Appropriate Technology for Water Quality Improvement in the Perspective of Sustainable Development: The analysis of BioSand Filter(BSF) in Local Context

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June 29, 2014

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This research is supported by a grant from the Global Engagement & Mobilization in affiliation with Handong Global University. Special thanks to Professor Younsik Han for his help in preparation of this thesis.

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Abstract

The purpose of this research is to evaluate in relation to sustainable development, the BioSand Filter the (BSF) project, implemented from 2011 to 2012 by the Global Engagement & Mobilization (GEM) team in Handong Global University. The aim of the BSF project is to improve the quality of water, one of the most important sectors for improvement included in the post-2015 Millennium Development Goals (MDGs). This research focuses on Goal 6 of the post-MDGs, "Achieve Universal Access to Water and Sanitation." This research considers the possible impact of the BSF project on other goals in the perspectives of environment, socio-culture, and economics. The focus of this paper is to review the case study at Nakta Island located in the state of Bihar, India. Through a critical review, this research reveals the progress and challenge in achieving access to safe drinking water. This research aims to create policy suggestions for universities and students and the UNAI body in order to better prepare for similar projects in the future. The evaluation and analysis of this research confirm that a BSF model with sustainable development is the key to achieving Goal 6 along with the other targets of the post-MDGs.

Keywords: Sustainable Development, Appropriate Technology, BioSand Filter (BSF), Bihar in India, Drinking Water Improvement, Global Partnership

Appropriate Technology for Water Quality Improvement in the Perspective of Sustainable Development: The analysis of BioSand Filter(BSF) in Local Context

There is an international concern in the developing countries' access to safe drinking water. Since 1990, an important progress has been made in the improvement of safe drinking water sources that over 2.1 billion people have gained access to quality water. Despite this achievement, according to a joint research of World Health Organization (WHO) and UNICEF (2013), almost 768 million people still drew from unreliable water sources in 2011.

It was discovered, however, that there are inequalities in access to safe drinking water between the urban areas and the rural areas. It was recorded that among the 768 million people in the world, about eighty-three percent (636 million people) lived in rural areas. WHO and UNICEF reported (2013) that about 180 million people depended on rivers, streams, ponds or lakes. These reports mention that a number of people in the 21st century had difficulty of access to quality water supply.

BioSand Filter (BSF) allows the management and supply of clean water for more people. The Centre for Affordable Water and Sanitation Technology (CAWST) encourages the poor to use BSF. With the support of 400 clients in 63 developing countries, BSF provides safe drinking water to over six million people (CAWST, 2013).[1] For an achievable sustainable development, CAWST sees the importance of social and environmental investments/programs from the private sector (p. 3). Thus, it is necessary to examine the long term use and effectiveness of BSFs in order to achieve sustainable development before its further implementation.

Statement of Problem

The Global Engagement & Mobilization (GEM) project team in Handong Global University conducted a "Water Solution Project" from 2011 to 2013 at Nakta Island in Bihar, a state in the eastern

[1] CAWST is a non-profit organization that provides training and consulting to organizations that work directly with populations in developing countries who lack access to clean water and basic sanitation. The former executive Camille Dow Baker in the oil and gas industry and Dr. David Manz, the inventor of Biosand Filter co-cofounded CAWST and have worked together since 2001 (Official Website: www.cawst.org).

region of India. The GEM team implemented the BioSand Filter (BSF) in that region for the indigenous people's access to SDW. It involves the removal of pathogens and arsenic problems from unimproved water resources in Ganges River (GEM, 2011).

Even with GEM's contribution to this water project in Nakta Island, concerns related to distribution, management, and sales arose in the course of implementation (GEM, 2013, p. 49). The concerns were relevant to the sustainability of appropriate technology in the local context. In order to find solutions to these concerns, a critical evaluation with sustainable development as the main framework is necessary. Although a final report is released by the GEM project team, this review did not include a sustainable development strategy grounded in global development studies.

Research Objective

The research team chose the GEM BSF project in Bihar in order to find a possible framework that promotes local, national, and global cooperation to achieve the post-MDGs. From the review of previous projects by Korean university and students, the research team expects to look for necessary conditions of a sustainable development achieved with the engagement of various sectors. From these findings, the research team aims to help formulate a sustainable development framework for future BSF projects.

The BSF project implemented from 2011 to 2013 in Nakta Island was evaluated. As an appropriate technology project, BSF needs recommendations that drive sustainability. This qualitative research emphasizes the core aspects of sustainable development. This research reveals the gap that exists between the ideal of appropriate technology and the actual implementation in the local context.

The objective of this qualitative research is (1) to find necessary factors of appropriate technology in sustainable development perspective; (2) examine how indigenous people are sustainably involved in BSF projects from implementation to management; (3) offer recommendations to help universities and students, including Handong Global University, to overcome difficulties in implementing BSF projects and to improve its working process.

Research Question

This research will study the potential factors in the sustainable use of BSF by the indigenous people of developing countries. The main research questions are as follows:

Q. What are the necessary conditions of appropriate technology in view of sustainable development? To answer to this question, two research questions are needed.

RQ 1. How are the indigenous people sustainably involved in the implementation and usage of the BSF project?

RQ 2. What are the necessary factors to facilitate a sustainable BSF project?

The answers to these questions are structured as follows: The main question is a research framework which requires a literature study. To evaluate the concepts of sustainable development and its correlation with appropriate technology, the literature discusses the necessary elements for a sustainable BSF implementation, usage, and maintenance. The first sub question examines, in relation to sustainable development, the case study which GEM conducted for three years. This first sub question forms a basis of comparison between an ideal BSF model, according to the literature review, and the actual implementation according to the review of the case study. The second sub question suggests the supplementary factors to develop a BSF program in a sustainable way. The case result serves as the ground for policy suggestions to future students and universities that will be involved in future BSF projects.

Research Framework

The 1987 Brundtland report defines[2] that in the long term, "social, economic, and environmental objectives should be complementary and interdependent in the development process" (OECD, 2001, p.21). Through the 1987 Brundland Report, the research team designed a structure of sustainable

[2] In Brundland report, sustainable development is defined as "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" (WCED, 1987, p. 43).

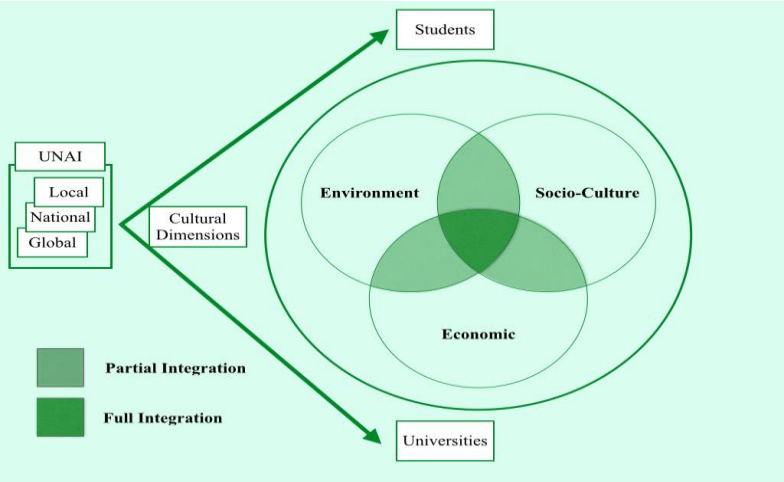

Figure 1. A modified Framwork for describing Sustainable Development with UNAI from OECD (OECD, 2001, p. 22)

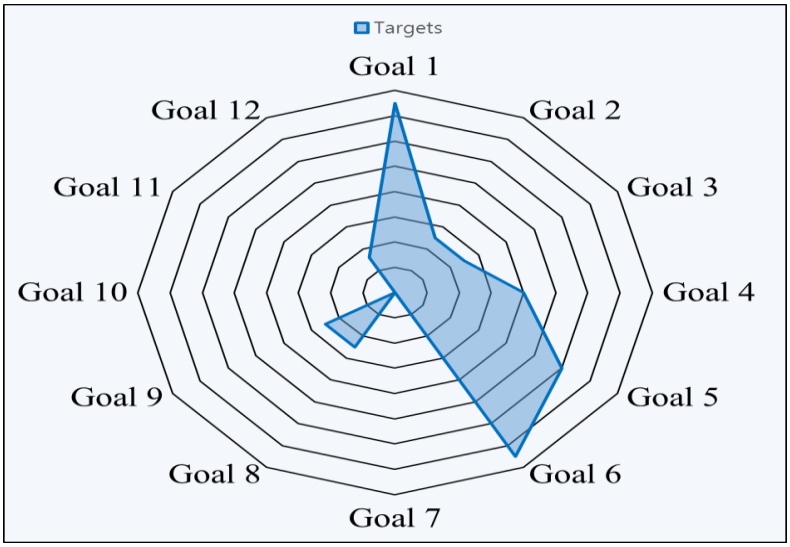

Figure 2. The Impact of the BSF project on the Post-MDG as Highlighted by MinJeong, Kwak.

Table A.

The Impact of the BSF Project on the Post-MDG Adopted from UN (UN, 2013, pp. 30-31).

Goal	1	2	3	4	5	6	7	8	9	10	11	12
Targets	b,c,d	d	d	a,c	a,b,d	a,b,c	None	d	a	None	None	F
Impact (%)	75	25	25	40	60	75	0	25	20	0	0	16

development with UNAI and its impact to achieving the post-MDG goals. Figure 1 explains the sustainable balance between environment, socio-culture, and economic perspectives. In sustainable development, mutual supports and holistic integrations are involved in partial and full integration of these three perspectives.

UNAI consists of local, national, and global network of universities and students. Through policy changes and international cooperation, UNAI can support students and universities involved in programs and projects related to appropriate technology like the BSF project. As shown in Figure 2, an ecological operation of appropriate technology is crucial in achieving the post-MDG goals to transform a community. The detailed description is given in Table A.

Division of the thesis

This thesis consists of the following: the next chapter includes a literature study of sustainable development, appropriate technology, water resource, and BioSand Filter. Chapter 3 describes the case study, target area and method. Chapter 4 shows the result of the case analysis. Chapter 5 summarizes this research and suggests policy changes and recommendations to UNAI, universities, students for future BSF projects.

Literature Review

Sustainable Development

Historically, the concept of sustainable development was applied even in ancient times by having it expressed in the household. In Aristotle's thought, "household" (Greek οἶκος) implies the ability to produce and reproduce what is needed for living (Ehnert, 2009, pp. 35-36). However, the household as a core value in household management "had to be self-sustaining at least to a certain extent and could not be just consumption-oriented" (as cited in Nagle, 2006). From this view, the concept of sustainability expanded to an economic concept from the 12th to the 19th century. It also expanded to an ecological and development aid concept in the 1970s (as cited in Hulsmann, 2004, p.41).

The global consensus about the relationship between the environment and development had no clear direction until the year 1987 when the first mention of sustainable development was officially mentioned in Our Common Future, a report made for World Commission on Environment and Development (WCED) at Brundland in 1987. According to this report (1987), sustainable development is defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 44). The main idea is to conceptualize development into sustainable development in a holistic manner. The initial emphasis is on the preservation of environment and resource usage regulation. However, this emphasis was criticized by developing countries because it seemed difficult for developing countries to adopt the concept of sustainable development. Therefore, in the 21st century, the revised concept of sustainable development that contains the effective use of natural resource, the attention to climate change and socio-economic development was announced (Mebratu, 1998, pp. 502-503).

The term "sustainable development" began to have a wider definition. Beyond the environmental protection, it now includes sustainable social, cultural, political, economic, and environmental development, resulting in Millenium Development Goals (MDGs) (UN, 2000). Meanwhile, the United Nations Conference on Sustainable Development (Rio+20) in 2012 concludes that water is the core sector of sustainable development (UN, 2014, p. 107). Water use and allocation are essential to operate the sustainable development system in local communities through socio-cultural, economic, and environmental interdependence.

Appropriate Technology

Appropriate technology (AT) was originally expressed as an intermediate technology by economist Dr. Ernst Friedrich Schumacher in 1965 for a Conference on the Application of Science and Technology for the Development of Latin America, organized by UNESCO in Santiago, Chile (Schumacher, 2010, pp. 179-180). After the Second World War, massive foreign aids by developed countries were poured into developing countries of Latin America and Africa. However, this

unilateral aid and development plan of advanced countries did not necessarily benefit the developing countries. Schumacher argues (2010) that the international aid led by advanced countries devastated these developing countries. He adds that this development that starts with economic and social goods are grounded in materialism, without considering the capacity of indigenous people and the local context (pp. 173-180).

A number of writers on AT believe that Mahatma Gandhi (1869-1948) is the father of AT. Initially, AT was devised for the purpose of reducing poverty by creating jobs and preventing unemployment in rural areas (Schumacher, 2010, pp. 182-184). Gandhi's usage of spinning wheel and Ghadhi's thought of self-reliance inspired Schumacher to form an argument of intermediate technology beyond "the system of mass production on the basis of sophisticated, highly capital-intensive, and high energy input dependent technology"(Akube, 2000; Schumacher, 2010, pp. 163-164). This intermediate technology is helpful for people to be self-reliant without excluding human labor and damaging ecologically environment. To summarize, appropriate technology is a self-reliant technology with which developing countries can cope poverty issues on their own through sustainable development by utilizing cheap capital and native resource. It is 'technology with a human face,' a technology that can harmonize with humanity.

However, recent theoretical developments and practices of AT went beyond its original intent, without considering the local people and their context. There was too much emphasis on appropriate technology transfer and appropriate technical cooperation. A detailed socio-culture, economic, and environmental context in a particular region was overlooked in favor of the technology provider's approach (Han et al, 2013). There were several instances that AT projects were not utilized by the indigenous people because it did not fit their local context. Instead, the AT projects damaged their people and the local community. An example of an AT project that failed is Play Plump which was designed for water, sanitation and hygiene programs. According to a UNICEF report (2007), Play Pump technology had a number of technical, social, operational, managing, administrative, and fiscal issues. In order for

one technology to be utilized and implemented, stake holders who accept or buy a technology should consider sustainability. The discretionary participation of the indigenous people requires a collaboration process within the socio-cultural, economic, and environmental perspectives. Technology requires a voluntary participation of the indigenous people who will use it. This is a technology with a human face that is needed as suggested and promoted by Gandhi and Schumacher.

Water Resource

Water resource is the most necessary resource for human survival. Humans, by nature, cannot live for more than three or four days without water. Since it is a basic necessity, clean water is not only important for drinking, food production, and sanitation but also for human dignity. Water as a right was declared at the 1977 Mar del Plata UN Water Conference – "All peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs" (UN, 1977).

Water is often considered as a fundamental driving force for social and economic development. In other words, water is recognized as a social and economic good. The demand for quality and quantity of water resources will increase. This demand will continue along with population growth, global urbanization, and industrialization in developing countries (Flint and House, 2001). Thus, water resource is an essential aspect of sustainable development. Year 1992, water usage was discussed in Rio de Janerio – "Water is needed in all aspects of life...Innovative technologies, including the improvement of indigenous technologies, are needed to fully utilize limited water resources and to safeguard those resources against pollution" (UN, 1992, p. 275).

Water impact is also correlated with poverty issue. The 6th session Commission on Sustainable Development emphasizes the importance of water resources for sustainable development (UN, 1998, p.3). Additionally, the commission encourages donors to support programs and projects related to water in order to eradicate poverty (UN, 1998, p. 10). For a more systematic water management, the issue of poverty should be considered along with the existing water resource management. UN suggests in their

2000 United Nations Millennium Declaration that the affordability of safe drinking water is one of the keys for poverty eradication – "We resolve further to halve, by the year, the proportion of the world's people whose income is less than one dollar a day and the proportion of people who suffer from hunger and, by the same date, to halve the proportion of people who are unable to reach or to afford safe drinking water" (p. 5). This declaration shows the close correlation between water security and poverty issues. Therefore, the management of water resource should be considered along with sustainable development.

BioSand Filter

In 1993, Dr. David Manz invented a simple household water treatment called BioSand Filter (BSF). It was adapted from Slow Sand Filtration (SSP) that has been successfully used since the mid-nineteenth century (Manz et al., 1993). On the same year, the first experiment with BSF was launched in Nicaragua, where it became a household water filter project. According to CAWST (2013), it estimates that over 650,000 BSF have been implemented in more than fifty-five countries around the world, giving a great impact upon over four million people. Since 1993, BSF has undergone ten versions.[3]

BSF removes pathogens and suspended solids through a biological and chemical process that occurs in the bio film and sand layer. According to the BSF construction manual (CAWST, 2012), pathogens and dirt in the filter are removed through four stages – mechanical trapping, predation, adsorption, and natural death.[4]

In the dimension of public health, the impact of BSF was evaluated in several areas. Stauber, Kominek, Liang, Osaman, and Sobsey (2012) studied the health impact of BSF in the northern region of Ghana in Sub-Saharan Africa. Positive results were discovered – diarrheal disease was reduced and the

[3] The relevant information is updated in CAWST official website: http://www.cawst.org/en/resources/biosand-filter

[4] In mechanical trapping, the water can flow through the sand, but some dirt and pathogens are too big to fit though. In Predation, the microbes eat each other inside the filter, especially in the biolayer. In adsorption, some pathogens stick to the sand and cannot get away. Some pathogens die because there is no enough food or air for them inside the BSF.

water quality was improved in that region and in other regions such as South Africa and Zimbabwe (p. 3818-21).[5]

Even with the known positive benefits of BSF, there were cases of disuse. An example is the case of BSF use in Haiti as assessed in 2013 by Sisson, Wampler, Rediske, and Molla. In Haiti, those in rural areas are usually away from home for an extended period of time to attend to their work, personal, illness in the family, or visit their family and friends. As a result, they are not able to regularly maintain the biofilm in the BSF. With this sample case of extended travels, therefore, the lifestyle in the community should also be considered when implementing BSF (as cited in Sobsey et al. 2008)

Among the Haitians, the belief is that there is no link between water and illness (Sission et. al, 2013). Also, they have the tendency to ignore the capacity of the BSF to prevent water-borne disease. Culturally, most Haitians believe that diseases are associated with religion or political suspicion, not with unclean water, poor sanitation, and hygiene (as cited in Smith, 2001; Grimaud& Legagneur, 2001). In order for BSF to be used sustainably by the indigenous people, it is not only important to consider the technical aspects of its development and implementation but also the cultural aspects of the locals, how they understand water, sanitation, and hygiene.

Case Analysis

Background Study of Bihar

India is the second most populated country in the world with an estimate of 1.2 billion people. Nakta Island, a part of Bihar, is known as the third most populated state in India with over 86 million residents. Ninety percent of these populations live in rural areas. Ganges river runs through the region of Bihar. In this region, the infant mortality rate is 67 per 1,000 live births and the maternal mortality rate is 452 per 100,000 live births (Mishra, 2009). The average infant mortality rate in India is estimated at 44 per 1,000 live births (WHO, 2012).[6] The infant mortality rate in Bihar is much higher than the average

[5] The research team compared the impact of plastic BSF with concrete BSF. Regardless of the kind, it shows over 50% reduction of diarrheal disease (Stauber et al, 2012, p. 3817).
[6] The average infant mortality rate in world is estimated 35 deaths per 1000 live births in 2012 (WHO, 2012).

rate in India and the world. Meanwhile, the average maternal mortality rate in India as estimated in 2010 is 200 per 100,000 live births with cases related to or aggravated by pregnancy or its management (excluding accidental or incidental causes).[7] This average maternal mortality rate (452) in Bihar is considerably two times higher than that in India. The same statistics with Biar is Angola in Africa, 450.

When it comes to water supply, the government has the responsibility to provide safe drinking water to their citizens. However, the current situation is not optimistic. According to UNICEF (2013), a total of 11.9 percent urban people have access to piped water supply in their households (p. 35). Most people in urban and rural areas of Bihar are dependent on public tap or hand pump to get water. The region has an approximate of 800,000 hand pumps (Mishra, 2009). Since Bihar is located near Ganges river, the source of water is strategic. However, the major problem in Bihar is the availability of safe drinking water. With this lack of knowledge and access to an affordable safe drinking water, the region is at risk of being affected by water contamination.

Water from hand pump or public tap is contaminated with iron, fluoride, and arsenic. These chemical elements can cause "diseases like diarrhea, dysentery, typhoid fever, intestinal helminthiasis, jaundice, and cholera" (Mishra, 2009, p. 4). Table B shows the poor quality of water in Bihar.

Table B

Habitations affected by Water Contamination in Bihar From UNICEF (UNICEF, 2013, pp. 42-43)

	Bihar Habitations (%)	**Ranks in India (29)**
Iron	12.98	5
Fluoride	3.1	3
Arsenic	1.032	3
Water Quality Affected States	17.11	4

The government conducted a test from November 2007 to February 2008 mapping 226,145 water samples covering all the 38 districts of India (Mishra, 2009). The result indicates that the "water sources

[7] The information is from CIA World Factbook official website: https://www.cia.gov/library/publications/the-world-factbook/

of 1750 habitations of 80 blocks in 13 districts situated along the Ganges river are partially affected by arsenic contamination (As >50 ppb) whereas the drinking water sources of 6373 habitations in 22 districts are affected with excess fluoride (>1.5 ppm). The presence of excess iron in groundwater is in the majority of the districts (p. 4). With this result, it can be concluded that the drinking water sources in Bihar are not safe in most areas due to iron, fluoride, and arsenic contamination.

Global Engagement & Mobilization (GEM) in Nakta Island

Nakta Island. Nakta Island is located in Patna district, the capital and largest city in the state of Bihar. This small island is located in Ganges river. According to the GEM report (2011), this 8.4 square kilometers island is a home to an approximate of 100,000 people. Figure 3 shows that the small island is divided into two main districts – Patna and Chapra. The areas of Naya Tola and Akilpur, where the GEM team conducted the BSF project, are located at Nakta Diara subdivision in Patna district. In Nakta Diara subdivision, an estimated population of 20,000 and an official number of 2212 households already exist in 2011. Most of the residents are small scale farmers. Some are also into stock farming.

In terms of access to safe drinking water, some of the habitats along the Ganges river fetch water directly from the river. Most of them also use manually operated hand pumps to get water. The quality of

Figure 3. Physical Map of Nakta Island (GEM, 2011)

Figure 4. Hand Pump in Nakta Island (GEM, 2011)

the water, however, is poor because their source in Ganges River is polluted by human activities. They use the water from hand pumps without filtering or boiling. Therefore, a systematic research on water quality in that region is required.

BioSand Filter Project. The GEM mission of Handong was conducted for three years. The first phase in 2011 winter was conducted for the regional research of water. The second phase in 2012 summer was conducted to research for an optimal BSF model and its application. The third phase in 2012 winter was conducted to create a BSF manual and train the indigenous staff. The last phase in 2013 winter was conducted to build a BSF network. The details of the project are listed in Table C:

Table C *Adopted Project Process From 2011 To 2013 (GEM, 2013, pp. 3-4)*

Stages	Goals	Result	Conclusion
Phase 1 (2011 Winter)	a. Conduct an area study with focus on water quality. b. Test the usefulness of BSF.	a. Provided a sample test. b. Considered sand as a material for BSF and cheap labor to manufacture.	a. Understood status of water quality, culture, and life style. b. Discovered that many hand pumps were contaminated with chemical elements.
Phase 2 (2012 Summer)	a. Design an optimal BSF b. Customize the BSF for the local context.	a. Conducted a BSF function test. b. Applied the test in target areas and received feedbacks from BSF owners.	a. Completed the BSF design to manufacture and distribute. b. Found suppliers needed to manufacture the BSF.
Phase 3 (2012 Winter)	a. Revise the BSF model. b. Train the local staff. c. Create a BSF manual.	a. Enhanced BSF efficiency. b. Improved sanitation awareness. c. Completed the BSF manual.	a. Turned over the BSF project to the indigenous people.
Phase 4 (2013 Winter)	a. Select a BSF model. b. Conduct a training seminar for the indigenous people. c. Develop a network for the local community.	a. Provided a solution to water leakage. b. Improved sanitation awareness. c. Suggested additional tasks for future BSF projects. Created a video film for public awareness.	a. Completed the best optimal BSF model after several iterations. b. Conducted a training seminar for the indigenous people c. Created a network for the local community.

Method of Analysis

A qualitative method was used to conduct this study. The team selected five people for this research – a Korean director, a Korean volunteer, a Korean woman assistant manager who is the wife of the director, an indigenous BSF owner, and a professor at a local university. Their inputs were gathered through a questionnaire. The interview is conducted through E-Mail. Four out of five gave their replies to the questionnaires. The research team used the GEM annual report as the main resource. With the papers, The DAC Guidelines - Strategies for Sustainable Development (2001) and The Sustainable Development of Water Resource (2004), the research team created a set of criteria to review the BSF project within the environmental, socio-cultural, and economic perspective

Environmental Perspective. Two main criteria are suggested to evaluate the GEM project. The first is the environmental sustainability of the BSF design and operation. This criterion is from the comprehensive concept of appropriate technology that considers local culture, natural, social, and economic appropriateness (Schumacher, 2010). Appropriate technology requires cheap price, simple manual, small scale applicability, creativity, and environmental preservation (KIAT, 2012, p.11). This criterion is related to the use of eco-friendly materials and natural elements like water and sand. The second is in the capacity of BSF to improve water quality. This criterion is aimed at evaluating the capacity of BSF to pass the standards of WHO for drinking water.

Socio-Cultural Perspective. According to a GEM report (2013), "the local BSF owners will consistently use it over one year. While using it, the BSF owners shall give a feedback of BSF. From the feedback, local NGO or local autonomous bodies can distribute, maintain, build network. In the long term, BSF should be a business model of local community" (GEM, 2013, p.42). In order to review the BSF project in the socio-cultural perspective, it requires considering a wider scope. This study will carry out the review with a narrow scope through a set of criteria selected by the researchers.

The first criterion is in having an appropriate educational program. It is expected through this training that the public would be aware of the relationship between water quality and health. These items

need to be considered in the educational program: (1) accessibility of the locals to the training contents; (2) systematic readiness programs for long term use.

The second criterion is in building partnerships. This is necessary in order to ensure the sustainability of the BSF project. The local and global partnerships involve cooperation with (1) local NGO, (2) international NGO, and (3) local university, aiming at turning over the BSF to the local community.

Economic Perspective. Economic capital should be considered in this perspective. Flint suggests (2004) that economic capital contains "industrial use; resource ownership; true-cost pricing; waste as a resource; value-added production; transportation support; waste treatment; flood control" (p. 53). Paul Polak argues, "If you can't sell it, don't do it" and suggested that one practical solution is "to design to specific cost and price targets" (Polak, 2009, p.14). The average salary of the locals should be considered in deciding true-cost pricing

Another concern is funding for a long-term sustainable development. According to the report on the Post-2015 development agenda (UN, 2013), a sufficient and better long-term finance needs to be a priority (p. 12). Thus, it urges developing countries to obtain substantial external funding. Therefore, it is important for the GEM project to prepare funding that can sustain a long term development plan that will provide training on BSF manufacture and awareness on water quality improvement.

Figure 5. Method of Analysis in Sustainable Development Perspective

Case Result

Environmental Perspective

Environmental Sustainability of BSF design and operation. Two points are important in this criterion: (1) coexistence with natural capital (water and sand) and (2) simplicity of assembling and operating. In the "coexistence with natural capital," BSF utilizes water and sand. The water used in Nakta Island is surface water and that which is available from Ganges River. The surface water is easily polluted by sewage. In Hindus culture, Ganges River is regarded as sacred by the local people. Materials such as livestock waste used in religious rituals like bathing and funeral services pollute the river. Although the supply of water is abundant in Nakta Island, the value of water as a natural capital is affected because of the pollutants accumulating in the river. BSF is a technology that can enhance the value of unimproved water as an essential natural capital, thereby improving the environment.

BSF requires another natural capital in the form of sand. A large amount of sand is deposited on the riverbed of Ganges (GEM, 2011). Sand is readily available in that region. Since BSF requires much sand, the abundant supply in the region can reduce the manufacturing cost of BSF. The only problem is when there is a need to replace the sand in the BSF. The GEM project did not consider the aspects of disposing the sand contaminated by arsenic. Sand contaminated by arsenic will likely become a pollutant again once disposed.

The last criterion is in eco-friendly materials usage. To manufacture a BSF, it requires cheap plastic materials. These materials can be non-biodegradable pollutants. Replacement and repairable parts used in BSF can also be pollutants. Plastic materials allow lowering costs in manufacturing a BSF. However, these materials can damage the region's environment. Therefore, it is suggested to design a BSF model with a longer lifespan to avoid these pollutants caused by repairing and replacements.

Capacity of BSF to improve water quality. The GEM BSF project team tested the efficacy of improving water quality. One of the local owners expressed satisfaction with the use of BSF (BaBa,

personal communication, June 25, 2014). This owner witnessed the improvement of the water treated by BSF in terms of taste and smell, making the product recommendable to the neighborhood. Buyers can take advantage of the model upgrade from 2013 that repaired a previous defect seen in the previous model. D. H. Jeong confirms this technological innovation of BSF (personal communication, June 25, 2014). In spite of this upgrade, the water from the purification process in BSF is still not appropriate for drinking. It may be true that the coliforms in the water treated by BSF are already undetected and that the arsenic density is substantially reduced, however, the water from BSF still cannot meet the standards of WHO. Therefore, further improvements are still needed in order for BSF to be efficient in generating safe drinking water. Table D shows the result of the test.

Table D

BSF Efficacy Test (GEM, 2013; GEM, 2012b)

Element	WHO	Before BSF	After BSF
Arsenic (2013)	0.01mg/L	0.043mg/L	0.05mg/L
Total Coliforms (2012)	0 CFU/ml	10 CFU/ml	0 CFU/ml

Socio-Cultural Perspective

Appropriate Education Program. GEM offered several education programs to local staff and indigenous people. The education program included two parts – water sanitation and BSF operation. Two criteria are suggested by the research team to evaluate the appropriate education program. The first criterion is in the accessibility of local people to contents. The second criterion is in having systematic readiness program for long term use.

In the first criterion, the primary focus is on how the local people can learn water sanitation and BSF operation. The literacy rate in Bihar is significantly lower than most states of India. In order to facilitate comprehension in this low literacy region, GEM used pictures to supplement the written instructions (GEM, 2013, p. 34). Moreover, GEM ensured that the BSF manual included illustrations. The manual was also translated to the local Hindi language.

The next focus is in the participation of women. They have essential roles for sustainable development using BSF. In Bihar, women are the ones mostly doing the household chores such as fetching drinking water through hand pumps, using water to cook and clean. The active participation of women in education is necessary to improve awareness in the need to manage water quality. However, the GEM report seems to show a limitation of active participation in the women sector, particularly in the GEM education program about water quality improvement and sanitation.

The second criterion is in having systematic readiness programs for long term use. Before the GEM project began, three people were interviewed. All have little awareness of water quality (Song, 2010, pp. 115-120). A systematic approach in education programs is needed in order to promote the sustainable use of the BSF. One interview cites the need of a systematic program for future projects to enhance the efficiency of training (G. Lee, personal communication, June 25, 2014).

The length of training is also important in transforming the mindset of the locals to focus on the importance of water quality and promote the use of BSF. According to a GEM report (2013), short term education programs have little impact to the indigenous people (p. 34). Therefore, in order for an education program to be effective in improving awareness of water quality, a long term readiness program is essential.

Partnership. Partnerships can be from these three sectors – the local NGO, the local university, and the international NGO.

In this research, the local NGO of Canaan Farmer's School created an extensive network with the local community. The local NGO provided the valuable resource of support such as translation and interpretation. They were also able to exchange feedback between the local BSF owners and the BSF project team. The local NGO also enabled the team to provide education program related to water quality improvement.

Meanwhile, in terms of working with the global NGO, the primary issue has always been the expected longer commitment on their related projects. Global NGOs operate in a particular timeline and

scope. It is difficult to maintain close cooperation with the local community because of the usual limited time and commitment provided by global NGOs. In Bihar, some of the global NGOs who initially collaborated with the GEM team already withdraw their support. It would be more ideal for global NGOs to partner with local NGOs in the research and actual implementation of projects. Partnerships with global NGOs provide a venue to exchange views, valuable advice and suggestions needed to create an optimal model of the BSF project for developing countries. GEM, for instance, received a number of valuable inputs from its collaboration with other global NGOs in the TW conference. Partnerships with global NGOs are vital to the improvement of a sustainable development model through appropriate technology.

The role of local universities is significant in building partnerships. A local university may conduct activities such as researching, planning, and internship. For example, the GEM project team partnered with with local universities, namely, Anugrah Narayan College and National Institute of Technology (NIT). Along with these institutions, GEM conducted seminars that introduced and demonstrated the use of BSF. In 2011, the GEM research team was also able to work with Professor Ashok K. Ghosh, a professor who is active in the research of water quality, particularly arsenic and fluoride contamination in water sources. The team had regular meeting with him about the problem with arsenic. They were also able to work on related experiment designs in his laboratory. A confirmation of success is the synergy created by the partnership in the entire process of the BSF, from the research design, to manufacture, and its distribution. However, these universities were not able to collaborate in other areas of the BSF project such as training and distribution. It would have been ideal to have these local universities play the vital role in training and project management.

Economic Perspective

True-cost pricing. According to a GEM report (2011), most of the residents in Nakta Diara subdivision earn their living either through farming, stock-farming, or dairy farming. However, these sources are usually not able to meet their cost of living. The residents usually work outside the

subdivision as part time workers. The average salary per month of the residents is estimated at 2000 INR ($33) to 5000 INR ($83). With this average salary, it is difficult for most residents to survive without having to loan from the government. Meanwhile, the average cost to manufacture one BSF is around 800 INR ($13) to 1,000 INR ($16) (GEM, 2013, p. 8). Interviews with the main director of the BSF project and one of the BSF owners attest that the average cost is not appropriate. They suggest that the optimal price of BSF should be 600 INR ($10) (Y. G. Lee; BaBa, personal communication, June 25, 2014). The cost to manufacture or buy a BSF is too high for a local resident with an average income. Aside from this problem on the average low salary of the residents that hinders them to buy or manufacture a BSF, the model is also under beta testing. The current BSF model still needs scientific verification and optimization. Therefore, further improvements in costs and models are needed in order to further encourage "willingness to pay" for the BSF.

Fund for a long-term sustainable development. Since 2010, the GEM BSF project in Bihar is supported through the ACE aid of the Korean government. The bulk of this budget is used to support the university student participants of the project like their travel expenses and the cost of their related materials and experiments. Other expenses like the costs of stay in the community are shouldered by the students. One of the main problems in the BSF project is its high dependency on the ACE fund. Due to insufficient funds, GEM stopped its support of the BSF project in Bihar after its contract with ACE ended in 2013. A BSF project, however, requires a long term commitment in order for the community to self-maintain the project. For future BSF projects, it is necessary to diversify the funding of the government in order to sustain for a longer term. Support from the local government should also be considered to ensure the long term maintenance of BSF projects.

Conclusion and Policy Suggestion

This research analyzed the GEM BSF project for Nakta Island in the view of sustainable development. A Korean student, who served as a volunteer for the BSF project, mentions that not only a single factor but a combination of holistic reasons caused the failure of the project to be sustainable (D.

H. Jeong, personal communication, June 25, 2014). The evaluation of the GEM BSF project reveals a need for a more systematic development process to ensure sustainability. There is a high capacity for the BSF to remove arsenic and total coliforms. However, considerations were not provided on the disposal of sand with arsenic from each BSF filtration process. Moreover, non-biodegradable plastic materials were used in BSF. The use of this potential pollutant and the concern on arsenic disposal contradict the advocacy of appropriate technology in protecting the environment. Relevant studies are needed to solve these potential environmental issues from the use of BSF.

The evaluation also reveals the low participation of women, particularly in the GEM education program about water quality improvement and sanitation. Another issue is in the selection of an appropriate pricing strategy for the BSF. Resolving this issue is important in encouraging more BSF owners and promoting the usage of BSF. The evaluation reveals an issue in the project's continuity because of its dependence on temporary funding. This can be resolved by having a long term approach that will not only include research and development but also the aspects of marketing and distribution.

From the findings highlighted on this paper, the research team suggests policy changes to the body of UNAI, along with participating universities and students.

For UNAI, it is suggested for the body to grant incentives that will allow universities to invest and sustain more long term projects. Moreover, projects like in Bihar should be considered as internship programs to allow a longer collaboration of the participating students with the local community. Another suggestion is for UNAI to play a vital role as a hub for global partnerships. This can be done by offering conferences and seminars related to appropriate technology and community development. UNAI can bring together experts from related disciplines to form the best model of BSF. UNAI can also collaborate with the UNITWIN network to develop a research and training program for similar projects. It will also be helpful for UNAI to provide a shared website to publish project reports. These reports should follow a guideline to be established by UNAI. Lastly, the research team suggests UNAI to encourage and promote crowdfunding and crowdsourcing for projects related to appropriate technology. As an international

network, UNAI can develop creative ways to solicit contributions to benefit social projects like in Bihar. The participation of an international body like UNAI calls for more accountability and can therefore encourage more cooperation from the local government and the local community.

For universities, it will be helpful for the academe to provide long term social projects that can offer participating students with incentives like tuition fee discounts, scholarships, or course credits. For example, if a student works on a social project in a particular community over a course of one year, the university may award the student with a certificate of completion. Active participation of universities in social projects strengthens their partnerships with various sectors. Relationship between local and foreign universities are also encouraged through exchange student programs, particularly that which are related to cross-disciplinary studies. In the case of BSF, for instance, skills and knowledge related to disciplines such as biology and development studies are highly relevant to the project. For example, a director of BSF cites marketing as the main issue with the project (Y. G. Lee, personal communication, June 25, 2014). Therefore, in addition, universities can provide research in the discipline of marketing. Moreover, universities can provide relevant studies and find an optimized business model for a particular local context.

For students, certain attitudes toward their participation in BSF projects are encouraged. Local development projects that usually collaborate with various sectors demand a teamwork attitude. The culture and environment in developing countries can be entirely different from what one has grown accustomed to in Korea. It is important to be sensitive with the local context, the indigenous culture and society. Therefore, attitudes that promote cultural sensitivity and diversity awareness are also important. Moreover, an open attitude towards cross-disciplinary studies is also relevant as with the case of the BSF project which deals with inputs from a variety of disciplines such as biology, chemistry, business, education, and development studies.

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