; an Electrical Conductivity of 209-6890; a TSS of 168-9280 mg/L; a NH_4^- reading of 0-504.5 mg/L; a PO_4^- reading of 0-82.8 mg/L, and a Biological Oxygen Demand (BOD) reading of 0-3358 mg/L. The concentration of the chemical parameters in greywater was explained by Uddin et al. (2014a) and ACF/USTB (2010) which include low water consumption in the Ger areas, excessive and intensive usage of chemical detergents. In order to increase water use efficiency, households use the kitchen greywater to feed dogs, laundry greywater is reused for floor cleaning and only water which was used for personal hygiene is dumped directly. The diet and cooking manners differs from those countries where they are generally referred to as ‘usual values’. Mongolian style cooking uses much fat and milk.

Table 1. Characteristics of household greywater.

HH #	Types*	pH	EC	TSS (mg/L)	NH_4 (mg/L)	PO_4 (mg/L)	COD (mg/L)	BOD (mg/L)
1	A	4.0	342	432	6.3	4.4	687	923
	B	6.1	1011	1456	21.3	4.3	49969	827
	C	7.1	2650	580	6.5	5.6	8786	0
2	A	3.5	796	3810	31.4	31.3	41517	0
	B	8.1	3300	1120	301.3	27	6362	0
	C	6.5	1800	1330	36.3	2.8	20062	3183
3	A	3.0	727	4772	8.2	9.1	1672	0
	B	5.8	3000	3880	74.1	5.6	70032	0
	C	6.1	2640	1620	24.7	2.2	33437	0
4	A	3.1	655	2710	6.3	4.6	38081	0
	B	5.1	426	860	9.5	0.3	35759	0
	C	6.2	1350	1480	41.5	0.0	11796	3210
5	A	4.8	1020	790	8.8	2.9	17787	0
	B	8.4	6010	500	420.4	41.5	8499	0
	C	6.1	3090	3060	131	45.9	8591	0
6	A	4.0	362	3750	11.6	4.6	15511	3120
	B	6.7	261	580	11.2	0.8	1904	343
	C	7.0	3490	610	27.1	1.5	5062	712
7	A	4.5	631	560	0.5	0.0	3111	0
	B	6.5	550	1090	2.6	0.2	5016	0
	C	6.6	617	670	6.5	0.4	35	0
8	A	4.1	272	1550	0.5	3.0	4365	0
	B	6.3	979	2550	38.5	4.1	10263	0
	C	4.9	733	1750	10.3	0.8	5991	0
9	A	4.9	5800	8980	142.4	82.8	31951	0
	B	5.8	425	540	10.8	0.2	4783	0
	C	8.9	2780	608	8.2	4.3	3994	0
10	A	9.3	6890	530	504.5	60.3	8638	1211
	B	3.3	1047	7580	30.9	14.2	33112	1621
	C	5.4	4500	8960	6.5	81.2	23499	1646
11	A	4.6	315	432	0.0	1.4	3947	1675
	B	5.7	209	288	3.5	0.4	1393	484
	C	6.6	570	1016	13.8	0.8	4969	2539
12	A	3.4	841	9230	6.9	25	12539	0
	B	6.2	430	1420	16.8	0.2	3297	0

	C	6.8	1001	2620	15.9	1.8	11471	0
13	A	4.3	1109	5110	0.0	14.8	107	0
	B	7.3	1194	1030	0.5	2.7	789	0
	C	8.9	3490	1040	4.7	8.0	4365	2184
14	A	3.7	232	720	0.5	4.6	2833	0
	B	5.8	1351	900	34.4	2.2	4690	0
	C	6.9	2250	1710	44	7.0	5851	1854
15	A	4.2	740	3290	13.8	2.2	26006	0
	B	6.6	1344	2020	35.7	0.5	12632	0
	C	5.6	2260	5360	18.1	63.3	20852	0
16	A	5.3	609	1180	21.1	12.5	2972	0
	B	5.7	453	324	4.7	1.0	2368	0
	C	8.8	3010	430	10.1	8.9	5480	708
17	A	3.3	417	1390	7.8	6.8	4690	0
	B	5.0	280	588	4.5	0.6	5573	0
	C	10	4360	1120	14	10	5108	1106
18	A	4.6	375	1376	1.3	1.0	1533	0
	B	5.8	434	830	2.8	0.4	743	0
	C	8.0	3380	2780	65.3	32.2	20294	33
19	A	3.7	712	9280	17.4	13	9752	0
	B	6.3	1702	2300	39.5	6.1	8127	0
	C	7.0	2140	1920	50.3	8.2	9009	3358
20	A	3.4	360	830	8.6	1.6	3065	0
	B	4.7	240	740	4.7	1.1	1579	0
	C	9.7	4860	168	32.4	16.2	21455	3103

*Types of Greywater, A- Hand washing, B- Kitchen and C- Laundry
Source: (ACF and USTB, 2010)

The influent of the current GH-GWTU was also analyzed and found to have higher values for the different chemical parameters (Table 2). In most of the samples, these parameters were higher than industrial wastewater from phenol formaldehyde resin manufacturing, oil refinery (Rajkumar and Palanivelu, 2004) and even wastewater effluent from slaughterhouses (Rajeshwari et al., 2000). The major sources of phosphorus in the influent derive from non-degradable chemical detergents and shampoos used by at household members (Christova-Boal et al., 1996).

Table 2. Fluctuation and characteristics of influent

Week	TSS	COD	NH_4	NO_2	NO_3	PO_4	*E. coli* 10^5 CFU/100 mL
1	626	1929.6	215.3	0.166	0.25	7.964	0.81
2	1484	2653.2	122.14	1.133	3.04	7.04	0.57
3	840	1640	147.5	0.317	3.79	12.276	0.75
4	64	1302.5	148.6	0.34	2.78	7.854	0.57
5	122	385.9	1.76	0.374	1.64	8.76	0.375
6	330	4824	27.89	0.546	4.87	5.86	0.65
7	290	1785	48.36	0.49	1.64	4.08	0.43
8	1186	1254	328.6	0.162	13.6	6.48	0.45

System Performance

The overall performance of the GH-GWTU is satisfactory. The chemical analysis results indicate that the maximum removal rate of the system is over 90% of COD, NH_4^+, NO_3^-, NO_2^-, NO_3^-, P and TSS. The removal rate is much higher than the rate shown in other studies such as Chaillou et al., 2011. However, these authors did not deal with greywater of comparably high concentration of chemicals and biological agents. Figure 3 shows the graphical presentation of the system performance of the GH-GWTU. The average TSS of the influent ranged from 66-1484 mg/L whereas the treated samples ranged between 44-290 mg/L. The maximum removal rate of TSS in the treated greywater is 92%. This rate is much higher than the results reported by Chaillou et al. (2011) and Friedler et al., (2005), however the water does not meet the Chinese discharge standard of pollutants for municipal wastewater treatment plant (SEPA, 2002). The COD concentration of influent ranged from 385.9-4824 mg/L, while the effluent ranged from 139 to 820 mg/L. This can be explained by the high concentration and fluctuation of produced greywater composition in different days. Although the maximum removal rate of COD was 94% and is indeed higher than reported by Friedler et al., (2005), the effluent standard still exceeds the suggested guidelines in other countries such as China (Uddin et al., 2014a). In relation to ammonium removal, the maximum removal rate was 98%, which is again higher than the rate reported in a study conducted by Leal et al. (2010). Fluctuation of some effluent samples can be seen due to the variation of the rate of greywater production and the difference of retention time in different days. As there is still no guidelines in Mongolia for practicing greywater treatment and reuse, the guidelines of neighboring countries can be followed due to some similar geographical and climatic conditions. The concentration of ammonium in most of the effluent samples meets the GB Chinese discharge standard of pollutants for municipal wastewater treatment plants (SEPA, 2002). Accordingly, the treated effluent can be discharged to the designated places to reduce the risk and hazards to both human and environmental health. The performance of the system on P removal is higher than most of the other parameters with a maximum of 98%. The effluent concentration ranges from 0.188-0.924 mg/L and is more efficient than the results of other studies (e.g. Jabornig and Favero, 2013). The performance of the system was not as stable with respect to P removal. The concentration of P in the effluent was <1 mg/L and met the GB Chinese discharge standard (B grade) of pollutants for the effluent of municipal wastewater treatment plants (SEPA, 2002).

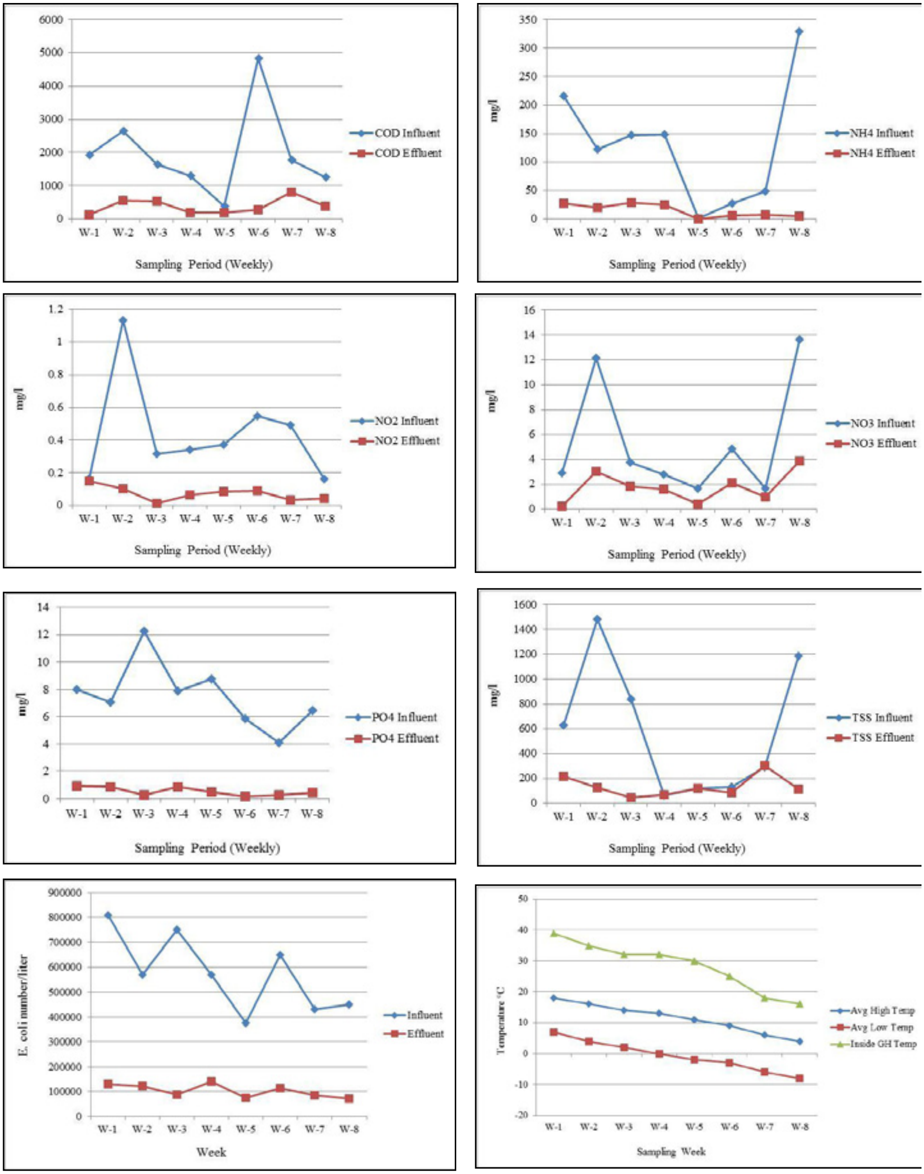

Figure 4 Removal rate of chemical parameters and *E. coli (Sampling Sep-Oct 2013)*.

Uncontrolled land discharge of treated wastewater or unplanned household greywater discharge can cause nitrate contamination in surface, groundwater resources and soils. Such contamination can create hazards to infant and pregnant women (Shrimali and Singh, 2001) though direct, indirect or cross-contamination of drinking water sources. Parslow (1997) reported that the risk of childhood diabetes increased from a baseline of 1.00 at nitrate concentrations below 3.22 mg/L to 1.27 at concentrations of more than 14.85 mg/L. The system of the current study has achieved up to 91% removal rate of nitrate which is much higher than the reported results of other studies and the effluent quality meet the guidelines of reclaimed water use in other countries such as Jordan (Kapoor and Viraraghavan, 1997; Ammari et al., 2014). The influent quality of the nitrite ranged from 0.162-1.133 mg/L where most of the samples are higher than the influent quality of 0.03-0.30 mg/L reported by Chang et al. (2013). The maximum removal rate of nitrite up to 96% was achieved and can meet the Chinese Municipal discharge standard to the environment.

The greywater also contains the greater number of *E. coli* bacteria in the samples (Figure 5). Although the removal rate of *E. coli* has a maximum rate of 88.4%, the effluent quality does not meet the Chinese discharge standard to the environment. An effective and appropriate disinfection process such as simple chlorination is required before discharging this treated water to the environment.

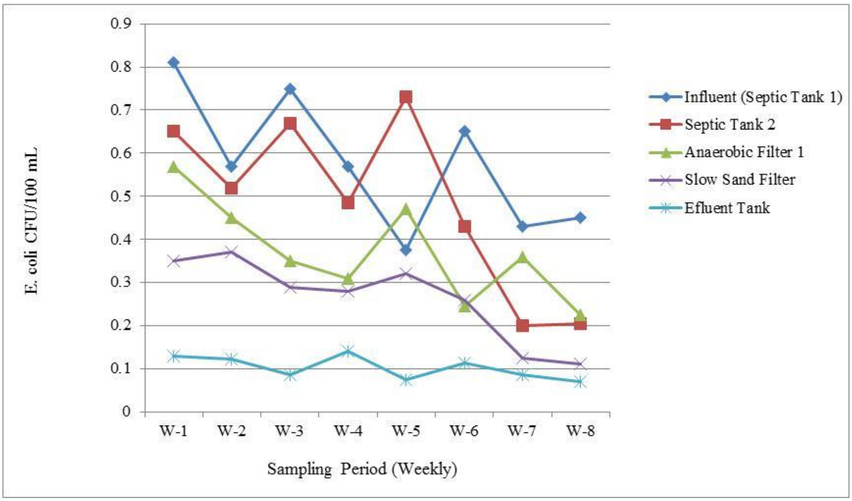

Figure 5 *E. coli* removal (CFU 10^5/100 mL) in each step of the GH-GWTU

The fluctuation of the composition of the influent may be due to the different composition of the greywater across different days which likely influences the uniform test results of the effluent. As noted in the previous study by Uddin et al (2014a), the factors leading to a high concentration of effluents within greywater is due to the re-use of water for different purposes and considering the high content of fats and grease in the water being re-used. Aggravating this problem, the people migrating to peri-urban settings have retained a nomadic cultural tradition of consuming high fat, milk and meat products These consumption habits may have a high influence on the high concentration of greywater. . A post-treatment of effluent from the system is needed for some parameters to meet the norms of various field applications for reuse. In Mongolia, no standard and guidelines exist for greywater reuse and is a new concept for Ger residents as well as for Mongolian government and non-governmental agencies.

Factors of Ger Settings and Nomadic Lifestyle on Greywater

The influence of technology on behavioral change is very slow in traditionally nomadic societies than other parts of the world. Most of these people reside in Yurts (felt tents) (Mauvieux et al., 2014) without connection to water supply, sewerage or any sanitation system (Uddin et al, 2014a). In the Ger areas, each Ger conglomeration is comprised of a combination of families belonging to a 'kin' (or clan) representing a particular village. Normally, this family clan consists of between two to four brothers and their families. Upon marriage, each male member of the family receives his own Ger which increases the number of Gers within a single compound until one family moves away from the compound due to overcrowded of population or their willingness to move in a separate place in the Ger areas. Thus the practice of greywater production and disposal of the new residents in the Ger areas remained unchanged. These practices may influence greywater production and its technological replication processes.

Due to their traditionally nomadic culture, the Ger area residents have no historic or cultural attitude to on-site or off-site waste and greywater management. As they live on small urban compounds, they are now confronted with their own residual materials from daily life which they were never confronted with living on open pastures in the countryside. This contributes among other conditions to uncomfortable living conditions. As there is no sewerage system in the Ger areas, the inhabitants dig their own pit latrine toilets. Being sedentary in the more urban setting, they depend on animals rather than crop production. Although more people continue to migrate to the urban and peri-urban settings, most of the pastoral nomads retain their food habits and lifestyles. Consumption of other liquids (e.g. milk tea, fermented milk, horse milk) instead of water is highly practiced in nomadic societies. The consumption rate of those liquids is much higher during the long winter than the short summer. Less consumption of water due to the difficulty of water collection, more time to collect water and excess fuel consumption to boil drinking water result in lower greywater production (Uddin et al., 2014a Most herders intake of vegetables is very low and is comprised primarily of meat. The use of high chemical detergent usage is becoming increasingly common over the past decade (Uddin et al., 2014a; Schüßler, 2011). Table 3 shows the types of chemicals used by the residents in the Ger areas.

Table 3. Chemical detergents used in the Ger areas.

Personal Cleaning Products	**Laundry cleaning products**	**Dishwashing products**	**Household cleaning products**
Hand soaps	Detergent powder	Dishwashing liquid soap	All kinds of cleaners

Skin cleaning products: • Bath foam • Shower gel	Fabric softener		Window/glass cleaners
Hair cleaning products: • Shampoos • Conditioner			

Source: Uddin et al. (2014a), Schüßler (2011)

Greywater-Borne Hazards and Vulnerabilities

During last 40 years, 'vulnerability' has been considered in a wide range of multidisciplinary fields such as development, medical science, public health and nutrition, environmental hazards, climate change, and disaster management (see for instance, Cutter, 1996; Glewwe and Hall, 1998; Adger, 1999; Webb and Harinarayan, 1999; Alwang et al., 2001; Haines et al., 2006; Gaillard, 2010). Although, many researchers and authors define 'vulnerability' in different ways in particular fields, the concept is essentially centred around the physical or mental risks or hazards for human communities associated with natural events or anthropogenic activities. Chambers (2006) defined vulnerability as "defenselessness, insecurity, and exposure to hazards, shocks and stress". Some argue that vulnerability should be seen not only in terms of individual harm but also linked to the broader context of crises, including the differentiated nature of responses across households and communities (Webb and Harinarayan, 1999). Alwang et al. (2001) identified the poor and near-poor as vulnerable groups due to their low access to assets and limited abilities to respond to risk. Watts and Bohle (1993) mentioned that the prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential and bolster damage control via private and public means.

The urrent study has emphasized the high concentration of chemical and biological agents in greywater which may have the potential to cause health and environmental hazards and may increase vulnerability of the population in the Ger areas to various greywater-borne diseases such as Lagionnaires (by *Legionella pneumophila* presence in domestic wastewater), various gastrointestinal and infectious diseases (Dixon et al., 1999; Ottosson, 2003). Although some argue that greywater is considered safer than blackwater (the water released only from toilets), it has been shown in the literature that greywater can cause risk and hazards to various human organs as well as to the environment (e.g. soils, plants, useful organisms/decomposers, surface and groundwater) due to both chemical contaminants and transmission of hazardous microbes and pathogens (Eriksson et al., 2002; Ottoson and Stenstrom, 2003; Winward, 2007; Maimon et al., 2010; Teodoro et al., 2014). With the exception of common chemicals and biological agents assessed in the greywater, it has been identified that 900 types of xenobiotic organic compounds (XOC) can also be found in greywater which can accumulate in soil and groundwater leading to human, plants and environmental health hazards (Eriksson et al., 2002). Thesehave a high potential to cause human health and environmental hazardsAdditionally, fecal contamination can be transmitted through greywater through a range of medium including laundry, childcare (e.g. diapers), shower, food-handling in the kitchen, the sink basin, and viruses or bacteria such as P*seudomonas aeruginosa* which thrive on easily degradable organic matter (Barker et al., 2013; Teodoro et al., 2014). In the current study, a high concentration of

E. coli bacteria was found in the greywater with the potential sources of fecal contaminations deriving from the laundry, kitchen sinks with high content of fats and grease, and dishwashing water from the fermented milks, milk tea, and meat. As phosphorus is considered one of the potential environmental risks (Turner et al., 2013), the discharge of household greywater with high concentrations of phosphate and other chemicals released to the environment can also create environmental and health hazards for the residents in the study area (Uddin et al., 2013; 2014c). In this manner, people may become morevulnerable to greywater-borne risks and diseases. Due to a lack of legislation on detergent imports and low level of public awareness related to detergent usage, phosphorus content is high in the greywater produced resulting in both health and environmental risks (Turner et al., 2013; Uddin et al., 2014c; Knud-Hansen, 1993). Untreated discharge of greywater in the soil of the Ger compounds can enhance the movement of chemicals such as phosphorus in the environment and cause contamination to soil, surface and groundwater. Currently, a conventional seweage system may not be feasible for collecting only greywater from households due to high economic costs, short construction period, harsh climatic conditions and the lack of planning and standardization of infrastructures in the Ger areas. Therefore treatment of greywater with economically feasible, socially acceptable, technically suitable methods is needed to remove the various chemicals and pathogens from the greywater in the Ger areas before discharge to the environment.

Towards Reduction of Greywater-Borne Vulnerability

Various hardware (e.g. technological) and software (non-technical) solutions are required to reduce the greywater-borne vulnerability in the study area which can be replicable to other parts of the world. A holistic or integrated approach has been already proposed by Uddin et. al. (2014c) to reduce the water, sanitation and hygiene (WASH)-borne hazards which can be applied to reduce the greywater-borne vulnerability in the current study area. The study suggested both hardware (e.g. technological) and software (e.g. policy) initiatives to reduce the WASH-borne hazards. Given the lack of legal regulations and treatment infrastructure for greywater in Mongolia, both policy and technological introduction would be useful directions for the government to deal with the greywater produced in the study area and other parts of the country. Although economic cost recovery through greywater treatment and reuse is a salient and highly discussed topic at the governmental level, these discussions have not focused on the hazards and vulnerability to the environment and human health resulting from greywater contamination. Moreover, the challenges faced by residents in collecting water and subsequent contamination of surface and groundwater sources is also omitted from these discussions. Advocacy tools and experimentation of various technological options and social dialogue can be constructive catalysts for the government to consider relevant regulations or policies for onsite, decentralized greywater treatment and reuse options in Ger areas.

Conclusions and Recommendations

Overall the removal rate of different parameters was satisfactory and a removal rate of over 90% was achieved for all parameters.. Regarding TSS, the maximum removal rate was 92%, higher than the results reported by others. Although the maximum removal rate of COD was 94%, the effluent standard was still over the suggested guideline in other countries, such as China. In Mongolia, there is no standard and guidelines for greywater reuse. Greywater treatment and reuse is a novel concept for the Mongolian nomadic communities, particularly for the residents of peri-urban Ger areas of Ulaanbaatar. The results show that GH-GWTU is technically feasible in the study area of Mongolia. Although the removal rate of both chemical and biological agents in the treated water were satisfactory, further advanced or tertiary treatment and disinfection processes such as chlorination are needed to deal with the treated greywater for reuse purposes. In addition, the efficiency of the system can be improved effectively by increasing the amount of greywater disposal in the treatment unit and by efficient operation and maintenance. As Mongolia will continue to face serious water scarcities in the near future, various options of greywater treatment and reuse such as technological, social, and economical options should be considered for meeting future water demand in the study area and beyond.

Thus onsite greywater treatment systems are encouraged to treat greywater before re-use or discharge to the environment and to protect human and environmental health. Proper legislations on greywater treatment, production and discharge or reuse are needed to safeguard human health and the environment. Environmental education and awareness may help the population to be aware about the usage of chemical detergents and encourage environment friendly and bio-degradable cleaning products. Such practices can substantially reduce both health and environmental risks (Turner et al., 2013). Further research on environmental and health consequences related to untreated greywater discharge is needed to assess the risks and hazards in this unique context. Monitoring of the treatment system throughout the year is suggested in order to examine the effect of temperature on the operation, maintenance and treatment process. Further, a detailed economic study is required to upscale the system at both the household and community levels. The analysis of other chemicals including sodium, zinc, aluminum and heavy metals is also suggested to examine further risks that these may contribute in greywater production. Future studies could examine the effect of natural freezing conditions on removing physical-chemical contaminants but also to deactivate *E. coli* in the greywater (Gao et al., 2006). Such analysis would be particular relevant given given the natural climate of Ulaanbaatar, Mongolia.

Acknowledgement

Support from ACF International France and Mongolia is acknowledged.

References

ACF and USTB 2010 Suitability of different technology options for greywater and human extreta treatment/disposal units in Ger areas in Ulaanbaatar/Mongolia. Study Report, Final Version, Action Contre La Faim Mongolia and University of Science and Technology Beijing, China.

Adger, W. N. 1999 Social vulnerability to climate change and extremes in coastal Vietnam. World Development, 27(2), 249-269.

Alwang, J., Siegel, P. B. & Jorgensen, S. L. 2001 Vulnerability: a view from different disciplines. Social Protection Discussion Paper Series, The World Bank, Washington D. C., USA.

Ammari, T. G., Al-Zu'bi, Y., Al-Balawneh, A., Tahhan, R., Al-Dabbas, M., Ta'any, R. A. and Abu-Hard, R. 2014 An evaluation of the re-circulated vertical flow bioreactor to recycle rural greywater for irrigation under arid Mediterranean bioclimate. Ecological Engineering, 70, 16-24.

Barker, S. F., O'Toole, J., Sinclair, M. I., Leder, K., Malawaraarachchi, M. and Hamilton, A. J. 2013 A probabilistic model of norovirus disease burden associalted with greywater irrigation of home-produced lettuce in Melbourne, Australia. Water Research, 47, 1421-1432.

Batimaa, P., Myagmarjav, B., Batnasan, N., Jadambaa, N. and Khishigsuren, P. 2011 Urban water vulnerability to climate change in Mongolia, Water Authority, Government of Mongolia, Ulaanbaatar, Mongolia.

Chambers, R. 2006 Vulnerability, coping and policy (Editorial Introduction). IDS Bulletin, 37(4), 33-40.

Christova-Boal, D., Eden, R. E. and McFarlane, S. 1996 An investigation into greywater reuse for urban residential properties, Desalination, 106, 391-397.

Cutter, S. L. 1996 Vulnerability to environmental hazards. Progress in Human Geography 20(4), 529-539.

Chang, J., Wu, S., Dai, Y., Liang, W. and Wu, Z. 2013 Nitrogen removal from nitrate-laden wastewater by integrated vertical-flow constructed wetland system. Ecological Engineering, 58, 192-201.

Cutter, S. L. 1996 Vulnerability to environmental hazards. Progress in Human Geography, 20(4), 529-539.

Dallas, S., Anda, M., Ho, G. and Mathew, K. 1998 Water conservation in Australian indigenous communities. Proceedings of 24th WEDC Conference on Sanitation and Water for All, 1998, Islamabad, Pakistan.

Dallahmeh, S. S., Assayed, M. and Suleman, W. T. 2009 Themes of stakeholder participation in greywater management in rural communities in Jordan. Desalination, 243, 159-169.

Dixon, A. M., Butler, D. and Fewkes, A. 1999 Guidelines for greywater re-use: Health issues, J. CIWEM, 13. 322-326.

Dore, G. and Nagpal, T. 2006 Urban transition in Mongolia: Pursuing sustainability in a unique environment. Environment: Science and Policy for Sustainable Development, 48(6), 10-24.

Eriksson, E., Auffarth, K., Henze, M. and Ledin, A. 2002 Characteristics of grey wastewater, Urban Water, 4, 85-104.

Gaillard, J. C. 2010 Vulnerability, capacity and resilience: perspectives for climate and development policy. Journal of International Development, 22, 218-232.

Gao, W., Smith, S. W. and Li, Y. 2006 Natural freezing as a wastewater treatment methods: *E coli* inactivation capacity. Water Research, 40, 2321-2326.

Glewwe, P. & Hall, G. 1998 Are some groups more vulnerable to macroeconomic shocks than others? Hypothesis tests based on panel data from Peru. Journal of Development Economics, 56(1), 181-206.

Gross, A., Azulai, N., Oron, G., Ronen, M. and Nejidat, A. 2005 Environmental impact and health risks associated with greywater irrigation: a case study. Water Science and Technology, 52(8), 161-169.

Haines, A., Kovats, R. S., Campbell-Lendrum, D. & Corvalan, C. 2006 Climate change and human health: impacts, vulnerability, and mitigation. Lancet, 367, 2101-2109.

Hofmann, J., Hurdler, M., Behrendt, H. and Opitz, D. 2010 Integrated water resource management in Central Asia: Nutrient and heavy metal emissions and their relevance for the Kharaa River Basin, Mongolia. Water Science and Technology, 62(2), 353-363.

InfoMongolia: www.infomongolia.com (accessed November 2013)

Jabornig, S. and Favero, E. 2013 Single household greywater treatment with a moving bed biofilf membrane reactor (MBBMR). Journal of Membrane Science, 446, 277-285.

JICA, 2010 Study on the strategic planning for water supply and sewerage sector in Ulaanbaatar city. Project Report, Ulaanbaatar, Mongolia. Website: http://www.jica.go.jp/english/our_work/social_environmental/id/asia/east/c8h0vm0000013i5h-att/mongolia_b03_02.pdf (accessed July 2014)

Kapoor, A. and Viraraghavan, T. 1997 Nitrate removal from drinking water- review, Journal of Environmental Engineering, 123, 371-380.

Knud-Hansen, C. 1993 Historical perspective of the phosphorus detergent conflict. *In*: Knud-Hansen Chris, editor. “Conflict Research Consortium”, Colorado, Colorado University of Colorado, 94. *In*. Turner, R. D. R., Will, G. D., Dawes, L. A., Gardner, E. A. and Lyons, D. J. 2013 “Phosphorus as a limiting factor on sustainable greywater irrigation.” Science of the Total Environment, 456-457, 287-298.

Leal, L. H., Temmink, H., Zeeman., G. and Buisman, C. J. N. 2010 Comparison of three systems for biological greywater treatment. Water, 2, 155-169.

Maimon, A., Tal, A., Friedler, E. and Gross, A. 2010 Safe on-site reuse of greywater for irrigation- a critical review of current guidelines. Environmental Science Technology, 44, 3213-3220.

Malsy, M., der Beek, A., Eisner, M. and Florke, M. 2012 Climate change impacts on Central Asian water resources. Adv. Geoscience, 32, 77-83.

Mauvieux, B., Reinberg, A. and Touitou, Y. 2014 The yurt: A nomadic populations dwelling in the Mongolian steppe is still used both as a sun clock and a calendar. Chronobiology International, 31 (2), 151-156.

Musa, N. S. and Ahmad, W. A. 2010 Chemical oxygen demand reduction in industrial wastewater using locally isolated bacteria. Proceedings of Regional Annual Fundamental Science Seminar 2010. Malaysia.

Ning, R. Y. 2002 Arsenic removal by reverse osmosis. Desalination, 143, 237-21.

Ottosson, J. 2003 Hygiene aspects of greywater and greywater reuse, Master's Thesis, Royal Institute of Technology, Stockholm, Sweden.

Ottoson, J. and Stenstrom, T. A. 2003 Faecal contamination of greywater and associated microbial risks. Water Research, 37, 65-655.

Parslow, R. C., McKinney, P. A., Law, G. R., Staines, A., Williams, R. and Bodansky, H. J. 1997 Incidence of childhood diabetes mellitus in Yorkshire, northern England, is associalted with nitrate in drinking water: an ecological analysis, Diabetologia, 40, 5550-556.

Priess, J. A., Schweitzer, C., Wimmer, F., Batkhishig, O. and Mimler, M. 2011 The consequences of land-use chance and water demands in in Central Mongolia. Land use Policy, 28, 4-10.

Rajeshwari, K. V., Balakrishnan, M., Kansal, A., Lata, K. and Kishore, V. V. N. 2000 State-of-the-art of anaerobic digestion technology for industrial wastewater treatment. Renewable and Sustainable Energy Reviews, 4, 135-156.

Rajkumar, D. and Palanivelu, K. 2004 Electrochemical treatment of industrial wastewater. Journal of Hazardous Materials, B113, 123-129.

Schüßler, A. 2011 Greywater treatment units in Ger settlements in Ulaanbaatar, Mongolia. Work Report on Phase 1, Specific Activities: Greywater Handling & Treatment, University of Science and Technology Beijing, China.

SEPA 2002 Discharge standard of pollutants for municipal wastewater treatment plant. GB 18918-2002, State Environmental Protection Administration, China.

Shih, MC. 2005 An overview of arsenic removal by pressure-driven membrane processes. Desalination, 172, 85-97.

Shrimali, M and Singh, K. P. 2001 New methods of nitrate removal from water, Environmental

Pollution, 112, 351-359.

Teodoro, A., Boncz, M. A., Junior, A. M., and Paulo, P. L. 2014 Disinfection of greywater pre-treated by constructed wetlands using photo-Fenton: Influence of pH on the decay of *pseudomonas aeruginosa*. Journal of Environmental Chemical Engineering, 2, 958-962.

Travis, M. J., Wiel-Shafran, A., Weisbrod, N., Adar, E. and Gross, A. 2010 Greywater reuse for irrigation: Effect on soil properties. Science of the Total Environment, 408. 2501-2508.

Turner, R. D. R., Will, G. D., Dawes, L. A., Gardner, E. A. and Lyons, D. J. 2013 Phosphorus as a limiting factor on sustainable greywater irrigation. Science of the Total Environment, 456-457, 287-298.

Uddin, S.M.N., Li, Z., Mang, HP., Schubler, A., Ulbrich, T., Huba, E.M., Rheinstein, E., and Lapegue, J. 2014a Opportunities and challenges of greywater treatment and reuse in Mongolia: Lessons learnt from piloted systems, Journal of Water Reuse and Desalination, 4(3), 181-193.

Uddin, S.M.N., Li, Z., Mang, HP., Huba, E.M., and Lapegue, J. 2014b A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems, Journal of Water, Sanitation and Hygiene for Development, 4(3), 437-448.

Uddin, S.M.N., Li, Z., Gaillard, J. C., Tedoff, PF., Lapegue, J, Mang, HP., Huba, E.M. Kummel, O., and Rheinstein, E. 2014c Exposure to WASH-borne hazards: A scoping study on peri-urban Ger areas in Ulaanbaatar, Mongolia. Habitat International (In Press).

UN WATER 2013 Mongilia: UN Water country brief, Ulaanbaatar, Mongolia. Website: http://www.unwater.org/downloads/WCB/ebooks/MNG/MNG.html#p=1 (accessed September 2014)

Watts, M. and Bohle, H. 1993 Hunger, famine and the space of vulnerability. GeoJournal, 30(2), 117-125.

Winward, G. P. 2007 Disinfection of greywater, PhD Dissertation, Cranfield University, United Kingdom.

Webb, P. and Harinarayan, A. 1999 Measure of uncertainty: the nature of vulnerability and its relationship to malnutrition. Disasters, 23(4), 292-305.

WHO, 2006 Guidelines for the safe use of wastewater, excreta, and greywater. Volume IV, Excreta and greywater use in agriculture, World Health Organization, Geneva, Switzerland.

3. AN ASSESSMENT OF THE FEASIBILITY OF HOUSEHOLD GREYWATER TREATMENT IN WATER STRESSED REGIONS IN COLD CLIMATES USING 'ICE-BLOCK UNITS': A CASE STUDY IN ULAANBAATAR, MONGOLIA

14th International Conference on Wetland Systems for Water Pollution Control (ICWS)
Shanghai, China, 12-16 October 2014.

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Abstract: This study explored the feasibility of household greywater treatment in a water stressed region with a cold climate, namely Ulaanbaatar, Mongolia. After selecting a suitable site, an 'Ice-Block Unit' was designed and constructed to test for greywater treatment during the summer period (July-September) in the peri-urban Ger (informal settlement) areas of Ulaanbaatar, Mongolia, This system is based on storing water during the entire winter freezing period as an ice block, and then starting treatment during the summer/non-freezing period. A customer survey was carried out to assess the customer interests in greywater treatment and reuse, their perceptions and practice to dispose greywater. The Ice-Block Unit is currently in the storage and monitoring stage. Customer survey revealed that over two third of the respondents were interested in greywater treatment and to share the installation and maintenance cost of greywater treatment system with their neighbors to save money. This can be explained that a community scale of greywater system can be scaled up in the areas. As the greywater treatment and reuse is a new concept of Mongolian communities including the government and non-government officials, a comprehensive and multi-disciplinary research is required to convince them for scaling up the system.

Key Words: Greywater treatment, Ice-Block Unit, Cold Climate, Wetland System

INTRODUCTION

To date, there have been numerous studies published on the use of wetlands for wastewater/greywater treatment at the household level in tropical and arid regions (see for example, Konnerup et al., 2009). There have also been some studies published that focused on regions with cold climates. However, very few studies have been carried out in countries with cold climates, and in conditions where water consumption is significantly less (average 8 l/day/person) than the WHO standard.

Mongolian water resources are under threat due to numerous human and natural factors. The number of dried up streams, lakes and springs has been increased by 30% since 2003. In addition, surface water is not available for 6-8 months of the year due to freezing temperatures that can reach -40^{o} C in extreme cases. Significant withdrawal of freshwater from underground water aquifer may create high stress on water availability in future. Major parts (87%) of water consumed by industries, crop irrigations, livestock cleaning and watering, and cooling of thermoelectric plants from the total yearly withdrawal of water (Ning, 2002; Shih, MC., 2005; Batimaa et al. 2010; Priess et al., 2011; Malsy et al., 2012; Hofmann et al., 2010; UN WATER 2013, Uddin et al., 2014a).

Meanwhile, 55.4% of the total population does not have access to improved water sources. Wide inequalities exist between the two dwellers (Ger and apartment) in terms of access to heat, electricity, water, sanitation and communication (Dore and Nagpal, 2006). Although municipalities (e.g. in Ulaanbaatar) have central water supply and sewage systems for residents, the peri-urban Ger areas, where over 60% of urban population inhabit, are completely disconnected from the central water supply and sewage systems (Uddin et al., 2014a; Uddin et al, 2014b). Residents of the Ger areas collect water from various water points (water kiosks) during both favorable and unfavorable weather conditions, with consumption around 8-10 litters/person/day compared to apartment residents who consume between 240 and 450 liters/person/day (Dore and Nagpal, 2006). As a result, in Ger areas, less greywater is produced (4-5 litters/person/day). The water contains high chemical and biological contaminants at household levels, which may Ger residents to be exposed to environmental and health hazards (Uddin et al., 2014a; Uddin et al., 2014c). Indeed, the greywater production in the Ger areas is much lower than other high and low income countries in the world (WHO, 2006).

To overcome these challenges, an 'Ice-Block Unit' was selected, constructed and tested for greywater treatment during the summer period (July-September) of 2013 in the peri-urban Ger (informal settlement) areas of Ulaanbaatar, Mongolia to assess the system feasibility, socio-cultural acceptability and marketability.

MATERIALS AND METHODS

Study area

Mongolia, is distinguished as 'Modern Mongolia', which is landlocked by China and the Russian Federation. The detailed of the study area (Figure 1) has been discussed elsewhere. Majority of population particularly in the Ger areas of Mongolia use unimproved and unhygienic sanitation technologies (e.g. pit latrines, soak pits) for solving sanitary problems especially the greywater disposal purpose (Uddin et al., 2014a; Uddin et al, 2014c).

Site Selection and System Construction

After reviewing various technological options, an 'Ice-Block Unit' was selected, constructed and tested for greywater treatment during the summer period (July-September) of 2013 in the peri-urban Ger (informal settlement) areas of Ulaanbaatar, Mongolia. This system is based on storing water during the entire winter freezing period as an ice block, and then starting treatment during the summer/non-freezing period. This project was conducted in 2013 as part of a joint research project involving the University of Science and Technology of Beijing (USTB) and Action Contre La Faim (ACF) Mongolia. A suitable site was selected after visiting seventeen sites in the study area based on defined factors such as availability of land for construction, agricultural lands and activities for reusing treated greywater, household interest regarding the Ice-Block

Unit and water reuse. Three major components (storage pond—septic tank—constructed wetland) were set up at the household level (Figure 2). Storage capacity for 7.5 months (mid-October to May) corresponding to 225 days for three residents was tested with a consumption of 8 l/p/d (24 l/d x 225 d = 5400 l). The Ice-Block Unit is currently in the storage/freezing stage and it is being monitored for disposal of greywater. Treatment will be subsequently monitored to analyze the water quality both for chemical (e.g. TSS, COD, $N\text{-}NH^+_4$, PO_4^-) and biological (e.g. *E. coli*) parameters, and to investigate the Ice-Block Unit's feasibility, adaptability, and potential for Mongolia.

Figure 1: Map of the study area.

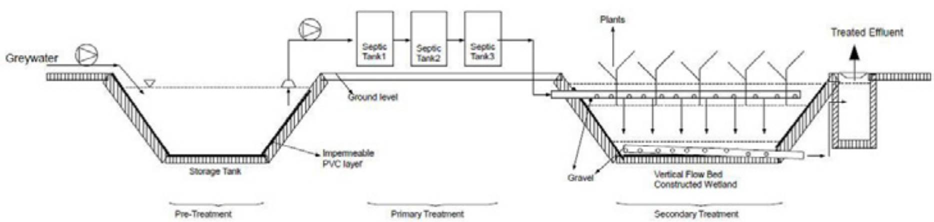

Figure 2: Schematic Diagram of Ice-Block Greywater Treatment Unit (IB-GWTU)

Figure 3: System construction stages

Figure 4: Side view of the system (Up- summer and below winter)

Customer Survey

A household survey, with structured questionnaire, was conducted between June and August 2014 in the peri-urban (Ger) areas of Ulaanbaatar, Mongolia, among the users of ACF sustainable sanitation (SuSan) technologies and services. The survey assessed customer satisfaction, their willingness to pay for the greywater treatment and reuse, knowledge and attitude about it. Eighty households were interviewed out of 350 SuSan technology users.

Policy Dialogue

A policy dialogue has been organized in March 2014 and the situation and possibilities of greywater treatment and reuse options in Mongolian context were discussed. Several government agencies, universities and NGOs were the participants for spontaneous discussion on the greywater issue for the Ger areas. The summary and key outcomes of the discussions were analyzed.

RESULTS AND DISCUSSIONS

Characteristics of Greywater

The greywater of Ger area's households has been already analyzed and characterized by Uddin et al. (2014a) and ACF/USTB (2010) and very high concentration of chemical parameters were found which even higher than many countries' industrial wastewater effluent. Greywater quality can be varied due to wide range of human activities and its value can be fluctuated (Santos, et al., 2012). The analysis that was done by Water Supply and Sewage Authority (USUG) Laboratory of Mongolian shown the concentration of chemical parameters, particularly the chemical oxygen demand (COD), of majority of the household samples were extremely higher than the COD of effluent from different industries, dairy mills (Rajeshwari et al., 2000; Rajkumar and Palanivelu, 2004). The concentration of TSS of half of the samples was higher than wastewater effluent from pineapple industry (Musa and Ahmad, 2010). There are three sources of greywater were sampled which include hand washing sink, kitchen, and laundry. The ranges of COD (35-49969 mg/L), pH (3-10), EC (209-6890), TSS (168-9280 mg/L), NH_4^- (0-504.5 mg/L), PO_4^- (0-82.8 mg/L), BOD (0-3358 mg/L).

Factors on Greywater

The concentration of chemical parameters in greywater was explained by Uddin et al. (2014a) and ACF/USTB (2010) as follows:

- The average water consumption in the Ger areas is very lower than the apartment areas.
- The water is used for several times for different purposes.
- The diet and cooking manners is different from those countries generally referred to as 'usual values'. Mongolian style cooking uses much fat and milk.
- Chemical detergents are used intensively.
- In order to increase the water use efficiency, households use the kitchen greywater to feed the dogs, the laundry greywater is reused for floor cleaning, only the water which was used for personal hygiene is dumped directly.

The influence of technology on behavioral change is very slow in traditionally nomadic societies than other parts of the world. Most of these people reside in Yurts (felt tents) (Mauvieux et al., 2014) without connection to water supply, sewerage or any sanitation system (Uddin et al, 2014a). The practice of greywater production and disposal of the new migrated residents in the Ger areas remained unchanged. These practices may influence greywater production and its technological replication processes.

As there is no sewerage system in the Ger areas, the inhabitants dig their own pit latrine toilets. Being sedentary in the more urban setting, they depend on animals rather than crop production. Although more people continue to migrate to the urban and peri-urban settings, most of the pastoral nomads retain their food habits and lifestyles. Consumption of other liquids (e.g. milk tea, fermented milk, horse milk) instead of water is highly practiced in nomadic societies. The consumption rate of those liquids is much higher during the long winter than the short summer. Less consumption of water due to the difficulty of water collection, more time to collect water and excess fuel consumption to boil drinking water result in lower greywater production (Uddin et al., 2014a) Most herders intake of vegetables is very low and is comprised primarily of meat. The use of high chemical detergent usage is becoming increasingly common over the past decade (Uddin et al., 2014a; Schüßler, 2011).

System Performance

The system is still under monitoring stage. However, there were some challenges faced during the operation and maintenance of the system. The data will be analyzed after receiving the complete monitoring results.

Customer Survey Results

The results from the customer survey shown that majority of the respondents (85%) dispose greywater to either pit latrines or soak pit and rest of the respondents dispose to the ground both inside and outside the household compounds. They practiced this due to the lack of other options to dispose greywater and their long terms behavior. The average amount of greywater disposal was 5 liter/person/day. There were a range of problems encountered by the respondents during the disposal of greywater which include full of soak pit and pit latrines, bad odor, flies, freezing during winter which may be hazardous for health, uncomfortable, frequent movement to dispose greywater. A number of respondents (21%) reused water for some purposes such as washing clothes, cleaning house, washing car, cleaning vegetable and irrigating tree at their gardens. Sixty four percent of the respondents were expressed that they are not satisfied with the current system and they were interested to grow vegetables in their compounds by using treated greywater. Fifty three percept respondents were agreed to treat the greywater before disposal due to sanitary, regulation, health and environmental reasons. Almost half of the respondents have gardens in their compounds which may be a trigger points scaling up the greywater systems in the areas and rest of the respondents may not aware much about the greywater treatment options and its benefits. Over two third of the respondents were interested to share the installation and maintenance cost with their neighbors to save money. This can be explained that a community scale of greywater system can be scaled up in the areas. Thirty seven percent of the respondents said that they were not interested in greywater treatment and almost two third of them expressed their interests to treat greywater.

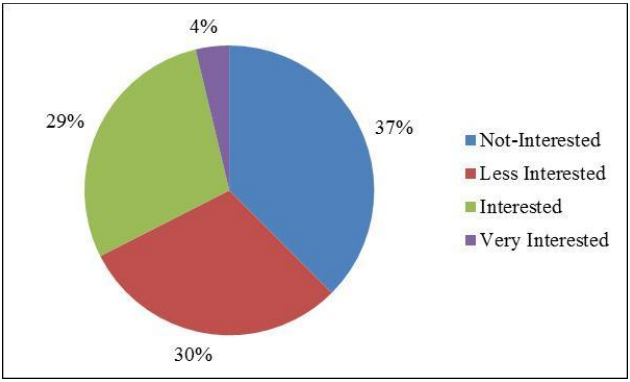

Figure 5: Respondents' interests in greywater treatment.

Ways Forward: Directions for Policy, Advocacy and Guidelines

There are some major findings from the policy dialogue which can be considered as major challenges, listed also by Uddin et al. (2014a).The economic issue is much concerned by government for greywater treatment and reuse options. As long as the price of new water is so cheap reusing greywater will not make economic sense for them in terms of reuse practices. Currently there are no legal regulations in Mongolia on treating/reusing greywater. The greywater treatment infrastructure does not exist in Mongolia (Uddin et al., 2014a). As Mongolia is in transition of development, the country may need lots of things to consider and develop. They may also need expert supports either from NGOs or other stakeholders. Convincing government agencies in many sectors is a challenge including the greywater treatment and ruse. Although economic part is very much important and highly discussed in many forum and they exclude the major parts of the hazards and vulnerability of both health and environment including surface and groundwater contamination due to unplanned discharged of greywater to the environment. Difficulties of water collection by residents due to a range of factors and the contamination issues are also omitted. Proper directions, evidence and advocacy tools on various technological options and social issues can be the major triggers to catalyze government for considering the onsite and decentralized greywater treatment and reuse options in the Ger areas and to formulate relevant regulations and policies on this.

Acknowledgement

Support from ACF International France and ACF Mongolia is acknowledged.

References

Dore, G. and Nagpal, T. 2006 Urban transition in Mongolia: Pursuing sustainability in a unique environment. Environment: Science and Policy for Sustainable Development, 48(6), 10-24.

Hofmann, J., Hurdler, M., Behrendt, H. and Opitz, D. 2010 Integrated water resource management in Central Asia: Nutrient and heavy metal emissions and their relevance for the Kharaa River Basin, Mongolia. Water Science and Technology, 62(2), 353-363.

Konnerup, D., Koottatep, T. and Brix, H. 2009 Treatment of domestic wastewater in tropical, subsurface flow constructed wetlands planted with *Canna* and *Heliconia,* Ecological Engineering, 35, 248-257.

Priess, J. A., Schweitzer, C., Wimmer, F., Batkhishig, O. and Mimler, M. 2011 The consequences of land-use chance and water demands in in Central Mongolia. Land use Policy, 28, 4-10.

Malsy, M., der Beek, A., Eisner, M. and Florke, M. 2012 Climate change impacts on Central Asian water resources. Adv. Geoscience, 32, 77-83.

Ning, R. Y. 2002 Arsenic removal by reverse osmosis. Desalination, 143, 237-21.

Rajeshwari, K. V., Balakrishnan, M., Kansal, A., Lata, K. and Kishore, V. V. N. 2000 State-of-the-art of anaerobic digestion technology for industrial wastewater treatment. Renewable and Sustainable Energy Reviews, 4, 135-156.

Rajkumar, D. and Palanivelu, K. 2004 Electrochemical treatment of industrial wastewater. Journal of Hazardous Materials, B113, 123-129.

Schüßler, A. 2011 Greywater treatment units in Ger settlements in Ulaanbaatar, Mongolia. Work Report on Phase 1, Specific Activities: Greywater Handling & Treatment, University of Science and Technology Beijing, China.

Shih, MC. 2005 An overview of arsenic removal by pressure-driven membrane processes. Desalination, 172, 85-97.

Uddin, S.M.N., Li, Z., Mang, HP., Schubler, A., Ulbrich, T., Huba, E.M., Rheinstein, E., and Lapegue, J. 2014a Opportunities and challenges of greywater treatment and reuse in Mongolia: Lessons learnt from piloted systems, Journal of Water Reuse and Desalination, 4(3), 182-193.

Uddin, S.M.N., Li, Z., Mang, HP., Huba, E.M., and Lapegue, J. 2014b A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems, Journal of Water, Sanitation and Hygiene for Development, 4(3), 437-448.

Uddin, S.M.N., Li, Z., Gaillard, J. C., Tedoff, PF., Lapegue, J, Mang, HP., Huba, E.M. Kummel, O., and Rheinstein, E. 2014c Exposure to WASH-borne hazards: A scoping study on peri-urban Ger areas in Ulaanbaatar, Mongolia. Habitat International (In Press).

UN WATER 2013 Mongilia: UN Water country brief, Ulaanbaatar, Mongolia. Website: http://www.unwater.org/downloads/WCB/ebooks/MNG/MNG.html#p=1 (accessed September 2014)

WHO, 2006 Guidelines for the safe use of wastewater, excreta, and greywater. Volume IV, Excreta and greywater use in agriculture, World Health Organization, Geneva, Switzerland.

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