WATER RESOURCES RESEARCH IN SRI LANKA

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Transdisciplinary Research in Integrated Water Resources Management in Addressing Issues Related to Water Pollution of Mahaweli River

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ABSTRACT

Complex and interconnected nature of most of the activities which led to the pollution of water resources of Sri Lanka is a major concern at present. Therefore, it is important to identify the causes of such problems and approach it in an interdisciplinary or transdisciplinary manner so that the problem can be well understood as well as the management interventions can be formulated effectively.

With this background, a research programme was initiated to improve water quality of the river Mahaweli by introducing technically sound, economically feasible, environmental friendly and socially acceptable approaches and techniques to reduce the pollutant loads. In addition, it was expected to strengthen the formal and informal institutional mechanisms related to water pollution issue in the study area to improve the effectiveness of their activities.

This paper describes the basic concepts of transdisciplinary research and the process which took place in developing proposals and implementing the research programmes at the Post Graduate Institute of Agriculture (PGIA) under the Crossing Boundaries (CB) Project, which is a regional project implemented in six partner institutions in South Asia with funding from the Government of the Netherlands. The research studies along with the findings and the experiences from five PhD candidates who spearheaded the research programme have shown that all PhD projects could be classified under the transdisciplinary research. The achievements as well as challenges faced in conducting transdisciplinary research were also described. The entire research programme was steered through a learning process with regular course correction by interaction, monitoring and intervention as this was a new experience for all those who participated in this project.

INTRODUCTION

Currently, water pollution is one of the main concerns in the water sector of Sri Lanka. Though, the country is blessed with water resources, pollution of surface and sub surface water is a serious environmental concern with the increasing population, rapid urbanization and intensive agricultural and industrial activities. Careful analysis of this problem reveals the complex and interconnected nature of most of the activities which led to the pollution of water resources. Therefore, it is important to identify the causes of the problems and approach it in an interdisciplinary/ transdisciplinary manner so that the problem can be well understood as well as the management interventions can be formulated effectively.

Within this background, a research programme was initiated under the Crossing Boundaries (CB) Project, which is a regional project implemented in six South Asian partner institutions with funding from the Government of the Netherlands (SaciWATERs, 2004). The aim of the CB project is to contribute to the paradigm shift in water resources management in South Asia, summarised in the concept of Integrated Water Resources Management (IWRM), by means of a partnership-based programme for capacity building of water professionals on IWRM and gender & water through higher education, innovation and social learning focussed research ('research with an impact'), knowledge base development and networking.

The ultimate goal of the research programme is to improve water quality of the river *Mahaweli* in order to provide good quality water for domestic, irrigation, hydropower and recreational purposes in a sustainable manner while maintaining the health of water resources and associated ecosystems. The overall research objectives are to;

- introduce technically sound, economically feasible, environmental friendly and socially accepted approaches and techniques to reduce the pollutant loads to the reach of *Mahaweli* from *Kotmale* dam to *Randenigala* reservoir, and

- strengthen the formal and informal institutional mechanisms related to water pollution issue in the study area to improve the effectiveness of their activities considering technical, social, financial and environmental dimensions.

This paper describes the basic concepts of transdisciplinary research and the process which took place in developing proposals and implementing the research programmes at the Post Graduate Institute of Agriculture (PGIA) under the CB Project. The research studies along with the findings and the experiences from five PhD candidates who spearheaded the research programme are briefly

described. This is followed by a reflection on how far we have achieved the integration that was anticipated at the beginning of the research programme.

Definitions of Integrative Research Concepts

Lack of common understanding of integrated research concepts, such as participatory, interdisciplinary, transdisciplinary etc has been a constraint in defining, conducting, evaluating and communicating the research findings. In order to address this issue, Barbel *et al.* (2010) has provided clear definitions, summarized in Table 01, to differentiate different research concepts in integrative research.

Table 01: Definitions of type of research

Research Concept	Definitions
Disciplinary	Project that take place within the bounds of a single, currently recognized academic discipline. The research activity is oriented towards one specific goal, looking for an answer to a specific research question
Multidisciplinary	Projects that involve several academic disciplines researching one theme or problem but with multiple disciplinary goals. The research process progresses as parallel disciplinary efforts without integration but usually with the aim to compare results
Participatory	Projects that involve academic researchers and non academic participants working together to solve a problem
Interdisciplinary	Projects that involve several unrelated academic disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory to solve a common research goal
Transdisciplinary	Project that both integrate academic researchers from different unrelated discipline and non-academic participants to research a common goal and create new knowledge and theory. Transdisciplinary combines interdisciplinary with a participatory approach

Formulation of Research Proposals

While new research and innovation in the different water resources disciplines is important, the notion of 'integration' remains elusive, particularly that between natural/technical science perspectives and social science perspectives. Innovative research is – therefore – needed to enhance the IWRM knowledge base. Such knowledge is best developed in the concrete context of real water resources management problems, and efforts at intervention, transformation or reform towards IWRM (SaciWATERs, 2004).

The first set of activities employed during the initial implementation period of the project was to shape the technically oriented water resources management curriculum of the PGIA towards an interdisciplinary programme through introduction of three new courses, namely, Field Research Methodology, IWRM, and Gender and Water. The implementation process to incorporate three new courses commenced with the holding of three staff trainings during the second half of the year 2006 to train academic staff and formulate the course capsules. Most of the academic staff has never being exposed to disciplinary areas covered in staff trainings. These training activities have sensitized them to think beyond technical solutions in addressing water resources management issues.

The project also has taken initiatives to help formulate the research programme gradually along with the curriculum change process with clear interventions at various stages. International training was given to both academic staff and students of the PGIA on Field Research Methodology and other complementary subject areas. These changes were supported by a research programme to make this transformation effective. Therefore, formulating an interdisciplinary research programme has been constantly insisted upon and the themes and sub-themes were so designed to capture the interdisciplinary aspects. This is followed by the appointments of PhD candidates of different backgrounds to work cohesively in designing the detail research methodology as discussed below.

The formulation process of the research programme at the PGIA started with the appointment of Research Programme Manager (PRM) who is a permanent academic staff member and expected to coordinate the research programme. The CB project organized staff training activities which brought academic staff together to generate ideas for research. Brainstorming sessions were conducted to transform the research issues to a research programme through discussions and feedback from academic staff. How to address a "problem" through "participatory" methods using an "interdisciplinary" approach to produce "an impact" at the conclusion of the project were the basic parameters which were considered in formulating the research proposal (Gunawardena *et al.*, 2008).

The water pollution issue is interconnected and hence need to identify the network of issues to be researched. Therefore, mapping of the issues related to the problems revealed the contributing causes and their connectivity as described in Figure 01. Accordingly, the five sub themes were identified for the formulation of main research questions as follows:

- Solid waste disposal
- Health and sanitation in estate and rural communities
- Soil erosion and landslides
- Low cost wastewater treatment techniques
- Institutional and financial sustainability of urban and rural water supply and sewerage systems.

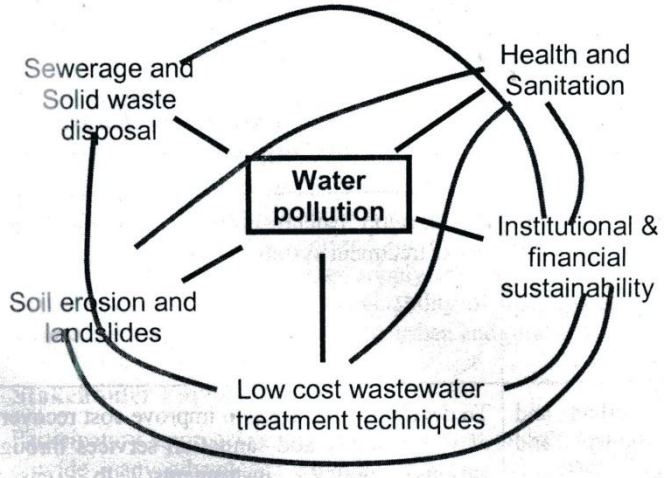

Figure 01: Mapping of issues related to water pollution in Mahaweli

The draft research proposals of each of PhD candidates were prepared with detail methodology. The main objective which reflected the nature of study is given in Table 02 along with the educational background (both undergraduate and postgraduate) of the students. It was anticipated that candidates with this diverse background would help to capture the interdisciplinary aspects of the research, as experienced during the interactions during the implementation of the research programme. The summary objectives with respect to the five sub-themes are summarized as shown in Table 02.

Table 02: Sub-themes and the objectives of research proposals

Five sub-themes and the academic background of 5 PhD candidates	Objectives
Solid waste disposal (Humanities[1], Sociology[2])	To develop an effective process to reduce solid waste disposal to river *Mahaweli* through community participation by intervening to address underlying socio-cultural, economic, political and gender-related factors.
Health and sanitation in estate and rural communities (Agriculture[1], IWRM[2])	To analyze the root causes related to poor sanitation and recommend appropriate technologies for sanitation for the *Pussella-oya* sub-catchment.
Soil erosion and landslides (Agriculture[1], Soil Science[2])	To develop management strategies to minimize soil erosion and landslides in *Kurundu Oya* catchment of the *Mahaweli* river.
Low cost techniques for waste water treatment (Civil Engineering[1], Resource Engineering[2])	To develop catchment-based low cost waste water treatment systems
Sustainability of urban and rural water supply and sanitation services (Agriculture[1], Economics[2])	To develop alternatives to improve cost recovery of water supply and sanitation services through various policy instruments to ensure sustainability of institutions which provides water supply and sanitation services in municipality, peri-urban and rural areas.

[1]/ Undergraduate degree

[2]/ Postgraduate degree

Implementation Strategy

The research programme was designed in such a way that 24 M.Sc. and 16 M.Phil candidates of the IWRM postgraduate degree programme of the PGIA funded under the CB Project, would supplement the studies conducted by the Ph.D. candidates. The sub-themes are mostly concentrated on the research areas of five Ph.D studies. Sub components of the main PhD research were undertaken by the M.Phil and M.Sc. students.

The five PhD candidates were provided with additional training to facilitate this research programme. This included the offering of courses of interdisciplinary field research methodology, gender in IWRM, and river basin planning and management in addition to two training programmes of two weeks durations each in India.

The continuous dialogue between the IWRM staff, CB Research Coordinator and PhD, MPhil and M.Sc. students helped to formulate the research programme in such a way to address all the aspects in a holistic and interdisciplinary manner. The members of Research Advisory Committee (RAC) are invited at regular intervals to attend student's presentations so that their advice also can be incorporated to the research programme as it develops. The regular input was also provided by the CB staff.

The synchronization of individual research themes are very much needed for better outcomes. For example, findings of the 2nd study on environmental socio-economic and institutional perspectives for appropriate sanitation technologies for *Pusella-oya* catchment is required for the 5th study to develop alternatives to improve cost recovery of water supply and sanitation services through various policy instruments to ensure sustainability of institutions which provides water supply and sanitation services in peri-urban and rural areas.

Stakeholder Participation

Participatory approaches by involving stakeholders and networks in research provide many advantages in addressing research issues (Van der Zaag *et al.*, 2009). According to Barbel *et al.* (2010) there are four levels of stakeholder participations, such as, *informed, consultation, involved* and *control*. At the lowest level, stakeholders get *informed* about a study. At the second level, stakeholders are *consulted* and provide data and input for a study. At the third level, stakeholders are *involved* in a study and have influence on its course. At the fourth level, stakeholders *control* or steer a study and determine the course of a project.

The participatory approach using stakeholder has been used from the inception of the CB research programme unlike conventional individual technical research which is normally conducted at the Board of Study in Agricultural Engineering under which the CB research programme is implemented. The feedback received from the first stakeholder meetings were incorporated into final research

proposals. A total of 38 participants, representing the local and national organizations which have a stake in the research problems identified, were present in the second meeting. A total of 9 members out of this list were selected as members of the RAC as shown in Table 03.

The methodology of almost all individual proposals include the use of technological tools such as physical and numerical modeling approaches, GIS and remote sensing, design and development of novel technology for waste water management, instrumentation etc. However, all sub-themes will also use various Participatory Rural Appraisal (PRA) tools along with social and gender analysis tools. Special attention were paid to variables such as key stakeholders, social and gender relations, institutional linkages, etc. In addition, the researchers worked closely with the existing projects and networks related to water pollution in the area such as field based NGOs, foreign funded projects, major water supply and sanitation service providers of the central and local governments, private sector and civil society organizations.

Research Advisory Committee (RAC)

The RAC appointed by the CB Project at the PGIA was expected to play a major role during the implementation of research programme. This RAC comprised of researchers, policy makers, practitioners, professionals, academics, NGOs etc so that they would be able to provide;

- access to networks and organizations in the research area.
- expertise that is complementary to the expertise available in the Partner Institutions (PIs).
- links with policy and practice, which can help to assure 'impact', and
- links with stakeholders groups/organization.

This committee does not have any legal binding with the institution and, therefore do not have any involvement in academic matters of the PGIA. The RAC acts as a sounding board and platform for discussion in addition to provide advice. Formal decision-making is located with the CB team at the PGIA which convenes the RAC at regular intervals.

PGIA has set up the RAC comprising of nine members coming from various backgrounds – professionals, practitioners, NGOs, business, academics, government departments, as shown in Table 03. The first RAC meeting was held on May 25, 2007. The major outcomes of the meeting were to have;

- a clear understanding to the role of the RAC in the research programme

- clarification of type of support the members would provide
- RAC meetings once in three months, and
- agreement to permit research students to meet any of the members any time they needed.

The list of RAC members, their affiliations and the support that they could provide to implement the research programme at the PGIA is indicated in Table 03. In addition to proving the guidance, the members of RAC have been very helpful in providing access to institutional resources including the supply of information. They also facilitated the process of transferring research information to practice and policy.

Brief Descriptions of Five Research Themes

The justification for transdisciplinary research stems from the fact that complex research issues cannot be solved using only disciplinary, multidisciplinary or participatory research. Therefore, it is important to look at whether research programmes of the PhD candidates of the CB project at the PGIA satisfy the criteria listed under the transdisciplinary research. The following sections briefly describe the complex nature of the research problem, objectives, how research is being carried out with stakeholder participation, the level of involvement of stakeholders, findings, lessons learned and challenges of conducting transdisciplinary research and impacts of each of the research theme.

Table 03:Designations, affiliations and the type of support provided by the members of RAC

No.	Designation and Affiliation of RAC members	Area of Influence
1.	Director, Head Works Operation & Maintenance, Mahawelli Authority of Sri Lanka (MASL)	In-charge of all the headwork reservoirs of *Mahaweli* river and has a mandate to protect its water resources.
2.	Executive Director, Environment and Forest Conservation Division of MASL	Has a mandate to implement catchment management activities to assure regular supply of good quality water to *Mahaweli* specially through the prevention of soil erosion and land slide
3.	Consultant Community Physician, Provincial Directorate of Health Services	In charge of health and sanitation services to the population in Central Province
4.	Deputy Chairman, Central Provincial Council	Member of provincial council elected by people. Also the president of the environmental committee. Helps to provides access to local bodies, people and the government
5.	National Advisor, Water & Environmental Sanitation Program, PLAN Sri Lanka	National NGO with many field based programmes funded by foreign donors.
6.	Associate Research professor, Institute of Fundamental Studies	Scientist with long years of experience in water quality research
7.	Asst. General Manager, National Water Supply & Drainage Board, Central Province	Mandated to provide water supply and sewerage services as the main service provider. All the foreign funded projects in the sector are implemented through this organization
8.	Scientists, National Building Research Organization	Government organization mandated to conduct research on landside hazards and implement regulation on construction and settlements in land slide prone areas.
9.	Businessman, *Kadugannawa* Town	Interested volunteer to support environmental conservation activities. Has a strong link to local organizations and people

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SANITATION AND HEALTH OF COMMUNITIES OF UPPER MAHAWELI CATCHMENT AREA (UMCA)

Research Problem and Objectives

The term 'sanitation' is highly related to the water, hygiene and health which should not be neglected in water resources management. It was reported that water intakes belong to the National Water Supply and Drainage Board (NWS&DB) and all other water sources in the *Pussella-oya* catchment are contaminated by improperly disposed sewerage. The problem primarily occurred due to poor sanitation and hygiene of the communities, posing serious threat on health of themselves and also of the downstream communities.

Therefore, a research study is conducted to analyze the issues and root causes related to poor sanitation and to find out appropriate technologies for improved sanitation of the catchments communities. The assessment of the institutional setup, policy and regulatory mechanisms of sanitation in Sri Lanka would help to formulate solution to address the above problems in the long run.

Methodology

Since the study area comprise of different socio-economic groups of communities, each group should be included in the assessment. Therefore *Pussellawa* town which is the most urbanized place and *Rothschild* estate which is the most upstream community and *Blackforest* village were selected for in-depth analyses of the issue. Field visits to some places in the catchment and transact walks along the stream were conducted to have a general understanding on the issue and root causes. Medical officer of health, *Grama Niladari*, community leaders, participated for these visits and transact walks. Stakeholder inception workshop was conducted mainly to raise the awareness among stakeholders on sanitation issues, and to gather information through a common discussion forum. For effective communication, awareness raising brochure was developed and distributed among the community to make them aware on sanitation issues.

A latrine provides the primary barrier against the spread of fecal matter, but the provision of sanitation facilities will improve people's health only if they are technically sound, and well maintained by the community or an institution. Even though the latrine is available, it would not be safe to use, if the disposal system is contributing to the contamination of surface or ground water. People would be interested on the dignity related with sanitation, but not the fecal pollution occurred underground. Therefore, sensitization on the real issue helped to extract true information from stakeholders. Focus group discussions (FGD) were conducted with a pocket voting activity which included some sensitive questions which people were reluctant to talk openly. Research tools were developed for efficient communication and for keeping the information undisclosed to each other. Specific issues in each community were identified through the FGDs.

Participants were sensitized on sanitation issues by presenting the research findings from transect walks. Testing of the water samples for fecal coliforms wherever necessary and testing of effluent and compost samples for existence of pathogens has helped in determining the appropriateness of different sanitation technologies. Case studies on success and failures of different sanitation systems were conducted and they were assessed in depth, using sustainability criteria. Institutional setup and gaps in policies, legislations and regulation mechanisms were assessed using content analyses and structured interviews with relevant stakeholders.

Summary of Findings

According to stakeholder's perception, estates, community, political leaders, Medical Officer of Health (MOH), and Pradeshiya Saba (PS) are the most responsible stakeholders for the issue as shown in Figure 02. Limited space, shallow water table at some locations, scarcity of water and rocky conditions have caused failures of existing onsite sanitation infrastructure. The settlements along the stream banks potentially pollute water by locating their cesspits at the stream bank. Community in the township contributes to water pollution by directly diverting their septic tanks into the open storm water drains during the rainy days and by inappropriate cesspits. Some urban locations are totally inappropriate for human dwellings, because it interrupts the natural quality of streams. Knowledge gaps and the attitude that 'providing sanitation facilities is an institutional role' caused the poor investment on sanitation by the people. Estate population always tries to be dependent on the management because of the poverty, land ownership issues, and lack of knowledge. Some estate people preferred open defecation, because water sealed latrines are provided without access to adequate water. The question "how they can use the water sealed pour flush latrine without having adequate water?" has not even considered when the technology was selected. The recommended distances among the cesspits and cesspits to water sources have been highly neglected in constructions. Even though the availability of toilets is high in all the communities, fecal contamination is still evident because those toilets themselves contaminate the water sources. Therefore, the local context should be taken into consideration for selecting a proper sanitation system. Lack of innovation of technological solutions considering local situation and knowledge, and poor knowledge transfer have led to these failures of sanitation technologies.

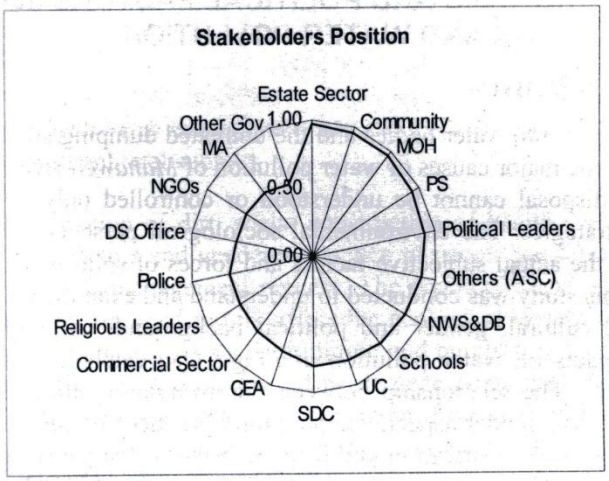

Figure 02: Responsibility ranking of stakeholders on prevailing issues of sanitation

Sustainability assessment of the sanitation systems found that the non-conventional onsite technologies are the most sustainable, whereas the conventional offsite systems have many issues such as institutional failures, poor community participation for maintenance of onsite components, and water contamination by onsite components. Reusing the compost and effluent should be done only if the treatment system efficient enough to produce a pathogen free product. However, people continued to reuse the effluent or compost without testing for pathogens.

The studies found that though there are adequate legislations available, the complex structure of the institutional setup and overlapping of responsibilities have prevented to take actions against continuing illegal disposal of sewerage.

Challenges and Lessons Learned

Since the research attempts to integrate several disciplines to find practical and sustainable solution for the existing problem concerned, more time is needed for understanding the concepts under different disciplines. Stakeholders were also involved in the research and more effort was made for rapport building and moving with stakeholders in process. It was learnt that involvement of the *Grama Niladhari* helped to increase the participation of the community for research activities. Accessing data was also difficult in some situations where people expected direct, tangible benefits from the project. It was also challenging to deal with the unexpected behavior of the stakeholders such as refusing to answer the questions, lack of interest, conflict among the community leaders, etc.

EFFECTS OF SOCIO-ECONOMIC AND POLITICAL FACTORS IN SOLID WASTE GENERATION AND WATER POLLUTION

Research Problem and Objectives

The direct solid waste disposal into water bodies and the untreated dumping sites are supposed to be some of the major causes of water pollution of *Mahaweli* river. The crisis of solid waste disposal cannot be understood or controlled only by technical or engineering strategies. The environmental sociological perspectives are helpful to comprehend the actual subjective factors and forces of solid waste generation and disposal. This study was conducted to understand and examine the underlying socioeconomic, cultural, gender and political backgrounds of solid waste disposal and its impacts on water pollution in *Pinga Oya* catchment, a tributary of *Mahaweli* river. The relationship between the awareness, attitude, livelihood, consumption pattern, gender aspect, socio-cultural practices of people and power structure on solid waste generation and disposal were investigated. It was expected to identify and promote social development for sustainable solid waste management on the basis of local knowledge, cultural notion and informal social mechanism of study area.

Methodology

The study was carried out in four Divisional Secretariats (DS) of Kandy District (*Akurana, Pujapitiya, Harispaththuwa and Pathadumbara*) through which *Pinga Oya* flows and main focus was given to *Akurana* DS considering objective of the study. Semi structured questionnaire survey method was used to collect data (mainly quantitative) from randomly selected 200 households and 150 shop-owners. Thirty five (35) in-depth interviews were used to collect qualitative data from the key informants of *Pinga Oya* watershed area using stratified random and purposive sampling methods. In addition, three stakeholders meetings, five informal group discussions and observations were also used to collect quantitative data and subjective information. The secondary information was mostly collected from the sociological literature and water quality studies done by natural scientists. Data were analysed both quantitatively and qualitatively.

Summary of Findings

The environmental awareness and attitude are found important aspects of solid waste generation and disposal. Households are more aware of the environmental issues related to solid waste disposal and water pollution than shop-owners. Awareness of women is higher than that of men. Women are conscious on local environmental issues based on environmental health crisis whereas men are interested in national or provincial level issues based on political-economic background. Households, female, elders and people with lower education level hold stronger environmental attitude and concern.

The livelihood and consumption pattern were the most leading factors in determining solid waste generation. A specific pattern of consumer culture

influenced by foreign remittance has a strong impact on food consumption and waste generation. It was identified that there is a positive link of income, employment and livelihood with solid waste generation. Educated and economically rich causes more damage to *Pinga Oya* by violating environmental rules with political support.

Cultural notion of dirt, social construction of health risk, social attitude toward waste collectors and gendered practice of people are found crucial in solid waste disposal and management process. The practice of endogamous marriage, dowry house and extended family affect the ecological system of area. It is the women who mainly influence on determining and purchasing food. Although women had higher capacity to control solid waste generation, they were not properly utilized for sustainable solid waste management. Educated middle class Muslim women play a significant role in conserving ecological system regardless of the cultural and patriarchal pressure on them.

The political influence was found as a serious barrier in controlling the illegal construction which has caused many issues related to water pollution of *Pinga Oya*. Informal mechanisms (Mosque) are powerful than formal institutes in terms of making decision in sustainable development. Solid waste management (SWM) by local authorities were not satisfactory to people and caused many other social and inter-community frustrations due to poor socio-cultural aspects of SWM. The conflicts among institutes and legal barriers prevent the proper SWM and conservation of *Pinga Oya*. Finally, this study reveals that a social development empowered with religious bodies, informal social mechanism and female participation should be utilized for sustainable solid waste management based on gender and cultural context of respective communities.

Challenges and Lessons Learned

There were number of challenges encountered during the study which included the practical difficulties of researching politically sensitive issues such as nexus between illegal construction, bribery and political interference, limited access to some data due to ethnic or community based tension or dissatisfaction, cultural and gender related restrictions in accessing of female respondents. Different power groups linked to the mosque has dominant influence compared to the government institutions. Therefore, societal research has to be implemented cautiously with the concurrence of these different power groups.

EFFECT OF INAPPROPRIATE LAND MANAGEMENT ON RIVER WATER QUALITY

Research Problem and objectives

Soil erosion in agricultural fields is the main process of land degradation in Upper Mahaweli Catchment Area (UMCA) which affects not only the land productivity but also the water quality of downstream water bodies. This water quality

deterioration is closely associated with the discharge of nitrogen and phosphorus in surface runoff from agricultural fields. This process is accelerated due to over fertilization on eroded soils especially in commercial, intensive vegetable farming systems. Despite the effort to promote soil conservation measures, the adoption by farmers is minimal and soil erosion continues to be a problem causing loss of soil fertility, deterioration of water quality and siltation of reservoirs. Most of the expert recommendations neither addressed farmers' needs nor did they suit their social and economic situations. Subsequently, locally adapted technologies were largely ignored even though they were effective. In this context, a comprehensive study on soil and water quality coupled with socio-economic and institutional set up of the UMCA was carried out to understand the underline processes. This includes a comprehensive analysis of land use change, water quality assessment, evaluation of existing soil conservation measures by stakeholders and a detailed analysis of socio-economic factors which affect land degradation of the UMCA.

Methodology

The study was conducted in *Kurundu oya* catchment in *Walapane* and the area is representative of potential soil erosion zones in the UMCA with respect to soil properties, landscape, farming systems and the socio-economic conditions. The methodology applied includes qualitative and quantitative techniques to collect information. A comprehensive literature survey was conducted to gather secondary data which was mainly used to analyze land use change of the UMCA. Formal household survey, focus group discussions and field observation were used to obtain socio-economic information. Standard laboratory techniques were used to analyze samples in water quality assessment. Matrix ranking was used to evaluate existing soil conservation techniques by the farmers.

Summary of Findings

The results revealed that about 20% of the sampled households live below the poverty line. The landless poor consisting of 28% of population showed high tendency to encroach hilltops and hill slopes which are strict natural forest reserves. They practice rain-fed subsistence farming and their income levels are relatively low. Approximately 25% of the total lands including more than 50% of the riparian zones of the study area have been encroached. The nitrate (NO_3) levels of the stream water flows through vegetable-growing areas range from 8 to 45 mg/l with high electrical conductivity, total dissolved solids and available phosphorus. Most of the families use this poor-quality water for drinking and other domestic purposes making them vulnerable to diseases.

The results further shows that, the investment on soil conservation measures is likely to increase with the farm income, level of awareness and the ownership security of the land. It was identified that even the encroachers can be mobilized towards soil conservation to a certain extent through awareness programs. The capacity of the extension service has to be strengthened in order to make the farming community aware of soil conservation. Land alienation programs could

make effective changes in soil conservation by giving social values to the land owner through a more secure land tenure system. Presence of more than 30 acts and 15 agencies dealing with land and water has led to duplication of responsibilities, confusion and inaction. The deficiencies in the existing policies and institutional arrangements do not warrant proper land and water resources management.

Challenges and Lessons Learned

At the beginning, it was difficult to get farmers involvement to the process. However, their participation has gradually increased though they were reluctant to provide sensitive information such as land tenure status and farming income since most of them were 'Samurdhi' recipients. They have the fear that the government may cut down their allowance if real income is disclosed.

There were some positive changes of the stakeholders during the study. The capacity of field level officers has gradually built up during their involvement in the process. Presently they have better understanding in soil conservation techniques and soil conservation act. There is a demand from farming community and field level officers to conduct more awareness programs. Most of the farmers have realized that more than half of the excessive application of inorganic fertilizers is lost. As a result, currently they are practicing split fertilizer application instead of bulk application. Several farmers started to plant *vetiver* grass to cover unprotected embankments of terraces to prevent soil erosion.

It is revealed that technically or economically feasible conservation measures are not always socially accepted and therefore, social and political dimensions also have a bearing on the adoption of soil and water resources conservation measures.

LOW COST WASTEWATER MANAGEMENT TECHNOLOGIES

Research Problem and Objectives

Inadequate and improper wastewater management has caused serious environmental degradation and health risks in the UMCA. Though, regulations on effluent discharge standards have been established since1980s, discharge of untreated or partially-treated wastewater to the river has been a common practice due to multitude of factors which includes lack of appropriate technologies for specific local situations, shortcomings in legal framework such as non stipulation of design requirements in the existing regulations and knowledge gaps in site specific treatment technologies. On the other hand institutional inefficiencies and inadequacies to implement the existing legal provisions against polluters, lack of implementation strategies, lack of awareness and knowledge of general public about treatment systems and their attitudes towards ill effects of pollution has further aggravated the problem. Therefore, this study was conducted to generate low-cost wastewater treatment systems suitable for different local conditions of the UMCA and to develop an internet based Geo-Portal on water related

information to share information among relevant authorities, institute and academic communities.

Methodology

The process followed during the study is given in Figure 03. Field investigations were carried out with knowledgeable people in the area to identify the sources of pollutants and information about the waste water treatment systems already available. Key informal discussions were held with Central Environmental Authority (CEA), Urban Council (UC) and with public to identify the most important issues in relation to waste water generation. To develop appropriate treatment system for leachate treatment, institutional capabilities on wastewater treatment services in terms of financial and technical capacities of Urban Councils were evaluated. Based on that institutional capabilities and opinions of host communities, deferent options of wastewater treatment systems were suggested to them to select most appropriate systems. After generating knowledge on low-cost treatment system, a waste water treatment was established at *Gampola* solid waste dumping site with the active participation with *Gampola* Municipal Council.

Discussions were held with service station managers and owners to obtain qualitative data through a questionnaire survey and chemical and physical parameters were measured to evaluate the pollution level of wastewater generated from service stations. Awareness program was conducted to fill the knowledge gaps and to change their attitudes and values.

Summary of Findings

In this study, different types of Constructed Wetlands (CW) were investigated as low-cost, maintenance free treatment systems to examine the reduction efficiency of leachate which was produced in open dumping sites of solid wastes. The results indicated that Surface Flow Wetlands (SFW) planted with *Tyhpa* shows highest removal efficiency of Biological Oxygen Demand $(BOD)_5$ of 65.5%, Chemical Oxygen Demand (COD) removal of 79%, and Nitrogen removal 63.3% at 8 m distances. Therefore, SFWs with Typha can be used to mitigate the problem of water pollution in dumping sites in the UMCA.

Even though, regulations on effluent discharge standards for service stations and treatment plants to treat wastewater are already established, average measured values for effluent discharge from service stations are still higher than the standards set by Central Environmental Authority (CEA). Questionnaire survey results show that lack of knowledge in environmental impacts, high operation and maintenance cost for available systems and owners attitudes towards wastewater treatment and environment effects are the key factors to malfunction of wastewater treatment systems.

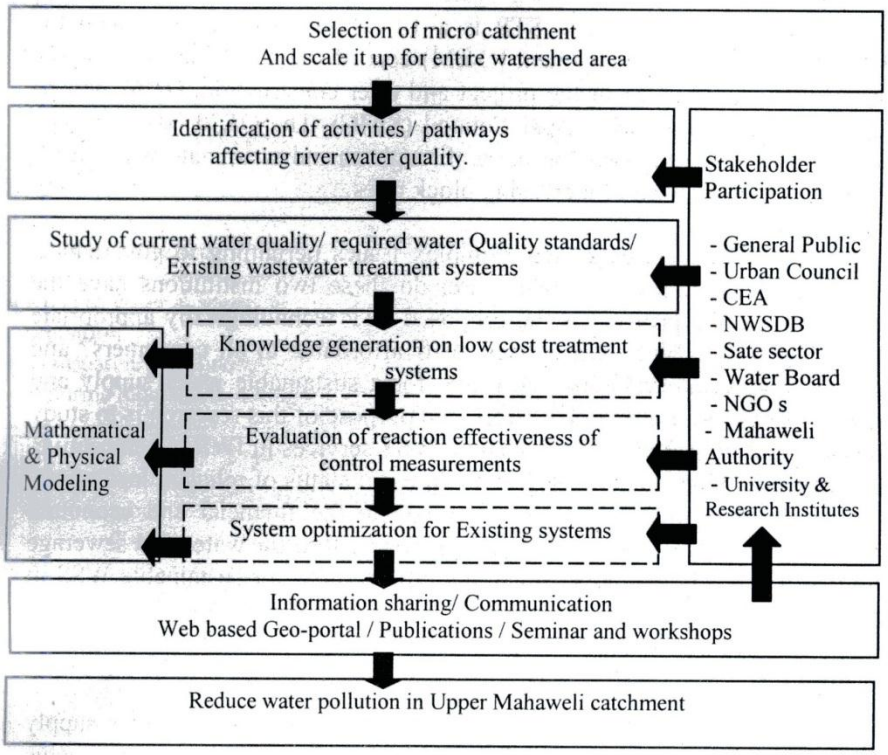

Figure 03: Proposed procedure of the study

Challenges and Lesson Learned

Individuals are more concerned about their own interests and agenda compared to their social responsibilities or well being. Therefore, it was need to adjust to their working schedules, time frames and interests. This has been a major constraint in conducting research work with stakeholders. Building trust with them is a very time consuming process and is a prerequisite to get reliable data for the study.

SUSTAINABLE WATER SUPPLY AND SANITATION SERVICES THROUGH INSTITUTIONAL AND FINANCIAL INTERVENTIONS

Research Problem and Objectives

Mahaweli River is the main source of water supply for domestic, commercial, industrial and agricultural sectors in addition to generates hydropower. However, the river is getting increasingly polluted due to improper wastewater management practices in Kandy city, peri-urban areas and the surrounding estates due to wastewater and sewerage contamination. As a remedial action the NWS&DB has proposed the Kandy Sewerage Treatment Plant (STP) to collect sewerage in the

city and surrounding areas through a system of lateral pipes and treat before releasing back to *Mahaweli*. The STP is a 14 billion worth project with the estimated Operation and Management (O&M) cost of Rs. 11 million per month. The NWS&DB will implement the project and after construction, O&M will be handed over to the Kandy Municipal Council (KMC). The O&M cost has been proposed to be recovered from the users through an indiscriminate water tariff system designed in the form of increasing block rates.

The proposed STP generates several complex issues pertaining to governance, technology and economics. The issues are; do these two institutions have the capacity to handle the project? is the proposed STP technologically appropriate and economically feasible?; is increased tariff affordable to all consumers? and what are the policy interventions applicable for a sustainable water supply and sanitation (WSS) in Sri Lanka?. Therefore, the purpose of this research is to study the proposed STP in providing a sustainable WSS services in IWRM perspective. More specifically the study will analyze the present status of relevant institutions in water supply and sanitation sector, investigate the financial and economic feasibility of STP, propose an appropriate tariff structure for water and sewerage for Kandy city and propose policy interventions required for sustainable WSS in Sri Lanka.

Methodology

The study was conceptualized as given in Figure 04. The urban water supply institutions mainly the NWS&DB and the KMC have to provide the sustainable service of WSS in order to achieve the Millenium Development Goals (MDGs). In that they have to build up its human resources, intra organizational management practices, inter-organizational collaborations and face the external rules and incentives in financing and cost recovery towards a sustainable WSS which is affordable and equitable. The external pressure on water institutions can be mostly the governance issues as right to water, access to improved sanitation, reforms, and political pressure on tariff setting etc. These institutions need to address financial and cost recovery issues to sustain the service while providing a service which is affordable and equitable to the consumers.

The methodology followed in this study included data collections and analysis which looked at the three major components as explained above, i.e. governance, institutional and financial aspects. This study was concentrated on the NWSDB and the KMC as key institutions of providing water and sanitation services to Kandy city. Though the study focused in Kandy city, issues of national importance were also highlighted since NWSDB is considered as the major national institutions which provide water supply and sanitation services to the entire country and thus cannot be looked at in isolation. The study used secondary data from the NWSDB and the KMC and primary data from focus group discussions, key informant interviews in analyzing the institutional capacity. Primary data from structured questionnaire surveys were used to perform multiple

regressions, simulation and choice modeling in order to quantitatively determine the appropriate tariff rates.

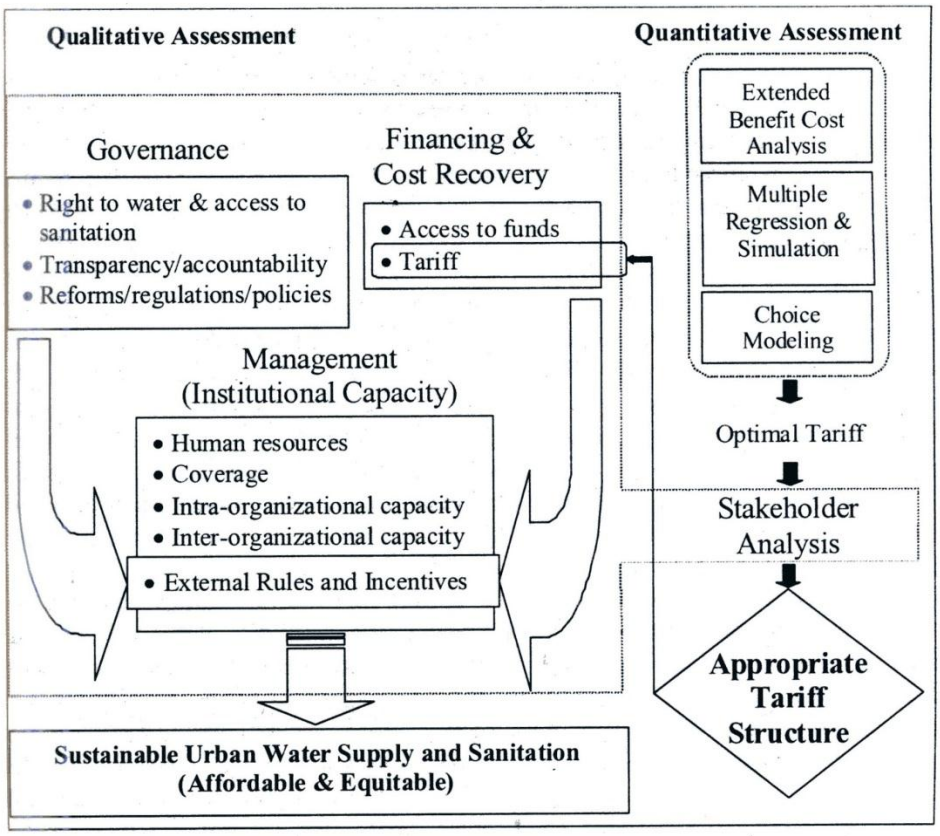

Figure 04: Schematics of the Methodology

Summary of Findings

Institutionally, the NWSDB appears to be strong, and is continuing to improve operational efficiency, skill development through training, online payment system and new infrastructure facilities, among others. Yet total expenditure (cost of production, personal expenditure and interest payments) is continuing to deviate from the revenue generated over the years. Continuous dependency on foreign funded projects would further aggravate this situation. Encouraging communities to rely on community based water supply schemes, adopting water saving techniques, commissioning locally funded WSS schemes and tariff revisions to reduce the gap between expenditure and revenue while looking after the poor are important strategies that requires serious attention. The KMC on the other hand has many problems which include lack of funds for infrastructure

improvements/rehabilitation along with the poor human resources. A decision to handover a sophisticated STP to such an organization needs to be reviewed very seriously. However, their legitimate role as a local service provider could not be overlooked and hence new institutional arrangements with the NWSDB need to be explored.

The quantitative analysis shows that the tariff structure imposed on consumers connected to NWSDB was more aggressive than that of KMC. Therefore, KMC users had the tendency to use piped-water for luxury uses. The impact of income was found to be more prominent in households connected to NWSDB than KMC. The results revealed that no substantial changes in residential water demand can be expected due to any of the policy shocks used by the two institutions. This is due to two reason; one is that the household water bill is fairly low and the water demand is income inelastic and the other is that the heavy subsidy given to low income categories, which consist a vast majority of users, does not act as an incentive for conservation. Although the degree of subsidy reduces with increasing income, people with high incomes also enjoy the subsidy benefits especially in households receiving KMC water. This study reveals that the tariff structures are highly subsidized and that there is room for increasing tariff levels at higher blocks which is pro-poor. This result is consistent with results obtained from the consumption data of the NWSDB.

The qualitative assessment of the STP shows that the technology may not be appropriate and there is a public protest against it and the NWSDB has to depend on the technology and money in order to establish the system and subsequent maintenance. The benefit cost analysis shows that the proposed STP is not financially feasible due to the high construction cost and the O&M cost for sewerage treatment. The economic analysis shows that project become feasible when environmental benefits are accounted. However, the sensitivity analysis with different tariff structures shows that tariff rates are not sensitive to the feasibility of the project. This is again due to the high construction and O&M costs of the project.

Challenges and Lessons Learned

There were number of challenges faced during the study, which included the convincing of stakeholders about the importance of the study and accessing undisclosed data. Building trust with the stakeholders has helped to get their corporation during the various stages of the study. The integration of econometric estimations with sociological and governance concepts had been a major challenge during the final analysis.

The study reveals that one discipline alone (disciplinary research) could not solve the problem of finding an appropriate tariff for WSS. The results of both qualitative and quantitative analysis should be critically discussed with the policy makers and the stake holders (at NWSDB and KMC and other related institutes)

in order to come with an appropriate and acceptable tariff structure for sustainable water and sewerage services in future.

CONCLUDING REMARKS WITH REFLECTIONS

As shown in Table 04, all the PhD projects could be classified under transdisciplinary research projects since all of them satisfy the attributes which are needed for transdisciplinary research. Though there are number of disciplinary areas covered, all the participants have focused deeper in to a selected discipline of their choice so that they could satisfy the intensive academic inquiry required for a PhD study.

The information in Tables 04 and 05 shows the intensity with which the candidates have worked with the stakeholders. Almost all the stakeholders have a role to play in addressing the issue. The level of involvement shows that the candidates have reached three out of four levels of stakeholder participation as identified in section 'Stakeholder participation'. They were not able to achieve the highest level of involvement (i.e. control). However, it would be possible to reach this level if research projects are formulated with the relevant institutions which could fund the researchers to address their problems. This approach is being suggested for the next phase of the CB project.

The impacts of five research studies are given in Table 06. Some of the impacts such as construction of toilets and establishments of field level water treatments are very direct, quick and tangible. Many other impacts are not so clear and the benefits could not be assessed in an objective manner. The interventions in terms of changing policies and institutional reforms could have substantial impacts if pursued consistently through advocacy.

This problem based, interdisciplinary research conducted through stakeholder participation to have an impact was new to PGIA. The traditional practice was to guide the student by the respective supervisor for a specific research project with clear objectives. In this case, academic staff along with the students addressed a common theme in different angles to address a major water management problem identified by the institution. Regular meeting of the academic staff, students and members of the PAC were held to make sure that all the individual research projects are interlinked while ensuring that repetitions are avoided. Closer interaction of all parties, especially the five PhD candidates have ensured the cohesion and integration of the problems from different angles. The entire research programmes were steered through a learning process by interaction, monitoring and intervention as this was a new experience for all those who participated in the project.

Table 04: Attributes of Research Projects

Research Project	No. of Disciplines	Non-Academic participation	Quantitative Assessment	Qualitative Assessment
Sanitation	Wastewater engineering, Health science, Political science and Social sciences	Community (Rural, Estate, Urban), Health officials (MOH, PHI, midwives..), District secretariat, Pradeshiya Sabah, CEA officials, Estate management health and welfare officers, NWSDB officials and NGOs	Questionnaire survey- the wealth, sanitation related parameters, water availability, knowledge, attitudes, and practices etc. Compost and effluent sample testing for existence of pathogens	Focus group discussions, Case studies on sanitation systems to assess the reasons for success and failures.
Solid waste management	Sociology, Political ecology, Cultural anthropology and Environmental science	Households, Shop-owners, State administrative bodies(DS), Local authorities (PS), Health sectors (MOH), NGOs/ CBOs, Mosques and Schools	Questionnaire Survey (SPSS), Water quality parameters from literature, Data of SW generation pattern from State documents	Informal discussions, Stakeholders Analysis, In-depth interviews
Soil erosion	Soil science, Watershed management, Social science and Economics	Farmers, Field officers and School children	Soil and Water quality analysis	Key informant interviews, Ranking methods
Waste water management	-Waste Water Treatment -Geo-informatics -Hydraulics -Social science	Service Stations managers and owners, Officers from CEA, UCs, MOH, Community and Workers form NGOs	Water quality, Institutional capacity assessment	Ranking methods
Water supply	Project analysis, Resource economics, econometrics and social science	Officials at the NWSDB, KMC, Department of Agriculture, and consumers of water	Benefit cost analysis, Econometric estimations and simulations, and Choice modeling	Key informant interviews and qualitative assessment, Institutional capacity assessment.

Table 05: Level of Stakeholder Participation

Research Project	Informed	Consultation	Involved
Sanitation	Stakeholder inception workshop was conducted to make aware all the stakeholders on the research problem and to analyze the stakeholder's position. Individual meetings, phone and email conversations with the officials of the sanitation improvement projects were conducted to gather details and locations of different sanitation technologies applied in the country.	Meetings with stakeholders to gather the required documents and information. Individual meetings were held with officials of the prevailing institutional setup of the sanitation sector. e.g.: Public Health Inspectors (PHI) Community consultation for in-depth interviews, structured interviews etc…	Officials such as Grama Niladari (GN), Medical officer of Health (MOH), estate welfare officer and community leaders involved in transect walk identifying pollution sources & communities. Community participated for focus group discussions, social mapping, and answered to the questions in the structured interviews. Some officers (PHI, maintenance engineers) involved in the research by providing continuous monitored data of the physical and chemical properties. Officials (MOH, field officers of NGOs) involved in the sample collection for testing of pathogens in the effluent or compost.
Solid waste management	Awareness program for women on how to control solid waste generation Educating school children on transmission of dengue fever due improper waste disposal Administering 350 questionnaires for both households and shop-owners	35 in-depth interviews with key informants of the field Informal discussions with health & environmental officers Three stakeholder meetings with MOH, DS, LA	The influential role of Mosque in the field study & awareness campaign Two day training workshop for field level officers (GS, PHI, environmental & women development officers) & community leaders on sustainable SWM Direct & positive participation of local female NGO (Akurana Women Welfare Association), e.g.

			mobilizing women against anti-environmental actions & publishing a special magazine
Soil erosion	Awareness programs were conducted for farmers, field level officers and school children	Discussions were held with Politicians, Govt. officers and community leaders to get their inputs Farmers and field level officers were interviewed through a questionnaire to analyze socio-economic factors	Farmers and field level officers were involved to evaluate existing soil conservation measures
Waste water management	Awareness programmers were conducted for service station owners and managers	Key informant interviews were held with CEA, Urban council, NGO and interested parties Questionnaire survey were conducted to identify issues and rank them	Officials such as Chairman UC, Engineer UC, PHI and community leaders have participated to identify pollution sources. Establish effective communication and made a trust between CEA and service station owners Options of treatment systems were given to stakeholders and they selected the systems
Water supply	Inputs from the RAC consisting of various stakeholders included in the proposal	Discussions were held with NWSDB and KMC who provided data for the study Users of the water supply & sanitation services were interviewed through questionnaire survey to get their inputs	Officials at the NWSDB and the KMC will be involved in the final decision on sewerage and water tariff

Table 06: Impacts of research projects

Research Project	Impacts on stakeholders	Impacts on policy and institutions
Sanitation	Construction of toilets and educate the estate people on sanitation by MOH using government funds. Contribute to improve the knowledge of the community and officials through training programs	Highlight the gaps in the sanitation policies and regulatory mechanisms and present recommendations. Propose more improved scale for measuring sanitation in national statistics. Recommendations on application of different sanitation technologies by assessing the sustainability of sanitation systems.
Solid waste management	Understanding of Muslim culture by Sinhalese officers Involvement of solid waste management programs (composting) by traders Empowerment of women & children for environmental management	Improved coordination and corporation among MOH, local and divisional authorities Positive change of the role of mosque towards environmental health management
Soil erosion	Farmers realized the drawbacks of existing soil conservation measures and cost effective techniques to improve them	Recommendations are proposed for restructuring the existing institutional arrangement
Wastewater management	Awareness program for service station manager and owners has changed their attitudes, values and increase their knowledge on legal requirements, impacts on environment, technical knowledge and service providers	Gampola Urban Council established a field level treatment plant to mitigate impacts from leachate generated from solid waste from their dump site CEA accepted the absent of proper sludge disposal system as a shortcoming and agreed to address the problem.
Water supply	Recommendations are important in formulating tariff, taking management decisions for stakeholders like NWSDB & KMC and consumers in efficient use of water.	Attempts will be made to incorporate the findings at policy decisions on water and sewerage tariff.

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