KOREA INTERNATIONAL WATER WEEK

KOREA INTERNATIONAL WATER WEEK

World Water Challenge 2017

Date September 21, 2017
Venue 201 HICO | Gyengju, Korea

Ministry of Land, Infrastructure and Transport

KOREA WATER FORUM

World Water Challenge 2017

World Water Challenge is an international contest and award for individuals and organizations towards solving the global water problems. As a follow up event of the 7th World Water Forum in 2015, this 3rd edition of the World Water Challenge has been planned and prepared to identify imminent water problems that world is facing and to find feasible solutions to them. As one of the signature programs of KIWW 2017, it is expected to serve its role as an important platform to share the innovative ideas and technologies on water issues arising from all around the world and to forge a broad network between a diverse pool of problem owners suffering from diverse water problems and solution providers together with water-related stakeholders.

- » Date/Venue **Sep. 21st 13:00~17:20 / Room 201(2F), HICO, Gyeongju**
- » Participants **Participants of final round, water-related organizations and corporations, Medias and other interested persons**
- » Host/Organizer **Ministry of Land, Infrastructure and Transport / Korea Water Forum**

World Water Challenge 2017

Program

Time	Contents
13:00~13:05	Opening
13:05~13:10	Opening and Congratulatory Remarks
13:10~13:15	Introduction of World Water Challenge 2017 Final Round
13:15~13:35	**Invited Talk : Development of water purifier with filter made by raw materials in Cambodia** Kwang-Taek Hwang, Chief Researcher, Korea Institute of Ceramic Engineering & Technology, Korea *The winner of the World Water Challenge 2016
13:35~13:55	**VAC Initiative for rainwater self-collection system for public space in Ho Chi Minh City** Du Duong Bui, Deputy Director, National Center for Water Resources Planning and Investigation (NAWAPI), Vietnam
13:55~14:15	**Improving water management with a game-based approach** Cheng Zi Chew, Head of Serious games, DHI, Denmark
14:15~14:35	**Groundwater Recharge Wells** Julien GOALABRE, Communication & Fundraising Officer, IDEP FOUNDATION, Indonesia
14:35~14:55	**Smart water management to overcome water crisis in Cisangkuy river and Bandung mega city, Indonesia** Ick Hwan Ko, Vice President, Yooshin Engineering Corporation, Korea
14:55~15:15	**Sanitation Revolution : From Waste to Resource** Shervin Hashemi, Research Student, Seoul National University, Korea
15:15~15:25	Coffee Break
15:25~15:45	**Integrated Urban Water Management : Tradition to Solution for Cities** Nikhil Shirish Kulkarni, Senior Project Officer, ICLEI, India
15:45~16:05	**Low cost Do it Yourself Rain water harvesting in cooperation with Local Government** Abian Marasini, Mechanical Engineer, Water and Energy Commission secretariat, Nepal
16:05~16:25	**Self-Tank Roof Water Harvesting Soil Cement base Ferro Cement Tank** Susan Shakya, Technical Coordinator, HELVETAS Swiss Intercooperation Nepal, Nepal
16:25~16:45	**A bucket brings fresh water, Sorain Bucket** HyeIn SHIN, Graduate school student, Sungkyunkwan University Graduate School of Water Resources, Korea
16:45~17:05	**Compact & improved onsite sanitation for urban centres of Bhutan using wind/solar assisted aeration** Hokyong Shon, Associate Professor, University of Technology Sydney, Korea
17:05~17:10	Closing Remark
17:10~17:15	Group Photo & Notification of Award Ceremony
17:15~17:20	Closing

KOREA INTERNATIONAL WATER WEEK

Contents

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Invited Talk

Development of water purifier with filter made by raw materials in Cambodia

WINNER of WORLD WATER CHALLENGE 2016

Kwang-Taek Hwang
Chief Researcher, Korea Institute of Ceramic Engineering & Technology, Korea

Development of water purifier with filter made by raw materials in Cambodia

- Kwang-Taek Hwang

Currently, a billion people in the world live without clean water supply service. Especially, it is difficult to use the commercial water purification system, due to its high cost and requirement of electricity usage, in the underdeveloped country. There are several ways to obtain the drinking water such as a well, life straw, hand pump, which are appropriate to the people in the underdeveloped country. Generally, the degree of the water contamination is various in the different region. It is important to search the best way of water purification with considering the element of the water contamination in the specific region.

For example, the undeveloped region in Cambodia has only 15% of the water supply system. The drinking water can be obtained from rainwater during rain rainy season (from March to October). In dry season, the people drink the water, which is obtained from puddles and ponds, after a few days of sedimentation. However, the remained mud and micro-organism still have a harmful effect to health.

[Concrete port for water storage and drink water from puddle after sedimentation]

Moreover, there are many people live in worse surroundings. The poor people live in the house built on water of Tonle Sap lake, which is the largest lake in South-East Asia. The problem is that they share the lake water for drinking, bathing and dish-washing, without any water purification. Although they are provided water purifiers, the filter inside the system is consumable and needs to be exchanged periodically. They are too poor to buy the expensive commercial filter.

Thus, the people in the underdeveloped country need the water purification system, which does not require electricity and expensive filters. The appropriate system for the water purification should be low cost and easy to be maintained. After the water purification system is provided, it is necessary that they should be able to produce the consumable filter for maintaining the system by themselves. The most important key issue of the appropriate technology for the water purification in the underdeveloped country is how to get 'sustainability'.

To develop the appropriate technology of water purification for the people in the underdeveloped country such as Cambodia, we tried to make the ceramic filter using natural raw material with low cost. We applied the manufacturing process of 'Onggi'. Onggi is Korean traditional earthenware, which surface is microporous. We used sand rich soil and plastic soil, which could be easily obtained in Cambodia region, as starting materials for making Onggi filter.

[Process of making Onggi filter: grinding, forming, formed cup shaped filter, firing]

The sand rich soil and plastic soil were crushed and mixed with water. Then, cup shaped filter was manufactured with the mixed soil using home-made jiggering molding machine. For the next firing step of molded filter, wood kiln was constructed using timbers, which were also obtained easily in Cambodia. Finally, the dried filter was loaded in wood kiln and fired at 1000℃.

We tested the developed cup type filter using the Cambodia pond water in comparison with diatomite filter. The develop filter showed higher water flux and better turbidity than conventional diatomite filter. pH, turbidity, TDS of the filtrated water using the developed filter were 7, 0.12 NTU, 34 mg/L, respectively. These values satisfy the standard of the drinking water. In addition, the contamination could be easily removed by home-use sponge due to the high strength of cup filter.

[Process of making Onggi filter: grinding, forming, formed cup shaped filter, firing]

The water purifying system was made using plastic bucket, and the filter was installed between 2 plastic buckets. Filtering was processed by free fall without electric power. The water purifier was developed using the materials, which could be obtained in Cambodia, and the filter was made using the natural raw materials. As a result, the total cost of manufacturing water purifier was successfully minimized. The developed technology of water purification using Onggi filter including the maintenance was transferred to Cambodian people. Especially, it was possible to get 'sustainability' by producing the consumable filter by themselves.

In order to develop and supply the water purifying system, we collaborated 'Good Neighbors', which is NGO in Korea. The specific region where we proceeded the development is Banteay Mean Cheay, located in northwestern part of Cambodia. We are planning to expand the supply of the developed water purifier to the people in floating house of Tonle Sap Lake, where has the worst environment of water supply.

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SOLUTION 1

- Problem -

How Can Rainwater Harvesting Be Implemented to Obtain an Alternative Resource in HCMC, Mekong Delta?

- Solution -

VAC Initiative for rainwater self-collection system for public space in Ho Chi Minh City

Du Duong Bui

Deputy Director, National Center for Water Resources Planning and Investigation (NAWAPI), Vietnam

Problem

How Can Rainwater Harvesting Be Implemented to Obtain an Alternative Resource in HCMC, Mekong Delta?

- Nguyen Duc Canh

Ho Chi Minh metropolitan area, Mekong delta, is facing a serious water crisis because of the increasing water demand due to the rapid population and economic growth; and the water quality and quantity problems regarding its two main water sources, river and ground water. Both waters are seriously polluted by ongoing sources in the highly populated and urbanized region. Seawater intrusion and groundwater depletion substantially limit the availability of the water resources.

This is threatening the public health of the residents and causing many serious economic-social conflicts in Ho Chi Minh city. Rainwater harvesting has been suggested as an effective way to obtain alternative water resources in the metropolitan area. The Vietnamese people has positive attitude toward rainwater harvesting as it is their tradition. The region receives a plenty of precipitation, which indicates a potential of the application of rainwater harvesting. However, the challenges of rainwater harvesting and the utilization of the collected rainwater are how to obtain a large and clean rainwater collection surface in the populated region. To obtain rainwater with reasonable quantity and acceptable quality, a technological breakthrough to place a large collection surface in the populated region and to maintain its cleanness is required.

Solution

VAC Initiative for rainwater self-collection system for public space in Ho Chi Minh City

- Du Duong Bui

Addressing the problem to harvest rainwater as an alternative resource in Ho Chi Minh city, the authors thus propose a solution based on a Vietnamese traditional ecological knowledge that has been approved sustainable for ages named VAC. In rural areas in Vietnam, Vuon (Garden) – Ao (Pond) – Chuong (Live-stock) (VAC) has been popularly practiced since a long time ago to be both productive and resource-conserving (Figure 1). VAC holds a strong sense of stewardship for natural ecosystems and place attachment. The most important features of VAC for rural environment are its close-loop process (Garden provides food for Livestock, then Livestock produces compost for Garden, Pond provides irrigation for Garden, then Garden provides food for aquatic species in Pond, etc.) and available use and recovery of natural resources (Pond restores rainwater for irrigation, Garden reduces excess water in heavy rain and naturally treats wastewater from livestock before releasing it to Pond). This has provided the most important implication for urban landscape designers and flooding managers that is to respect and follow functions and characteristics of natural ecosystems.

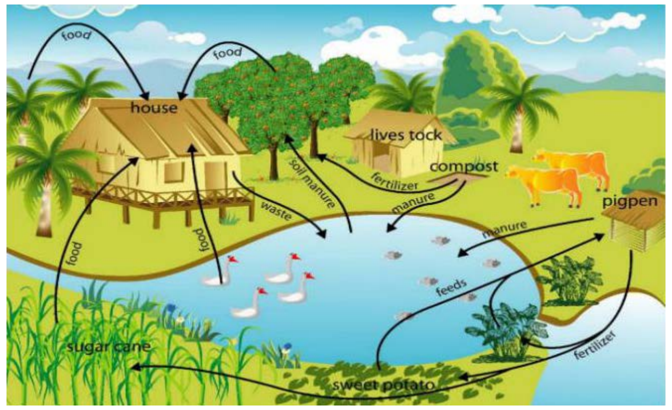

Fig. 1
Simplified sketch of VAC farming system in Vietnam (Duong et al, 2013)

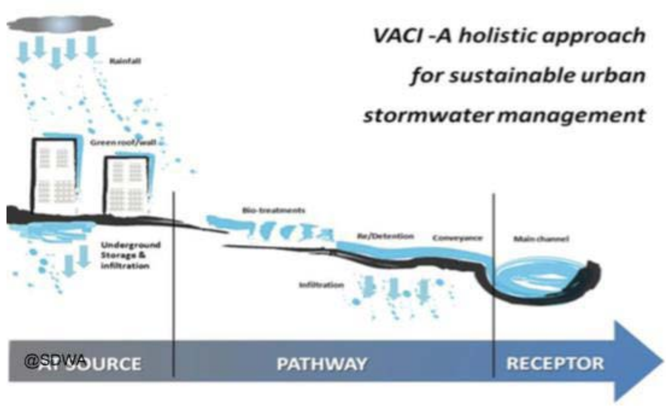

Fig. 2
Proposed VACI for urban stormwater management. Source: adapted from Singapore's ABC Water

In the context of cities, VAC provides important lessons to ensure that city can be also both productive and resource-conserving, particularly water conservation. Firstly, it conserves excess stormwater runoff as an alternative resource for vegetation watering through an entire runoff process, including at the Sources, on the Pathway, and to the Receptors (Figure 1). Learning from VAC practices in rural area, VAC Initiative in the cities aims to maximize the use of natural materials, functions and enhances the inter-connections

Solution

among relevant elements for future infrastructures construction. Some examples of natural measures that have been developed globally are green roofs, permeable surfaces, bio-detention, and swales (Figure 3). Secondly, with this natural infrastructure approach, it could reduce lag time (time from rainfall peak to flood peak), thus reducing severe pluvial flooding risks (Figure 4). Thirdly, stormwater harvesting through VACI could eventually optimize recharge aquifers as close to rainfall source as possible. Fourthly, with the holistic approach of VACI with green-water-biodiversity, it will ultimately enhance urban biodiversity and urban amenity.

The effectiveness of VACI approach in rainwater harvesting as an alternative resource has been tested by authors whether VACI could really help reduce flood risks in My Dinh suburb, Hanoi, Vietnam. Authors set up Model Urban Stormwater Improvement Conceptualization (MUSIC) which is a powerful tool to support decision making process in stormwater management. The study simulated drainage capacity of My Dinh for floods in 2003 and 2008 and evaluated the effectiveness of two different measures including rainwater tanks and buffer strips to reduce flooding based on the flooding in 2008. MUSIC model results showed that the flood peak flow reduced 10.2% and 19.4% respectively according to rainwater tanks and buffered area measure.

Fig. 3
VACI examples

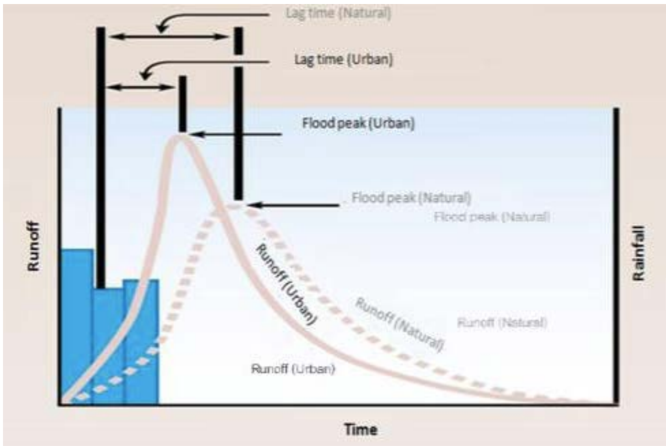

Fig. 4
Effect of urbanization on hydrograph & lag time. Source: FISRWG 1998.

The study results apparently show that this VAC could help address rainwater harvesting as an alternative resource in Ho Chi Minh city, Vietnam, which could also bring the smooth pathway towards a city of greenery (garden), water sensitive (pond), and biodiversity rich (livestock).

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SOLUTION 2

- Problem -

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- Solution -

Improving water management with a game-based approach

Cheng Zi Chew

Head of Serious games, DHI, Denmark

Problem

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- William Putuhena

Population increase and rapid urbanization in the West Java Indonesia bring significant challenges on sustainable water resources management. Especially, the Cisangkuy river basin, located in the south of Bandung Metropolitan is suffering from severe water shortage, poor water quality, and frequent flooding disaster. The basin is subject to tropical climate pattern which is marked by two seasons, wet season from October to March and dry season from April to September. 85% of the average annual rainfall occurs during wet season. Huge variation of rainfall is to be aggravated due to the increasing risk of extreme hydrology from global warming and climate change.

The basin is an important source of water supply to Bandung Metropolitan. However, the mega city has already stressed to secure water for dense population of 2,500/km2. Water shortage will hinder sustainable growth and welfare of the residents.

The population of Bandung Metropolitan will exceed more than 10 million in 2040. Corresponding water demands are to increase from 16.6 m^3/s in 2010 to 23.4 m^3/s in 2040. Competition on the limited available water resources among various water uses such as municipal, irrigation, hydropower, and industry has increased conflict significantly over the past 2 decades leading a situation of acute water and environmental stress in the region.

Too much groundwater abstraction traps the sustainability of water environment in the region, Reshaped water management to stop severe land subsidence should be prepared. Deforestation and rapid land use changes cause further challenges.

Furthermore, fragmented water management governance with poor water facilities operational capability of basin water managers deteriorates conflict among stakeholders in water resources management. Sharing data and information among stakeholders still challenges. **Building innovative technological approaches with institutional setting** through **intelligent and integrated basin water resources management** is urgently required to overcome water crisis in the region.

Solution

Improving water management with a game-based approach

- Cheng Zi Chew

The water management crisis in Cisangkuy River and Bandung Mega City in Indonesia attributes to a lack of good decision making process. To solve this crisis, the principles of Integrated water resources management (IWRM) has to be adopted to improve water management governance in the area.

Our solution is to address this situation from a bottom up approach, by raising awareness and communicating the importance of IWRM as well as possible feasible solutions to the general public and especially to the younger generations with a game-based approach.

A game-based approach combines a learning objective in an interactive media, in order to increase the potential for learning uptake. Such an approach is not new and has a long history of application for everything from the songs one learned as a child, to various work-related teambuilding events that one may have been subjected to over the years. Perhaps one of the best-known applications of an electronic -based serious "game" is that of flight simulators used in pilot training. One of the main reasons for the success of this kind of application is the recognized fact that pilots need a very realistic learning environment, but also one that is low risk and allows them to make non-catastrophic mistakes that they can learn from.

In terms of water management simulation, DHI has a serious game platform called Aqua Republica which combines game mechanics and hydrological simulations in catchments to help people better appreciate the critical connections between water, social and economic development, and environmental sustainability. This is especially important in situations where there is a lack of good decision-making, or even a complete lack of decisions, on how resources should be allocated between various municipal, agricultural, industrial and energy users and uses, while also taking into account environmental services and climate change impacts.

The platform is flexible enough to cover a range of settings, as well as age and competency levels. Where there is a need to go broader or deeper in certain areas, such as the Sustainable Development Goals, a specific geography, or with different learning goals, tailored versions of the game have been created. The ability to do this is primarily down to the structure of the game, which is much more sophisticated than the user-friendly interface might suggest.

In Aqua Republica a water allocation model simultaneously communicates and interacts with the game engine, while the player is playing the simulation. The engine uses the results from the model that are directly linked to other socio-economic parameters, such as population, economy as well as some non-quantifiable social and cultural concerns. The interaction between the game layer and the scientific model produces evolving scenarios to which players must react and adapt.

This level of sophistication allows DHI to help improve water governance through education around water resource management as well as facilitating stakeholder participation processes around water resource management.

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SOLUTION 3

- Problem -

How Can Rainwater Harvesting Be Implemented to Obtain
an Alternative Resource in HCMC, Mekong Delta?

- Solution -

Groundwater Recharge Wells

Julien GOALABRE

Communication & Fundraising officer , IDEP FOUNDATION , Indonesia

Problem

How Can Rainwater Harvesting Be Implemented to Obtain an Alternative Resource in HCMC, Mekong Delta?

- Nguyen Duc Canh

Ho Chi Minh metropolitan area, Mekong delta, is facing a serious water crisis because of the increasing water demand due to the rapid population and economic growth; and the water quality and quantity problems regarding its two main water sources, river and ground water. Both waters are seriously polluted by ongoing sources in the highly populated and urbanized region. Seawater intrusion and groundwater depletion substantially limit the availability of the water resources.

This is threatening the public health of the residents and causing many serious economic-social conflicts in Ho Chi Minh city. Rainwater harvesting has been suggested as an effective way to obtain alternative water resources in the metropolitan area. The Vietnamese people has positive attitude toward rainwater harvesting as it is their tradition. The region receives a plenty of precipitation, which indicates a potential of the application of rainwater harvesting. However, the challenges of rainwater harvesting and the utilization of the collected rainwater are how to obtain a large and clean rainwater collection surface in the populated region. To obtain rainwater with reasonable quantity and acceptable quality, a technological breakthrough to place a large collection surface in the populated region and to maintain its cleanness is required.

Solution

Groundwater Recharge Wells

- Julien GOALABRE

Ho Chi Minh City has an issue of uncontrolled growth in regards to its water resources. The deficit of water supply makes the city unsustainable in the long term. Both industrial and tourism growth is putting a high strengths on the water tables which rainfall itself cannot cope with. The constant pressure the ocean is putting on the coastal aquifers is creating space for the salt water to infiltrate the water tables, something that is irreversible as it would permanently pollute the groundwater.

Urbanisation is reducing the number and sizes of natural catchment areas, creating a negative cycle where groundwater harvesting is limited while its consumption is increasing.

Rainwater harvesting needs to be directed underground, where the aquifers are drying in order to refill the missing water naturally. To do so, we call for a solution called “Recharge Well” harvesting rainwater from the ground and roofs and direct it back into the ground after natural filtration. After much research into potential solutions and the way to connect them, looking at case studies around the world, technologies allowing rainwater to be returned to the water tables via gravity came clearly to the front for the rapidity of the recharge rate they allow, their low implementation cost (in some cases wells previously used for extraction can be rehabilitated), their overall high performance for minimal investment, their easy replicability and durability. They may also permit to avoid calling upon costly and potentially highly damaging environmentally-wise technologies such as dams for water supply (which in addition do not address the problem of aquifer replenishment).

here. Rainwater gravity-fed recharge wells allow to:

. rapidly increase the overall available supply of fresh water

. alleviate a ground subsidence condition that has been in progress for years

. supplement the quantity of groundwater available.

They replenish water supply sources without electricity nor short-life-cycle complex machinery and provide good quality water and in coastal areas in particular, help in maintaining the balance between the fresh and saline water aquifers, reducing or balancing salt water intrusion.

They also can be so placed as to conserve and help to dispose of run-offs and flood waters with the additional benefit to prevent water stagnation (mosquitoes breading ground); finally they can be implemented rapidly and are “easy” and cost-effectively replicated.

Our solution also proposes to integrate an education component in schools with children living along the provinces principal rivers, via a teaching session on ecological principles (basic biospheric cycles) and effects of garbage on water (to allow an objectification of the natural elements taken for granted) and via sharing a hands-on “playing in and cleaning the river” session with the children to invite them to become caretakers and ambassador of their section of the river.

Finally, the field and educational aspect being addressed, there remained the public awareness level in great need of assistance. The general lack of awareness about the water crisis will be addressed through a general media information campaign.

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SOLUTION 4

- Problem -

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- Solution -

Smart water management to overcome water crisis in Cisangkuy river and Bandung mega city, Indonesia

Ick Hwan Ko

Vice President, Yooshin Engineering Corporation, Korea

Problem

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- William Putuhena

Population increase and rapid urbanization in the West Java Indonesia bring significant challenges on sustainable water resources management. Especially, the Cisangkuy river basin, located in the south of Bandung Metropolitan is suffering from severe water shortage, poor water quality, and frequent flooding disaster. The basin is subject to tropical climate pattern which is marked by two seasons, wet season from October to March and dry season from April to September. 85% of the average annual rainfall occurs during wet season. Huge variation of rainfall is to be aggravated due to the increasing risk of extreme hydrology from global warming and climate change.

The basin is an important source of water supply to Bandung Metropolitan. However, the mega city has already stressed to secure water for dense population of 2,500/km2. Water shortage will hinder sustainable growth and welfare of the residents.

The population of Bandung Metropolitan will exceed more than 10 million in 2040. Corresponding water demands are to increase from 16.6 m^3/s in 2010 to 23.4 m^3/s in 2040. Competition on the limited available water resources among various water uses such as municipal, irrigation, hydropower, and industry has increased conflict significantly over the past 2 decades leading a situation of acute water and environmental stress in the region.

Too much groundwater abstraction traps the sustainability of water environment in the region, Reshaped water management to stop severe land subsidence should be prepared. Deforestation and rapid land use changes cause further challenges.

Furthermore, fragmented water management governance with poor water facilities operational capability of basin water managers deteriorates conflict among stakeholders in water resources management. Sharing data and information among stakeholders still challenges. **Building innovative technological approaches with institutional setting** through **intelligent and integrated basin water resources management** is urgently required to overcome water crisis in the region.

Solution

Smart water management to overcome water crisis in Cisangkuy river and Bandung mega city, Indonesia

- Ick Hwan Ko

According to OECD, 2.3 billion people (over 40% of the global population) are expected to be living with severe water stress by 2050. Rapid urbanization and increasing population in the West Java Indonesia cause extreme challenges for sustainable water resources management. The Cisangkuy river, located in the south of Bandung Metropolitan, is an important source of water supply to the mega city which is suffering from serious water scarcity, poor water quality, and repeated flooding disaster.

In the basin, Bandung Metropolitan has already stressed with dense population of 2,500 persons/km2. The population of Bandung city will exceed 10 million in 2040. The corresponding domestic, municipal and industrial water demands in the region are to increase from 16.6 m^3/s in 2010 to 23.4 m^3/s in 2040. At present, the entire Bandung Metropolitan suffers from water deficit 14.2 m^3/s. Structural measures such as dam construction are costly and time consuming due to land acquisition, resettlement of people and relocation of businesses and livelihood.

Furthermore, fragmented basin water management governance with poor water facilities operation capacity intensifies conflict among stakeholders and blocks efficient water resources management. Data and information sharing among stakeholders still challenges.
In order to meet these challenges, implementation of Smart Water Management (SWM) system has proposed as a solution for integrated basin water management. As part of implementing these efforts, a cooperative research project between Indonesia and Korea is on-going to develop SWM system in the Cisangkuy river basin. The system will provide sustainable decision support tool for the basin water managers and residents to promote optimized water supply and maximized water use efficiency through coordinated multi-water facilities (dam, weir and power plant etc.) operation as non-structural measure.
As a result of case study regarding two different scenarios, it shows that new operation rule as part of SWM measures will contribute not only for securing additional water for residents under severe water stress through the implementation of non-structural measures but also for contributing through capacity building for basin water management agencies to improve their water facilities planning, development, operation and management in an cooperative and coordinated way to achieve smart IWRM for the citizens and residents in the area.

If the basin water managers such as BBWSC (overall basin water development and management representing central government), Indonesia Power (hydropower facilities operator), Pdams (Water Supplies to Bandung city), DPSDA & BPLHD (water resources & water quality management departments for W. Java Province) build common data sharing system and common decision making governance for sustainable water resources management in the region throughout this Project, they can protect their residents from water related disasters in advance and enhance their quality of life with better water service. Furthermore, if they can show a success story from the advanced innovated scientific approach, their experience will be duplicated to the global water communities especially for developing countries who are in need of this technology and innovation.

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SOLUTION 5

- Problem -

Current Onsite Sanitation System in the Urban Areas of Bhutan is not adequate

- Solution -

Sanitation Revolution: From Waste to Resource

Shervin Hashemi

Research Student, Seoul National University, Korea

Problem

Current Onsite Sanitation System in the Urban Areas of Bhutan is not adequate

- Ugyen Dorji

Bhutan is a small country in the Himalayas sandwiched between the world's two most populated nations with China in the North and India in the south. Although the total population is just about 800,000, it is experiencing the most of the challenges faced by other developing nations both in terms of rapid urbanisation, economic development and environmental issues. Bhutan has made significant achievements on basic sanitation to date; however access to improved sanitation is still low. Improved sanitation is very important particularly in the urban areas where population is more concentrated and where basic sanitation is not adequate. A rapid urban growth has resulted in increased water usage and the volume of wastewater (black water from toilets and grey water from bathrooms and kitchens) generated which needs proper treatment and disposal has also increased significantly. Discharging untreated wastewater directly to the environment poses a significant risk to public health from the presence of highly infectious faecal matter. Besides, the untreated wastewater also contains organic nutrients and other contaminants that pollute our pristine environment (land and water) undermining the environmental health and its natural ecosystem.
Providing public wastewater management infrastructures (collection and centralised treatment system) require huge capital investments because of which Bhutan government has been struggling to provide adequate infrastructures for all urban centres. Currently only 10 out of 61 towns in Bhutan have municipal sewage collection and treatment infrastructures. All other towns including the unsewered areas of the 10 towns therefore depend on the onsite sanitation system for the treatment of domestic black water while the grey water is generally discharged directly to the environment without any form of treatment. The conventional onsite sanitation system consists of a watertight septic tank and soak pit, which is not appropriate for the modern urban settings for number of reasons. Firstly, the treatment efficiency of the septic tank is very moderate relying mainly on effective land infiltration treatment using soak pit. However, soak pit is effective only when large land area and good soil conditions are available and such conditions are not generally found in the urban areas where plots are generally very small and the soil has poor infiltration capacity. Secondly, the onsite treatment systems are also generally poorly designed, constructed and maintained. They have high carbon footprint due to release of methane, a highly potent greenhouse gas that accelerates global warming and climate change. All these ultimately result in the discharge of raw or poorly treated effluent containing highly contagious pathogens and organic nutrients to the environment posing high risk to public health and the environmental pollution.
Therefore there is an urgent need to improve the urban sanitation in Bhutan to replace the age-old system of using septic tank and soak pit system that are no more suitable for the current urban settings. The improved technology must accommodate both grey water and black water treatment as the current septic tanks are not usually designed. The technology should also be cost effective and affordable to the developing countries such as Bhutan.

Solution

Sanitation Revolution: From Waste to Resource

- Shervin Hashemi

Sanitation is a global issue and what is introduced as the challenge of the current onsite sanitation system in the urban areas of Bhutan is another example of this spreading worldwide problem.

The presented sanitation problems of Bhutan are actually a group of technical, social and economic challenges. Lack of a well-developed infrastructure, increasing the amount of wastewater because of high population growth, low capacity of the applied septic tanks and soak pits, and production of methane due to the improper treatment process can be categorized as technical challenges. Accordingly, poor maintenance of these sanitation systems can cause social problems. Thus the demand of importing wastewater treatment equipment is an example of the economic challenge.
As a solution, we are providing an innovative integrated sanitation system, suitable for urban area which not only is expected to sustainably solve the presented sanitation challenges in Bhutan, but also can be a very good example for a system which is matched with outlines of the Target 6 of the Sustainable Development Goals (SDG6).

The system follows two main strategies: reduction of water consumption and separation in sanitation. Reduction of water consumption is being done by applying water flow limiters and utilizing water-saving facilities for all sanitation activities except toilets. Separation strategies are applied by utilizing urine diversion composting toilet systems in the new buildings. In these systems, urine and feces are gathered separately and after a hygienic biochemical treatment process, they can be utilized as fertilizer. To have an economic approach, for existing buildings, only urine is being stored separately using flushing urine diversion toilets and feces is being sent to the existing septic tanks.

Through this system, there will be no requirement for applying any substantial changes to the correct infrastructure of septic tanks or soak pits. Applying the reduction of water consumption strategies can increase the detention time for the current infrastructures which not only can improve the operation and maintenance procedure of them but also it can effectively reduce the required costs and even bring benefits by considering sanitary matters as nutrient resources.

By applying this system, it is expected that there will be an overall improvement for the environment as well as lives of plants, animals, and human being by reducing the nutrient load and contamination in the produced wastewater. Thus this system not only may be able to solve the challenges of sanitation systems in Bhutan but also it can solve water problems globally by reducing the wastewater flow and nutrients loads. The system is well matched to be utilized in Bhutan as an agricultural oriented society by treating sanitary materials to be utilized as fertilizer.

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SOLUTION 6

- Problem -

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- Solution -

Integrated Urban Water Management: Tradition to Solution for Cities

Nikhil Shirish Kulkarni

Senior Project Officer, ICLEI - Local Governments for Sustainability, South Asia, India

Problem

Water Management Crisis in Cisangkuy River and Bandung Mega City in Indonesia

- William Putuhena

Population increase and rapid urbanization in the West Java Indonesia bring significant challenges on sustainable water resources management. Especially, the Cisangkuy river basin, located in the south of Bandung Metropolitan is suffering from severe water shortage, poor water quality, and frequent flooding disaster. The basin is subject to tropical climate pattern which is marked by two seasons, wet season from October to March and dry season from April to September. 85% of the average annual rainfall occurs during wet season. Huge variation of rainfall is to be aggravated due to the increasing risk of extreme hydrology from global warming and climate change.

The basin is an important source of water supply to Bandung Metropolitan. However, the mega city has already stressed to secure water for dense population of 2,500/km2. Water shortage will hinder sustainable growth and welfare of the residents.

The population of Bandung Metropolitan will exceed more than 10 million in 2040. Corresponding water demands are to increase from 16.6 m^3/s in 2010 to 23.4 m^3/s in 2040. Competition on the limited available water resources among various water uses such as municipal, irrigation, hydropower, and industry has increased conflict significantly over the past 2 decades leading a situation of acute water and environmental stress in the region.

Too much groundwater abstraction traps the sustainability of water environment in the region, Reshaped water management to stop severe land subsidence should be prepared. Deforestation and rapid land use changes cause further challenges.

Furthermore, fragmented water management governance with poor water facilities operational capability of basin water managers deteriorates conflict among stakeholders in water resources management. Sharing data and information among stakeholders still challenges. **Building innovative technological approaches with institutional setting** through **intelligent and integrated basin water resources management** is urgently required to overcome water crisis in the region.

Solution

Integrated Urban Water Management: Tradition to Solution for Cities

- Nikhil Shirish Kulkarni

Integrated urban water management (IUWM) is an approach to solve problems of urban water sectors (water supply, waste water treatment and storm water management). In many countries a tradition was followed by several human generations to reuse and recycle water for different needs of an individual. This is an alarming need of today to adopt same approach for our cities facing water related problems. The problem defined for Bandung Mega City needs a holistic understanding which can lead towards choice of best inclusive solution with community engagement; if not today's solution would be tomorrow's problem. It is important for Bandung Mega City to realize that IUWM provides an alternative approach for water management which can address the existing issues of urban water sectors while ensuring efficient use of resources for a water secure future.

The IUWM process promotes a planning-based approach for cities, developed as a part of the European Union funded project on Adopting Integrated Urban Water Management in Indian cities (AdoptIUWM) and has been tested/modified based on the experience of four project cities (Jaisalmer and Kishangarh in Rajasthan; Solapur and Ichalkaranji in Maharashtra) in India. This process is based on the principles of SWITCH Training Kit (Sustainable Water Management Improves Tomorrow's Cities Health) developed as a part of the European Union supported SWITCH research project.

The IUWM process reduces adverse impact arising because of wrong choice of technical solutions or a solution focused only on a limb of entire water cycle neglecting others. This process is flexible to accommodate local issues of a city and significant characteristics to focus on. IUWM process is a step by step guide for planning and management of urban water sectors in an integrated manner. Analysis of problem and choice of solution should be based on the recognition that urban water sectors are elements of the same Urban Water Loop and co-benefits between these sectors can be identified. An IUWM-based approach can lead to improved demand-supply balance which, in turn, can lead to water efficiency, economic benefits for the community, equitable water distribution, improved water access, improved natural resource management and social benefits for vulnerable sections of the society; leading to an inclusive, sustainable and water secure future.

IUWM process has been divided in six stages from assessing existing situation to monitoring and evaluation framework of implemented project.

An IUWM action plan developed under this process help city to prioritize projects on the basis of various parameters like environmental impact, social benefits, economic feasibility and integration across water sectors. Stakeholder involvement and community ownership are inclusive elements of this process. Main outcomes of the IUWM process are listed as following:

1. An approach to address existing water-related issues
2. Resource efficient water management
3. Creation of multi stakeholder platforms for participatory planning and decision making
4. Identification of co-benefits among the urban water sectors
5. Improved capacity of local authority towards managing urban water sectors
6. IUWM-based Vision
7. IUWM-based Action Plan

Priority projects (including technical solutions and strategies) for implementation

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SOLUTION 7

- Problem -

Drinking Water and Sanitation Problem in Bamgha Village, Gulmi Nepal

- Solution -

Low cost Do it Yourself Rain water harvesting in cooperation with Local Government

Abian Marasini

Mechanical Engineer, Water and Energy Commission secretariat (WECS), Nepal

Problem

Drinking Water and Sanitation Problem in Bamgha Village, Gulmi Nepal

- Kamala Dhakal

Bamgha is a beautiful village located in Gulmi district, western part of Nepal. It lies at an altitude of 1500m from sea level. 240 people reside in the village and there is a primary school for children. Modern water supply system is not available in village. People meet their basic demand of water via the water sources like spring and streams that are located far down the village i.e. at the height of 500m. The women and children fetch water by walking from the height of 1000m vertical height. Women and children in particular are often deprived of opportunities to be engaged in various creative and income generating activities because they spend most of their valuable hours in fetching water. Due to water scarcity, the sanitation practice is also poor.

The students of the primary schools are also facing the problem of drinking water and water for sanitation practice.

The village is now electrified. People are trying to install a water pump run by electricity. The running cost of the project with grid-connected electricity is high. Because, paying capacity of the people is less. The average rainfall is also good in the territory. There may be a good option for rainwater harvesting technologies.

But, the villagers are searching for a sustainable and cost effective technology to solve this problem.

Solution

Low cost Do it Yourself Rain water harvesting in cooperation with Local Government

- Abian Marasini

Bhunga village is one of the remote villages of the hilly region of Nepal. Houses are distributed both sides of the hills. Household at the top of the village have to walk 200m down at the winter season to fetch the water. But at the drought season they may have to walk 1000m downhill to fetch the drinking water. Water pumping could be the idea but the problem owner have already described about the financial capacity of the villagers as they can't afford the electricity bills for the pumping. It seems scarcity of the water source is the main problem of the village. Solar-wind powered water pumping could be the scientific solution but drought and low financial condition of the villagers doesn't makes sustainable at all. It is obvious sanitation have been the problem for the villagers due to the shortage of the water.
As annual precipitation of the village is 1600 mm to 1800 mm (as indicated by problem owner), rain water harvesting can be a good idea. Although several modern Rain harvesting system are available but it would not be economically feasible. So I recommend for the Do It Yourself rain water harvesting system. Nepal is typical country and its demography and climatic condition is different from the other country. The technique of harvesting rain water is different. Others countries rain water harvesting technology can't 100% feasible in Nepal but concept could be applicable.
All the equipment necessary for harvesting rain water must be locally made and raw material are locally available. The skills of villagers can be enough for construction. Using this system, there is no any pollution; neither it amplifies deforestation nor landslide. Villagers can be self-dependent for the drinking water and project can be completed within a week.
Although annual precipitation data provided by the problem owner indicates it will be enough for 12 months but for the 2-2.5 months of the peak drought time we can use water pumping as a backup. The bill of the electric water pump of around 2 months can be paid by the local government. Villagers can make a drinking water supply committee within the village and can cooperate with government so that local government will pay the electricity bills in case rain water supply can't supply the demands at the peak few months.

(NOTE: Solar-Wind water pumping is not feasible to scarcity of water in the river during winter season and heavy polluted water in the rainy season. Also Solar-wind project would be highly expensive for the villagers. Fog water harvesting system is also not feasible because specific humidity is low enough and clear sky days are higher than 25 days per month for this village.)

Required components for the rain water harvesting system per household (do it yourself model)
Catchment area: Although problem owner have not clearly indicated the type of the roof of the house in that village but we suggest whatever the roof, plastic will be wrapped at the roof of the house. This improves the quality of the harvesting water and increases the catchment area. That plastic sheet can be available at every household or even can be bought from the near market with small price as compared to its value.

Solution

Delivery system: Guttering is used for the transportation of water from the catchment surface plastic roof) into the filtering vessel. Usually gutters are used as half cut PVC pipe hanging at the edge of the roof. But villagers can also use half-cut bamboo as a gutter because bamboo trees are locally available in the village.
A coarse filter, preferably made of nylon or a fine mesh, can also be used to remove dirt and debris before the water enters the tank. This filter can also be locally made. Or fine transparent slice of clothes can be used as an initial filter for the debris before entering into filtration bucket.
Filtration bucket: This is the bio sand filtration equipment. Outlet of the gutter is connected at the top portion of bucket. Bucket is filled with different layer of gravel, coarse sand and fine sand. These materials are locally available. Outlet of this bucket is connecting to next storage tank. Or we can use directly from the filtration bucket.
Storage tank: This is the collection tank where rain water is collected in this tank. It is better to use two large size of the storage tank. And filter these water whenever is needed. Water must be free from the debris and can be done using simple debris filter at the outlet of the gutter before entering in the storage tank.

SOLUTION 8

- Problem -

Water scarcity issues in the small hilly villages of Gonpasingma, Kherigonpa and Gonpung under Pemagatshel district in Bhutan

- Solution -

Self-Tank Roof Water Harvesting Soil Cement base Ferro Cement Tank

Susan Shakya

Technical Coordinator, HELVETAS Swiss Intercooperation Nepal, Nepal

Problem

Water scarcity issues in the small hilly villages of Gonpasingma, Kherigonpa and Gonpung under Pemagatshel district in Bhutan

- Ugyen Dorji

Bhutan is a small country in the Himalayas sandwiched between the world's two most populated nations with China in the North and India in the south. Bhutan has a very unique development philosophy called Gross National Happiness (GNH), an index that measures the collective happiness in a nation instead of widely used gross domestic product. GNH is a currently based on four pillars: economic self-reliance, environmental conservation, cultural preservation and promotion, and good governance. Bhutan has rich water resources and the high flowing rivers is the main source of hydropower energy most of which are exported to India. Bhutan's constitution mandates to preserve 60% forest cover at all times.
Although environmental conservation is one of the most revered policies in Bhutan however, several rural communities in Bhutan are facing water scarcity issues mostly due to drying up of local water sources. One such typical example is in a remote village located in the eastern part of Bhutan under administrative district called Pemagatshel. Characterized by warm and temperate climate, the villages namely Gonpasingma, Kherigonpa and Gonpung under Pemagatshel are running shortage of drinking water in every winter season. The main sources of the water at the nearby streams have water available only during the summer rainy seasons. Often the aftermath of water shortages results in legal disputes bringing hostilities in the villages. As these villages are located in a steep and rugged terrain, underground water sources are not likely to occur however, such options are constrained as there are no studies recorded for the presence of groundwater in the area. Tapping of excess water from the running streams and harvesting rainwater during the summer season and storing for the winter season is not a suitable option as the dry season could last longer than 6 months and hence the storage capacity would be huge which is not feasible for rugged regions. Currently, these villages collect water from the rivulets below the villages which could be several hours on foot or some using tractors or horse backs, etc.

The water sources in these villages are limited and drying up of these sources is one of the major water issues in these villages. The streams form the main water sources for these villages but these streams are rain fed and dry up during the dry winter season. The drying of water sources is mainly associated due to loss of vegetation within the watershed or catchments to agricultural land. The climate change is also likely to partly blame for such water scarcity due to change in the rainfall pattern. The other reason is that, these villages are located on the border of two different water catchments and on the edge of the main water line where the water cannot be piped under natural gravitation. Shortage of water in the villages might compel the villagers to abandon their homes and farmlands which increase pressure on the urban areas due to rural-urban migration.

Solution

Self-Tank Roof Water Harvesting Soil Cement base Ferro Cement Tank

- Susan Shakya

Rain water Harvesting is only the best option to receive water in this area during winter season. Average annual rainfall in this area is about 1800 mm, which is good enough for domestic use of one family for the period of winter season. The storage tank made from Soil Cement base Ferro Cement lined with galvanized sheet roofing of capacity 6000 lit to 10,000 liters can be construct with very low cost (affordable) independently for each household. In this type of system, the rainfall from the tank roof itself is diverted into the storage tank for storing and the stored water is precisely used in winter season with simple treatment (chlorination).

Soil Cement base Ferro Cement Tank at Yudrik Kengkhar Bhutan

The soil cement base ferro cement lined tank is under-ground, affordable and durable water storage structure which is constructed by using soil-cement mix base coat plastering and two coat rich ferro cement plastering (cement plater with nominal reinforcement: chicken wire mesh) over the excavated earth and ring wall. The bottom of the tank is sealed with plain cement concrete (P.C.C) and the top is covered with CGI sheet or other appropriate roofing material. A low-height ring-wall is made with stone or brick in the mud mortar. It can be constructed in various sizes depending on the requirement of the storage volume. Most commonly, such tanks are made between 6,000 to 15,000 liter capacity. The tank is fairly simple in construction as well as operation and maintenance (O & M). This type of system is independent, fit for everywhere if the rainfall is sufficient, low cost & affordable. This system with water storing capacity 6,000 to 10,000 liters can be complete with 10-15 bags of cements which is quite enough for 3-4 months for one households with consuming 50 - 60 liter water per day.

The soil cement base ferro cement lined tank system can be install for small gravity fed piped water system also. It is common in low hill areas of Nepal in the last 5-6 years, recently it has been piloting in eastern part of Bhutan under Climate Resilient Mountain Hazelnuts Venture, TA support from Asian Development Bank.

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SOLUTION 9

- Problem -

Water Scarcity and Saline Groundwater Affecting Local Community of Kojani Zanzibar

- Solution -

A bucket brings fresh water, Sorain Bucket

HyeIn SHIN

Graduate School Student, Sungkyunkwan University Graduate School of Water Resources, Korea

Problem

Water Scarcity and Saline Groundwater Affecting Local Community of Kojani Zanzibar

- Aline Herrera Ruiz

Kojani island (part of Pemba Islands) in Zanzibar, Tanzania is around 7 square kilometers with a population of 15 000 inhabitants mainly concentrated in the main town called **Kojani**.
Many environmental and socioeconomic factors make the living conditions in Kojani very precarious and vulnerable. The main source of income is agriculture (rice, coconut and clove), fishing and seaweed farming and to some extent there is a certain dependency from tourism (Hansson, 2010).

Kojani Island suffers in terms of water supply, sanitation and hygiene. Groundwater being the primary source of fresh water, it depends on the rainfalls which are characterized by two rainy seasons with drier periods in between. The most important rainy season called Masika runs from the end of March to the end of May and is the most important groundwater recharge for the community.

Water supply in Kojani is very critical due to the inadequacy of infrastructure and water supply insecurity: besides collecting groundwater from the rainy season, the town also collects drinking water from Pemba Island but the amount remains insufficient and the lack of infrastructure doesn't allow the town of Kojani to have a pump station of their own.
To tackle this issue, the local population has developed alternative ways of collecting water but that are neither hygienic nor sustainable: using unclean plastic buckets to transport it from Pemba to Kojani by wooden boats; using shallow open water wells which are already polluted and collecting water directly from artificial ponds.

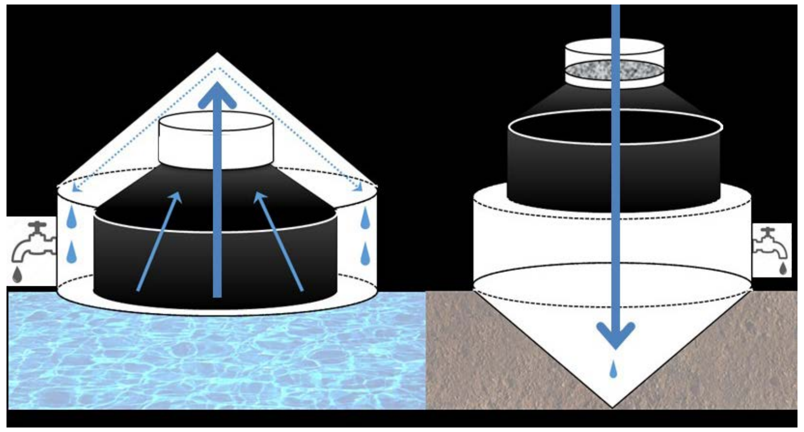
As a result, the city of Kojani has an important problem of water pollution due to a lack of sewage system which also makes villagers use soak-pits as toilets (located inside or near their house and leaks into the groundwater). Water wells are also contaminated by decomposing organic matters (such as leaves, small animals, or dust) which falls in. And finally, the biggest problem of groundwater remains the salinity.

Solution

A bucket brings fresh water, Sorain Bucket

- HyeIn SHIN

Residents of Kojani island, Tanzania experienced severe water scarcity because of lack of water treatment system and saline ground water. This island has four types of water supply sources. First source is pipe line water supply system from Pemba island to Kojani island, Second is brining water from Pemba to Kojani by using non-hygienic plastic buckets on wooden boats, Third is five shallow open wells and the last is artificial surface water pond used for livestocks and domestic purposes. But these sources are providing technically and economically insufficient quantity or not appropriate for health because of contamination and salinity. So, these water supply sources does not properly work to provide potable water, thus alternative water supply system needs to be developed.
There are three conditions considering for the design of water supply system. First condition is the main water resources, which are saline ground water and seawater. A solar thermal desalination method would be the best option as concern that tropical climate and saline water of Tanzania. Second condition is rainfall in the island. There are two rainy seasons so that constructing adequate rain water harvesting system can supply the fresh water to residents. The last condition to be considered is sustainability. The alternative system should be easy to handle and to maintain for local people. To sum up, we proposes a water supply system enabling a solar thermal desalination and rain water harvesting, which can be easily operated by local people. These will meet all the essential conditions of the alternative water supply system for Kojani island.



We select polycarbonate (PC) as the core material for the device because it is relatively inexpensive and transparent to transmit solar heat, and also has high strength and heat resistance. We admit that Sorain Bucket can reduce cost and it is sustainable because it is not only treating water, but also storing water over night during rainy season. The life time of this system is almost permanent and its maintenance costs would be negligible. For these reasons, we claim that Sorain bucket is the realistic solution for Water Challenge in Kojani island.

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SOLUTION 10

- Problem -

Current Onsite Sanitation System in the Urban Areas of Bhutan is not adequate

- Solution -

Compact & improved onsite sanitation for urban centres of Bhutan using wind/solar assisted aeration

Ho Kyong Shon

Associate Professor, University of Technology Sydney, Australia

Problem

Current Onsite Sanitation System in the Urban Areas of Bhutan is not Adequate

- Ugyen Dorji

Bhutan is a small country in the Himalayas sandwiched between the world's two most populated nations with China in the North and India in the south. Although the total population is just about 800,000, it is experiencing the most of the challenges faced by other developing nations both in terms of rapid urbanisation, economic development and environmental issues. Bhutan has made significant achievements on basic sanitation to date; however access to improved sanitation is still low. Improved sanitation is very important particularly in the urban areas where population is more concentrated and where basic sanitation is not adequate. A rapid urban growth has resulted in increased water usage and the volume of wastewater (black water from toilets and grey water from bathrooms and kitchens) generated which needs proper treatment and disposal has also increased significantly. Discharging untreated wastewater directly to the environment poses a significant risk to public health from the presence of highly infectious faecal matter. Besides, the untreated wastewater also contains organic nutrients and other contaminants that pollute our pristine environment (land and water) undermining the environmental health and its natural ecosystem.

Providing public wastewater management infrastructures (collection and centralised treatment system) require huge capital investments because of which Bhutan government has been struggling to provide adequate infrastructures for all urban centres. Currently only 10 out of 61 towns in Bhutan have municipal sewage collection and treatment infrastructures. All other towns including the unsewered areas of the 10 towns therefore depend on the onsite sanitation system for the treatment of domestic black water while the grey water is generally discharged directly to the environment without any form of treatment. The conventional onsite sanitation system consists of a watertight septic tank and soak pit, which is not appropriate for the modern urban settings for number of reasons. Firstly, the treatment efficiency of the septic tank is very moderate relying mainly on effective land infiltration treatment using soak pit. However, soak pit is effective only when large land area and good soil conditions are available and such conditions are not generally found in the urban areas where plots are generally very small and the soil has poor infiltration capacity. Secondly, the onsite treatment systems are also generally poorly designed, constructed and maintained. They have high carbon footprint due to release of methane, a highly potent greenhouse gas that accelerates global warming and climate change. All these ultimately result in the discharge of raw or poorly treated effluent containing highly contagious pathogens and organic nutrients to the environment posing high risk to public health and the environmental pollution.

Therefore there is an urgent need to improve the urban sanitation in Bhutan to replace the age-old system of using septic tank and soak pit system that are no more suitable for the current urban settings. The improved technology must accommodate both grey water and black water treatment as the current septic tanks are not usually designed. The technology should also be cost effective and affordable to the developing countries such as Bhutan.

Solution

Compact & improved onsite sanitation for urban centres of Bhutan using wind/solar assisted aeration

- Hokyong Shon

The rapid urban growth in Bhutan is contributing to significant increase in water demand and wastewater generated. Bhutan has made significant progress with basic sanitation however providing improvedsanitation is important particularly in the more concentrated urban areas. Untreated wastewater discharge poses a significant risk to public health besides pollution of its pristine environment, the asset which Bhutan highly values.

Public wastewater infrastructures require huge investment. Currently only 10 out of 61 towns in Bhutan have public wastewater infrastructures. All other towns including the unsewered areas of the 10 towns rely on onsite sanitation. The current onsite sanitation consists of conventional septic tank and soak pit system which is not appropriate for modern urban settings. It produces poor effluent quality and treats only black water while grey water is discharged without treatment. The plot sizes are generally small and inadequate for land treatment using soak pit. Hence, a better sanitation system is required to treat both black and grey water to reduce environmental pollution.

The solution proposed is to provide a compact and improved onsite wastewater treatment system combining anaerobic and aerobic processes to produce superior treated effluent quality that meets the national effluent discharge standard. This new and improved treatment system is designed with 4 chambers: primary settling, anaerobic biofilter, aeration tank and secondary settling tank. One of the innovative features of the system is to use shredded plastic waste as anaerobic biofilter media. Without plastic recycling facilities in Bhutan, recyclable wastes are exported however plastic waste being low density is not economically viable for road transport. Plastic waste has become a significant environmental issue in Bhutan. Using shredded plastic wastes as a biofilter media would be one of the innovative solutions to plastic waste problems in Bhutan. Another significant feature of this treatment system is that, the aeration is provided directly using wind flow. The wind is tapped using roof top wind collector that channels wind through a gradually decreasing funnel creating a jet and venturi effect providing high speed wind aeration. When wind speed is inadequate, aeration is provided using air compressor powered from a rooftop solar panel. Backup power is provided from the normal household power source when solar energy is inadequate.

The new treatment system has similar footprint as the conventional septic tank however the initial capital cost is estimated at least twice higher for including simple roof-top wind collector, solar PV, air compressor and modest automation. The annual operation and maintenance cost is about 50% higher assuming 20% of the air compressor powered from normal power grid. The advantages of the new system are however enormous in terms of environmental protection, public health safety, new social and economic opportunities. However, successful implementation requires government intervention through legislation and policy including cost-sharing or initial tax incentives. Urban properties have significantly higher values and have higher rental income and hence the increased cost of this improved onsite sanitation system may not be significant and can be easily absolved through modest rental increase.