RATIONALIZED RESOURCE ALLOCATION FOR IMPLEMENTING WATER SAFETY PLANS

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ABSTRACT

Water Safety Plan (WSP) is the most credible management tool to achieve water safety worldwide. This study looks into prioritization of risks and optimizing resource allocation for implementing WSPs with multiple stakeholders and multiple domains having no mutual accountability and line of hierarchy. The study methodology was in the form of a descriptive and interpretative case study involving three levels; academic, national and sub national. These levels respectively served the targets of studying similar research, understanding policy and decision making environment and analysing grass root level dynamics in implementing WSPs by focusing on Eheliyagoda water supply scheme under NWS&DB. Both quantitative and qualitative data, belonging to multiple categories, was associated.

The analysis showed that the risk-reassessment and improvement plan of WSP need critical revisit beyond semi – quantitative risk matrix method. Only the water supplier (NWS&DB) had incorporated accountability in the WSP while other stakeholders were just collaborating. Standard risk ratings alone were not rational enough to justify strategic decisions on allocating limited resources and instead it might lead to decisions based on induced impressions. It seems to make decision makers defensive even within the domains with accountability while other stakeholders are not convinced on dedicating resources for water safety which may not be under their direct mandate. It was found that graphical interpretation of risks & hazards across all the water supply elements followed with hazard quantification was much convincing in prioritizing risks. Introducing bottleneck analysis to WSP could successfully incorporate the influence of prioritized risks on the coverage of services thus rationally showing where to prioritize resources. Bottlenecks were seen in incorporating consumer element, creating demand for water safety and rationalized budgeting. It was recommended that the guidelines may assign the catchment element to accountable stakeholders other than water suppliers together with demand creation and communication methods.

Key words: multiple stakeholders, multiple domains, accountability, resource allocation, hazard quantification, bottleneck analysis, coverage of services

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LIST OF ABBREVIATIONS

CEA	–	Central Environmental Authority
CEA	–	Cost Effective Analysis
DRD	–	Drinking Water Directive
GND	–	Grama Niladhari Division
HACCP	–	Hazard Assessment and Critical Control Points
INGO	–	International Non-Governmental Organization
MDGs	–	Millennium Development Goals
MoWSD	–	Ministry of Water Supply and Drainage
NGO	–	Non Governmental Organization
NVZ	–	Nitrogen Vulnerable Zones
NWS&DB	–	National Water Supply and Drainage Board
RA	–	Risk Assessment
RDHS	–	Regional Director of Health Services
RRA	–	Risk Re-Assessment
RRI	–	Rubber Research Institute
RSC	–	Regional Support Centre
SDWA	–	Safe Drinking Water Act
SOP	–	Standard Operating Procedures
SWOT	–	Strengths, Weaknesses, Opportunities and Threats
UNICEF	–	United Nations Children’s Fund
USEPA	–	United States Environmental Protection Agency
USLE	–	Universal Soil Loss Equation
WHO	–	World Health Organization
WSP	–	Water Safety Plan
WSS	–	Water Supply System

1. INTRODUCTION

1.1 Background of the research

This research focuses on the dynamics pertaining to implementation of "Water Safety Plans" in the context of Sri Lanka. Unlike "conventional water supply," which is predominantly under the domain of engineering, "water safety" cuts across many other domains such as the general public, legislations, environment, media, education, health etc. This diversity and the independent nature of the respective domains have made "water safety" an entity to be associated with a greater customization and innovation rather than following a set procedure. In addition to engineering and managerial processes, water safety has to immensely deal with the human factor governed by knowledge, attitudes, practices and behaviour thus making it much dynamic rather than static. In this research, some efforts have been taken to focus on several critical dynamics with a view to adding value for implementation of water safety plans in Sri Lanka with much pragmatic approach.

1.1.1 Emergence of "safe water"

For many generations humans had considered drinking water as a naturally available "ready to drink" resource. However with many manipulations in the natural environment by humans themselves, water has fast become a resource that needs to be "processed" to make it "drinkable" for humans from the public health point of view. With growing population as well as environmental degradation, "drinking water" has become a sector of its own amid many other uses of water. The chronology of important milestones in drinking water as healthy consumable can be compiled as follows. (State of Alaska Division of Environmental Health, 2015).

400 B.C. : Hippocrates emphasizes the importance of water quality to health and recommends boiling and straining water.

200 B.C. : A Sanskrit manuscript observes that "It is good to keep water in copper vessels, to expose it to sunlight, and filter it through charcoal."

1774	:	Chlorine is discovered in Sweden.
1804	:	The first municipal water filtration works opens in Paisley, Scotland.
1835	:	Chlorine is first applied to drinking water to control foul odors
1849	:	Cholera epidemics claim 8,000 lives in New York City and 5,000 in New Orleans.
1854	:	Dr. John Snow discovers that victims of a cholera outbreak in London have all used water from the same contaminated well on Broad Street.
1877 -1882	:	Louis Pasteur develops the theory that disease is spread by germs.
1882	:	Filtration of London drinking water begins.
1890s	:	Chlorine is proven an effective disinfectant of drinking water.
1890s	:	Microbiologist Robert Koch attributes the low incidence of cholera in Altona, Germany, located downstream on the Elbe River from cholera infested. Hamburg, to water supply filtration practices in Altona.
1896	:	The Louisville Water Company innovates a new treatment technique by combining coagulation with rapid-sand filtration. This treatment technique eliminates turbidity and removes 99% of the bacteria from the water.
1902	:	Belgium implements the first continuous use of chlorine to make drinking water biologically "safe".

Current drinking water concepts and standards are apparently linked to three major schools of thoughts from United States Environmental Protection Agency, European Union and World Health Organization.

(a) Safe Drinking Water Act (1974) – US Environmental Protection Agency

Safe Drinking Water Act (SDWA) is the principal law governing drinking water safety in the United States. It authorizes the U.S. Environmental Protection Agency (USEPA) to establish comprehensive national drinking water regulations to ensure drinking water safety.

The SDWA mandated a major change in the surveillance of drinking water systems by establishing specific roles for the federal and state governments and for public water suppliers. The federal government, specifically the USEPA, was authorized to set national drinking water regulations, conduct special studies and research, and oversee implementation of the act. The state governments, through their health departments and environmental agencies, are expected to accept the major responsibility, called primary enforcement responsibility or primacy, for the administration and enforcement of the regulations set by USEPA under the Act. (Pontius, 1999).

In the United States, federal authority to establish drinking water regulations originated with the enactment by Congress in 1893 of the Interstate Quarantine Act. The evolvement of drinking water standards in United States up to SDWA has passed several important milestones as follows. (State of Alaska Division of Environmental Health, 2015).

1912 : Congress passes the Public Health Service Act which authorizes surveys and studies for water pollution, particularly as it affects human health.

1914 : The first standards under the Public Health Service Act become law. These introduce the concept of maximum contaminant limits for drinking water. The standards, however, apply only to water supplies serving interstate transportation because they are intended to protect the traveling public.

1955 : An infectious hepatitis epidemic in New Delhi, India is traced to inadequately chlorinated water at one of the city's two treatment plants. An estimated 1 million people are infected.

1962 : U.S. Public Health Service Drinking Water Standards Revision is accepted as minimum standards for all public water suppliers.

1965 : Due to immunization, reported cases of polio in the U.S. decreased from 20,000 in 1955 to 100.

1969 : U.S. Public Health Service Community Water Supply study reveals major deficiencies in the nation's public water supplies.

1972 : The Clean Water Act, a major amendment to the Federal Water Pollution Control Act, Contains comprehensive provisions for restoring and maintaining all bodies of surface water in the U.S.

1974 : The Safe Drinking Water Act is passed. Greatly expanding the scope of federal responsibility for safety of state drinking water. Earlier acts had confined federal authority to water suppliers serving interstate carriers. The 1974 Act extends U.S. standards to all community water systems with 15 or more outlets, or 25 or more customers.

Enactment of the initial Safe Drinking Water Act was inextricably intertwined with the discovery of Tri Halo Methane (THM) and organic contaminants in drinking water. In 1975 USEPA conducted a nationwide survey to determine the extent of the THM problem in the United States. This survey was known as the National Organics Reconnaissance Survey (NORS). The following key milestone were found afterwards.

1977 : The Safe Drinking Water Act is amended to extend authorization for technical assistance, information, training, and grants to the states.

1986 : The Safe Drinking Water Act is further amended to set mandatory deadlines for the regulation of key contaminants; to require monitoring of unregulated contaminants; to establish benchmarks for treatment technologies; to bolster enforcement powers; and provide major new authorities to promote protection of ground water resources.

1996 : The President of the U.S. signs the Safe Drinking Water Act Reauthorization requiring states to implement or establish:

- A revolving loan fund (SRF) to provide money to communities to improve their drinking water facilities;
- Source water protection - identify areas that may contribute pollution to sources of drinking water and assess potential pollution threats in these areas;

- Capacity development - obtain the authority to prohibit the establishment of new drinking water systems that do not have the capacity (technical, financial, and managerial) to meet health-based standards, and establish capacity development strategies for existing systems and;
- Assist public water systems in developing an annual "consumer confidence report" providing customers with information about their water sources, the contaminants in their water, and the health effects of these contaminants.

The SDWA Reauthorization of 1996 also directed EPA to develop rules regulating arsenic, radon, disinfection by-products, and ground water.

(b) Drinking Water Directive (1998) – European Union

(European Commission, 2015)

The European Drinking Water Directive (DWD), Council Directive 98/83/EC, concerns the quality of water intended for human consumption and forms part of the regulation of Water supply and sanitation in the European Union. In setting contaminant levels the Directive applies the precautionary principle. For example, the EU contaminant levels for pesticides are up to 20 times lower than those in the WHO drinking water guidelines, because the EU Directive not only aims at protecting human health but also the environment.

The directive requires Member States to regularly monitor the quality of water intended for human consumption by using the methods of analysis specified in the Directive, or equivalent methods. Member States also have to publish drinking water quality reports every three years, and the European Commission is to publish a summary report. Within five years Member States had to comply with the Directive. Exemptions were granted on a temporary basis, provided that they did not affect human health.

Early European water legislation began, in a "first wave", with standards for those of our rivers and lakes used for drinking water abstraction in 1975, and culminated in 1980 in setting binding quality targets for our drinking water. It also included quality objective legislation on fish waters, shellfish waters, bathing waters and ground waters. Its main emission control element was the Dangerous Substances Directive. In 1988 the Frankfurt ministerial seminar on water reviewed the existing legislation and identified a number of improvements that could be made and gaps that could be filled. This resulted in the second phase of water legislation, the first results of this were, in 1991, the adoption of;

- The Urban Waste Water Treatment Directive, providing for secondary (biological) waste water treatment, and even more stringent treatment where necessary.
- The Nitrates Directive, addressing water pollution by nitrates from agriculture.

Other legislative results of these developments were Commission proposals for action on;

- A Directive for Integrated Pollution and Prevention Control (IPPC), adopted in 1996, addressing pollution from large industrial installations.
- A new Drinking Water Directive, reviewing the quality standards and, where necessary, tightening them (adopted November 1998).

European Water Policy had to address the increasing awareness of citizens and other involved parties for their water. At the same time water policy and water management were to address problems in a coherent way. As a result a new European Water Policy was developed in an open consultation process involving all interested parties in 1996 with over 250 delegates. The represented Member States, regional and local authorities, enforcement agencies, water providers, industry, agriculture and, not least, consumers and environmentalists.

The outcome of this consultation process was a widespread consensus that, while considerable progress had been made in tackling individual issues, the current water policy was fragmented, in terms both of objectives and of means. All parties agreed on the need for a single piece of framework legislation to resolve these problems. In response to this, the Commission presented a Proposal for a Water Framework Directive with the following key aims:

- Expanding the scope of water protection to all waters, surface waters and groundwater
- Achieving "good status" for all waters by a set deadline
- Water management based on river basins
- "Combined approach" of emission limit values and quality standards
- Getting the prices right
- Getting the citizen involved more closely
- Streamlining legislation

(c) Guidelines for Drinking Water Quality – World Health Organization

(World Health Organization, 2010)

The World Health Organization (WHO) was set up in 1948 with the objective of promoting 'the attainment by all peoples of the highest possible level of health'. One of the main roles of WHO is to establish international norms to protect human health. Since 1958, as part of its activities on drinking-water and health, the Organization has published, at around ten-year intervals, several editions of International Standards for Drinking-water and subsequently, the Guidelines for Drinking water Quality.

The Guidelines for Drinking-water Quality is one of the longest-standing normative publications of WHO. They provide an evidence-based point of departure for standard setting and regulation as a basis for health protection. They include an assessment of the health risks presented by the various microbial, chemical, radiological and physical constituents that may be present in drinking-water. Where applicable, they derive maximum concentration guideline values for these hazardous constituents.

In the spirit of primary prevention, the WHO Guidelines recommend pro-active efforts to assess and reduce health risks. They have evolved from a prescriptive document, which established international standards for end-of-pipe water quality, into a normative best practice manual on drinking water management. Emphasis has shifted to promoting a holistic framework for safe drinking-water, which encompasses flexible and locally-relevant health based targets, a system of integrated risk assessment and incremental risk management from catchment to consumer, called water safety plans, and independent monitoring and surveillance.

In 1982, WHO shifted its focus from 'International Standards' to 'Guidelines. The main reason for the shift is the advantage provided by the use of a risk-benefit approach (quantitative or qualitative) to the establishment of national standards and regulations. Specifically, the application of the Guidelines to different countries should take account of the sociocultural, environmental and economic circumstances particular to those countries.

The Guidelines for Drinking-water Quality are recognized as the UN system's official position on drinking water quality. The European Commission and Japan use the Guidelines as the scientific point of departure for their drinking-water directive and drinking-water quality standards, respectively; the Australian Drinking Water Guidelines are based on the WHO Guidelines, while the United States Environmental Protection Agency (USEPA) and Canada's Health Canada actively observe and participate in the WHO Guidelines development and updating process.

The pace of development – in water supply and in the understanding of water and health – has accelerated dramatically. Keeping the Guidelines up to date when information and knowledge are moving so quickly is a major challenge. As a result, since 1991, WHO has been carrying out an ongoing process of 'rolling revisions' to update the Guidelines. Most of the work concerns either developing and substantiating the recommendations in the Guidelines, or of supporting guidance on good practice to assist in implementing programmes and project on drinking-water quality.

The first and second editions of the Guidelines for Drinking-water Quality were used by developing and developed countries worldwide as the basis for regulation and standard setting to ensure the safety of drinking-water. They recognized the priority that should be given to ensuring microbial safety and provided guideline values for a large number of chemical hazards. The third edition of the Guidelines has been comprehensively updated to take account of developments in risk assessment and risk management since the second edition. It describes a framework for drinking-water safety and discusses the roles and responsibilities of different stakeholders, including the complementary roles of national regulators, suppliers, communities and independent surveillance agencies.

The 2004 third edition has been significantly updated through the first and second addenda published in 2006 and 2008 respectively. The first addendum includes more guidance on management of emergencies and unforeseen events, additions concerning chlorination by-products, standards for volatile substances and several new fact sheets for chemical substances. The second addendum includes more guidance on household water management, rainwater harvesting, temporary water supplies and pesticides used for vector control in drinking-water sources. It also includes a series of new microbial and chemical fact sheets. Moreover, expanded fact sheets are included for key chemical risks such as arsenic, fluoride.

This study is based on WHO's water safety concept thus it has been discussed in detail in the 2nd Chapter on Literature Review.

Following several global and regional forums since 70s, drinking water became a key global development indicator when the United Nations General Assembly declared the Millennium Development Goals (MDGs) in the year 2000. MDG 7, on ensuring Environmental Sustainability, contains the dedicated Target 7C to "halve", by 2015, the proportion of the population without sustainable access to "safe drinking water" and basic sanitation" (United Nations, 2015).

The term "safe water" has revolutionized the way the drinking water was perceived earlier mainly with respect to a set of standard quality parameters. The concept of "water safety" itself shows the extent of challenge that the world is facing in terms of potable water. As a process, water safety goes much beyond mere verification of water quality parameters.

1.1.2 Shift in thinking vs Reality in implementation

Shift in thinking on drinking water could noticeably be found in the recent history when the World Health Organization (WHO) published guidelines on "Surveillance of Drinking Water Quality" in 1976. The concept of "surveillance" introduced the fact that attention on drinking water must be maintained regardless of the occurrence of water related public health hazards. This was contrary to the general practice of "being reactive" to such hazards in the aftermath. Instead, the concept of surveillance promoted "being preventive" without waiting till the hazard takes place.

Preventive approach needs to have a broad insight on all possible risks related to drinking water, not just confined to water itself but the whole system of producing it. Drinking water supply system ranges from the catchment to the point of use (consumer). Managing risks associated with such a wide spectrum needs conceptual clarity, well defined tools and institutional & accountability framework. Introduction of Water Safety Plans (WSPs) by WHO has fulfilled this fundamental requirement. Thus safe water has to be compliant with public health standards at the point of use at any random moment as a result of managing risks from the catchment to the consumer.

Assuring water safety across all the systems in a country does not seem to be a feasible task due to many socio-economic and technical realities, particularly in developing and middle income level countries. Hence, in reality, adaptation of WSPs has been an incremental process with course corrections on the go. However with MDG Target 7C defined on access to "safe water", many countries have been in a struggle to endorse that their water coverage is "safe" complying with WHO definitions. This is because most of the water sources reported under the coverage have not been under the purview of WSPs. This compelled many countries including Sri Lanka to find a proxy indicator to report against safe water coverage. The widely used indicator in this case was the "access to improved water sources."

The dilemma in this regard can be observed within the MDG reporting itself. Under the MDG Target 7C of progress update in 2010 (United Nations, 2015), it is said that "The world has met the target of halving the proportion of people without access to improved sources of water, five years ahead of schedule". This conclusion is based on the national statistics of each country where the definition of "improved water source" is highly inconsistent with no reference to its compliance with WHO water safety criteria. Hence it is high time to revisit the basics of "water safety" and reset the statistical interpretations and indicators on which most of the high level policy decisions and priorities are based. Having discrepancies and contradictions on water safety at this moment would endanger human life in future.

1.1.3 Need to re - visit the basics of water safety

Drinking water safety is an extremely diverse entity due to the vast range of domains, scenarios, parameters and determinants associated with it. Among several schools of thoughts, WHO provides the most comprehensive and globally accepted platform for water safety. Pertaining to the objective of this research, the following basics of WHO drinking water safety platform are worth revisiting.

(a) *Catchment to Consumer* - "The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer" (Bartram et el., 2009, pp.1). However in the reality the application of WSPs over the whole system from catchment to consumer encounters challenges and limitations. This has naturally led most WSPs to concentrate more around comfort zones. Such trends may supress the primary objective of WSP of ensuring water safety over the whole system of water supply.

(b) *Multiple Barrier Principle* - The components of WSP are built on the multiple-barrier principle, the principle of hazard analysis and critical control points and other systematic management approaches. The plans should address all aspects of the drinking-water supply and focus on the control of abstraction, treatment and delivery of drinking water (World Health Organization, 2011, pp. 22). While most WSPs document multiple barriers from catchment to consumer, implementation of those barriers under multi stakeholder domains are not seen to be carried out with the deserved potential.

(c) *Priority of Aspects* – There have been 4 major aspects of drinking water declared in the order of priority for managing risks (WHO, 2011, pp. 4 – 8); *microbial aspects, chemical aspects, radiological aspects and acceptability aspects*. It is further said that "The great majority of evident water-related health problems are the result of microbial (bacterial, viral, protozoan or other biological) contamination. Nevertheless, an appreciable number of serious health concerns may occur as a result of the chemical contamination of drinking-water".

Time of exposure to cause adverse health effects is also a key determinant for the prioritization of microbial contamination over chemical contamination where the former is a matter of days while the latter can be a matter of years or decades. On the other hand the spectrum of chemical contamination expands faster while detection and treatment remain sophisticated and less affordable compared to that of microbial. For these reasons many developing countries are much focused on microbial aspects which is apparently complying with WHO. However in the reality the chemical contamination is felt fast reaching the time of "exposure" that need to cause adverse health effects. Comparatively less focus and limited evidence based decisions on this aspect seems to create space for speculation and panic among public. Speculations and panic are likely to increase with the increase of certain non-communicable diseases of un-known origins.

1.1.4 Sri Lanka's status in drinking water

Sri Lanka is internationally recognised to have progressive drinking water statistics and reported to have already achieved MDG Goal 7C on "safe water". In their latest update on the global drinking water and sanitation progress under the Joint Monitoring Programme (JMP), WHO and UNICEF have reported that 94% of Sri Lankan population accessed "improved water sources" in 2012. This was against the baseline of 79% in 2000 thus Sri Lanka has been declared to have "met" the MDG Target 7 C for "safe drinking water" (WHO-UNICEF, 2014, pp. 69).

However through analysis of water related indicators in the Census of Population and Housing published in 2012 and Demographic and Health Survey for 2006-07 published in 2009, the following summary could be derived. (Complete derivation of the summary is explained under sub topic 2.2 of the Literature Review).

- 90% Households have access to improved water sources
- Classification of improved water sources is purely based on the physical nature of the source and do not reflect water quality and associated risks
- Only 40.2% households access drinking water from improved water sources with varying degrees of treatment and quality verification
- 59.8% Households access drinking water from sources (both improved and un improved) with no treatment and quality verification, unless opted by the consumer with household treatment
- 51.4% Households do not practice any water treatment for microbial contamination
- No data is available on household treatment for known chemical contaminants and associated risks in different localities.

These facts clearly indicate that Sri Lanka's status of water safety is volatile regardless of global reporting under MDGs and JMP. The classification of improved water apparently has created false sense of safety. This leads to a strong perception barrier in understanding the basics water safety as defined by WHO and particularly in allocating resources for water safety by water suppliers as well as households.

This unstable situation pertaining to water safety is however cannot be immediately reflected in drinking water coverage data due to obvious political and social repercussions, mainly due to possible mixing up between "risk" and "hazard".

1.1.5 Sri Lanka's progress towards drinking water safety

During the past decade, 2 milestones can be observed in mainstreaming the concept of *water safety* in Sri Lanka.

a) Cabinet memorandum (2009)

As the sector lead, Ministry of Water Supply and Drainage (MoWSD) triggered the first recent policy level initiative, a cabinet memorandum, on the WHO water safety criteria, in 2006. The memorandum had the principal objective of *Establishment of a Water Quality Surveillance System in Sri Lanka* with the emphasis on preventive and integrated management approach through the collaboration of relevant stakeholders. It proposed the implementation of Water Safety Plans (WSP) across all service providers with a coordination mechanism and suggested establishment of district level Water Quality Surveillance Committees for monitoring. These committees were to be co-chaired by the designated water and health stakeholders; National Water Supply and Drainage Board (NWS&DB) and the Regional Director of Health Services (RDHS). A national level panel was proposed to oversee and facilitate the entire mechanism (MoWSD, 2009). This initiative was supported by the United Nations Children's Fund (UNICEF) due to its long term benefits on future generations, particularly the children, due to the access to safe water. While the memorandum was being reviewed by national stakeholders the certain mechanisms were field tested as pilots in several districts.

b) Implementation of Water Safety Plans by NWS&DB (2014)

National Water Supply and Drainage Board (NWS&DB) is the largest and leading service provider in the water sector with 323 water treatment plants of varying magnitudes. In 2014 they initiated mainstreaming of Water Safety Plans (WSPs) with the support of World Health Organization (WHO). It functions under the umbrella of a national level steering committee which also accommodates the participation of development partners and academia. The program is progressing with a road map with clear actions and targets as listed below (NWS&DB, 2014).

i. Building institutional capacity of NWS&DB on water safety (in terms of knowledge and human resources)
ii. Piloting WSPs at 6 water supply schemes
iii. Development of regional WSP models from pilots to be replicated

iv. Establishment of WSP coordination mechanism
v. Integration of WSPs with catchment management programs
vi. Inclusion of WSPs in university short courses and post graduate courses
vii. Upstream advocacy at Ministerial level (both water supply and health)
viii. Establishment of internal monitoring cell
ix. Emergency preparedness and response related to WSPs
x. Quality assurance mechanism for WSPs

This research is particularly focusing on the second objective of the above while incorporating relevant components from other objectives. NWS&DB expects to have WSPs developed for all their schemes by 2016.

1.1.6 Recent social concerns related to water safety in Sri Lanka

There has been a varying degree of understanding and perception on water safety among both professional and non-professional stakeholders in Sri Lanka. Thus during the past decade, certain milestone issues with high intensity of social and public health concerns surfaced along with public panic and unrest.

a) Hepatitis A outbreak – Gampola (2007)

This was the most severe outbreak in the recent history due to microbial contamination of water. It was said to have originated from faecal contamination of the water stream Pussella Oya in Gampola thus making many parts of Kandy, Matale, Nuwara Eliya and Kegalle districts vulnerable due to network of water sources in the central hills. The identified stream has been the source of the local pipe borne water supply scheme which was later found to have substandard chlorination. More than 500 hospitalizations were reported during the peak of the outbreak (Fazlulhaq, 2007) due to which the average quarterly Hepatitis A cases in Sri Lanka was almost tripled during the 2^{nd} and 3^{rd} quarters of 2007.

b) Public unrest over uround water contamination – Rathupaswala (2013)

Severe public agitation over a speculated ground water contamination resulted in loss of 3 lives in Rathupaswala area of Gampaha district. Public as well as some professionals attributed the contamination to the industrial effluent from a rubber products manufacturing plant based on unfavourable physical characteristics and low pH of ground water. On the other hand some other professionals attributed the low pH to the geology of the area. The arguments and counter arguments got extended even to a level of questioning the credibility of the process issuing Environmental Protection Licence (EPL) (Rodrigo, 2013). The contradictory claims and counter claims made the whole issue prolonged and political thus making the factory to be relocated. Yet the prime concern on water safety has not yet been fully solved. This was a classic case that highlighted the importance of mainstreaming basic concepts of water safety in the society with a rationale so that mere speculations would not drive public opinion.

c) **Chronic Kidney Disease of unknown origin (CKDu)**

Since its first case reported in 1994, CKDu has become a catastrophic humanitarian issue during the past decades. Mainly young and middle aged population from agricultural areas has been victimized leaving serious socio economic crisis. As in 2013, Anuradhapura district was found with 15.1% of its population suffering from CKDu while that of Polonnaruwa was 20.6%. The disease prevalence shows doubling effect in every 4 years (Jayasumana, 2014). There are several interpretations of its root cause including chemical contamination of water. Yet regardless of the cause, it has been evident that safe drinking water either improve the patients' condition or sometimes reverse it. Both these facts have prompted the government to heavily invest on small scale Reverse Osmosis (RO) plants operated at community level. Though it is a lifesaving initiative its sustainability is still questionable. Absence of comprehensive water safety planning in the area is making more assumptions and concerns on drinking water quality influence on the disease prevalence. Application of water safety concepts in such a sensitive context would have helped the professionals to narrow down their focus on most likely issues in this regard.

In all the 3 cases the public opinion has been shaped mainly with speculations and fear psychosis. Lack of basic knowledge on water safety as well as lack of evidence based professional opinion have been the main challenges in overcoming public panic and unrest. These incidents are not a matter of “managing situations” but yet an indication of gaps in knowledge, attitudes and behaviour over a long time scale. Furthermore these are not merely issues of a single sector or a stakeholder such as health, water supply or administration. It is a multi-dimensional and expanded social issue that should have been addressed with a multi-pronged approach. This would have been much efficient and effective had comprehensive knowledge and systems pertaining to water safety been in place. Especially the basic principles on water safety planning such as catchment to consumer, multiple barriers and prioritization of aspects would give a fair visualization of the context to everyone thus limiting speculations and fear psychosis.

1.2 Need for research on piloting WSPs in Sri Lanka

1.2.1 Background

The discussion so far indicates the following areas of concerns when applying Water Safety Plans in Sri Lanka.

- Water safety is not yet a clear concept in Sri Lanka among both professional as well as public domains.
- Water safety has been often mixed up with accesses to improved water sources as well as a few known water quality parameters.
- Only 40.2% of water supply in Sri Lanka is facilitated by conventional pipe borne water supply under some sort of institutional framework with varying degrees of treatment and verification of water quality.
- The degree of influence of current pipe borne water suppliers (mainly NWS&DB and Community based organisations) over the full spectrum of water supply (catchment to consumer) has not been field tested.
- How other key stakeholders with no accountability on water supply would buy - in the concept of WSP has not been field tested.
- WSP is based on a comprehensive conceptual framework with subsequent operational level modules and tools. There needs to be thorough coordination and monitoring of the process itself to have a balance between conceptual knowledge and its applications by all stakeholders.
- Compliance and sustainability in applying WSP needs utilization of resources. Such commitment would only be realistic if there is adequate professional, institutional and social demand for WSP.

These points could be articulated as the “research question” below.

1.2.2 Research question

How effective and realistic could managing the risks associated with water safety be, when the elements of water supply are shared by multiple stakeholders in multiple domains, with neither mutual accountability nor a well-defined line of hierarchy?

1.3 Aim and objectives of the research

The research question touches a diverse and broader scope. Hence it was further narrowed down to overall Aim and Specific Objectives as explained below.

1.3.1 Aim

Rationalized Resource Allocation for Implementing WSP

Deriving an evidence based rationale for decision makers to further prioritize rated risks and optimize resource allocation during implementation of Water Safety Plans in the back drop of scattered multiple stakeholders across multiple domains with no mutual accountability and line of hierarchy.

1.3.2 Specific Objectives

1. To critically analyse a sample Water Safety Plan (WSP) of the NWS&DB with respect to the WHO fundamentals and the ground realities of Sri Lanka

2. To generate a rationale to prioritize resource allocation with the context based evidence other than standard risk priority criteria especially in the backdrop of limited resources and varying stakeholder demand & understanding

3. To interpret the developed rationale as an advocacy tool for the decision makers at policy, planning and operational levels

4. To interpret the developed rationale as a possible enhancement to WHO guidelines on WSPs

2. LITERATURE REVIEW

Since the research objectives ranged from fundamentals of WSPs to actual implementation, the literature too was selected accordingly under the following categories.

- Water safety guidelines of World Health Organization
- Sri Lanka national statistics on drinking water
- Research publications

2.1 Concept of water safety

WHO (2011) has provided a comprehensive framework for water safety based on a conceptual framework on water quality guidelines.

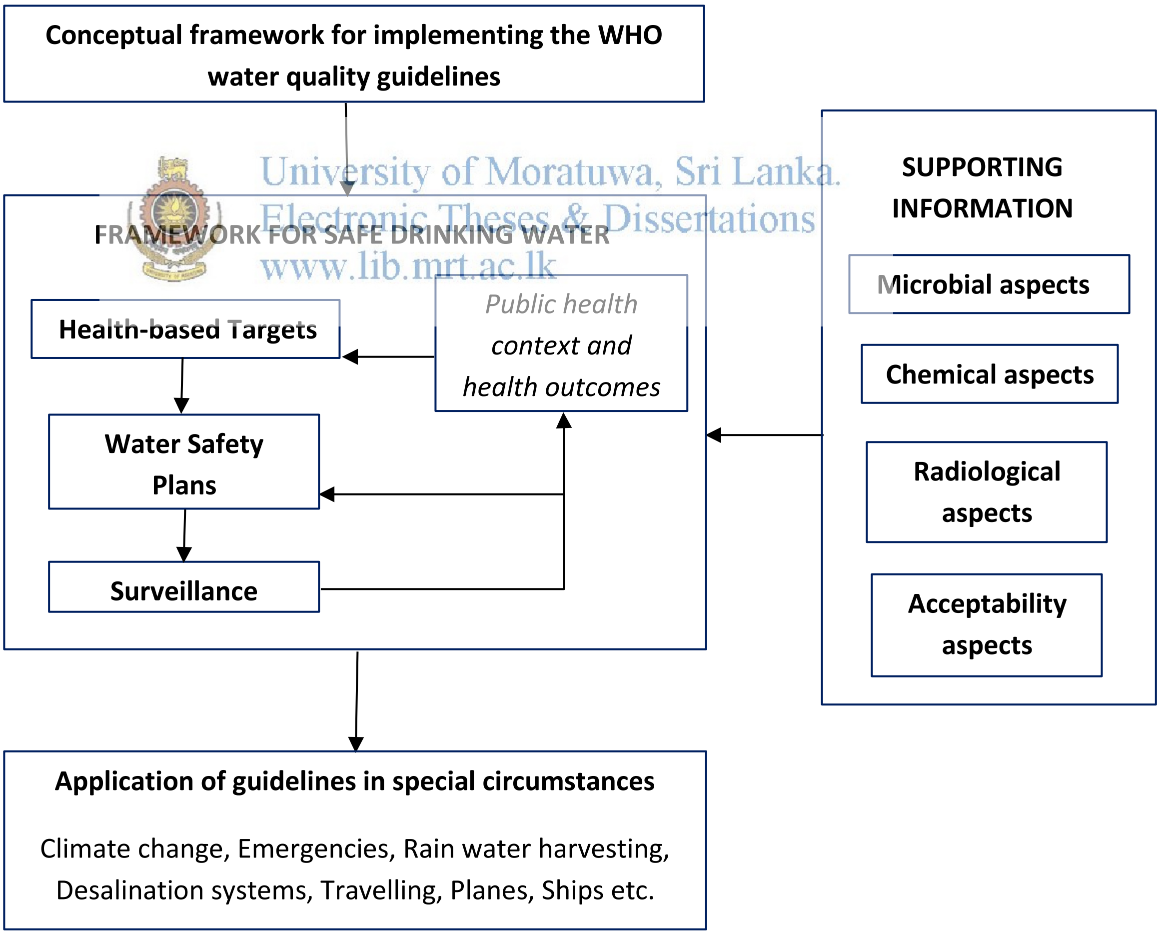


Figure 2.1 – Inter-relations of WHO Guidelines for Drinking-water Quality

The main objective of the WHO Guidelines for Drinking Water Quality is "protection of public health". It comprises recommendations on "managing risks" caused by hazards that compromise the drinking water safety. The guidelines are based on a strong "conceptual framework" that leads to a "framework for safe drinking water".

Framework for safe drinking water mainly consists of health based targets, water safety plans and surveillance. This framework is supported by the priority of aspects related to water safety. It also provides recommendations on adapting this framework for safe drinking water in special circumstances such as climate change, emergencies etc.

Optimum use of WHO Guidelines

Resource allocation on water safety needs thorough understanding on the guidelines that transforms the conceptual framework into actions. WHO (2011) articulates the following important facts on using the guidelines and basics of water safety:

- Safe drinking-water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (p. 1).

- The Guidelines describe reasonable minimum requirements of safe practice to protect the health of consumers and derive numerical "guideline values" for constituents of water or indicators of water quality. When defining mandatory limits, it is preferable to consider the Guidelines in the context of local or national environmental, social, economic and cultural conditions (p. 2).

- The main reason for not promoting the adoption of international standards for drinking-water quality is the advantage provided by the use of a risk–benefit approach (qualitative or quantitative) in the establishment of national standards and regulations. Further, the Guidelines are best used to promote an integrated preventive management framework for safety applied from catchment to consumer (p. 2).

- The nature and form of drinking-water standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential in the development and implementation of standards that the current or planned legislation relating to water, health and local government is taken into account and that the capacity of regulators in the country is assessed. Approaches that may work in one country or region will not necessarily transfer to other countries or regions. It is essential that each country review its needs and capacities in developing a regulatory framework (p. 2).

- The judgement of safety, or what is an acceptable level of risk in particular circumstances, is a matter in which society as a whole has a role to play. The final judgement as to whether the benefit resulting from the adoption of any of the Guidelines or guideline values as national or local standards justifies the cost is for each country to decide (p. 3).

- The basic and essential requirements to ensure the safety of drinking-water are a "framework" for safe drinking-water, comprising health-based targets established by a competent health authority, adequate and properly managed systems (adequate infrastructure, proper monitoring and effective planning and management) and a system of independent surveillance (p. 3).

Priory aspects of drinking water safety

Understanding on the aspects of drinking water safety is essentially helpful in decision making on resource allocation. In prioritizing the 4 aspects of drinking water safety, the WHO (2011) empathizes on following:

- *Microbial aspects* - Securing the microbial safety of drinking-water supplies is based on the use of multiple barriers, from catchment to consumer, to prevent the contamination of drinking water or to reduce contamination to levels not injurious to health. Safety is increased if multiple barriers are in place, including protection of water resources, proper selection and operation of a series of treatment steps and management of distribution systems (piped or otherwise) to maintain and protect treated water quality. The preferred strategy is a management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for removal of pathogens (p. 4).

- *Chemical aspects* – The health concerns associated with chemical constituents of drinking-water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure. There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a drinking-water supply. In situations where short-term exposure is not likely to lead to health impairment, it is often most effective to concentrate the available resources for remedial action on finding and eliminating the source of contamination, rather than on installing expensive drinking-water treatment for the removal of the chemical constituent (p. 6).

- *Acceptability aspects* - In assessing the quality of drinking-water, consumers rely principally upon their senses. It is therefore wise to be aware of consumer perceptions and to take into account both health related guideline values and aesthetic criteria when assessing drinking-water supplies and developing regulations and standards (pp. 6-7).

2.2 Status of drinking water safety in Sri Lanka

Sri Lanka's water sector indicators do not reflect water safety in compliance with WHO guidelines. Instead equivalent national statistics are available for *improved drinking water coverage* based on the physical nature of water sources. *Table 2.1* shows the latest published statistics in this regard from the Census of Population and Housing in 2012 (Department of Census and Statistics Sri Lanka, 2012).

Table 2.1 - Drinking water vs occupied household units, 2012

Category of Water Source	Principal Source of Drinking Water	% of Households
Dug Well	Protected well within premises	31.8
	Protected well outside premises	14.6
	Unprotected well	4.4
National pipe grid	Tap within the unit	20.8
	Tap within the premises but outside the unit	6.6
	Tap outside premises	3.1
Other Sources	Rural water supply project	9.5
	Tube Well	3.2
	Bowser	0.5
	Bottled Water	0.2
	River / Tank / Stream / Spring / Other	5.3

Source: Census of Population and Housing 2012, Department of Census and Statistics of Sri Lanka (http://www.statistics.gov.lk)

Total house households surveyed was 5,188,047

The water sources in shaded rows are accepted to be un-improved by local water and health authorities as a norm. Hence overall % of households with access to an *improved water source* can be derived as 90%. It is clear that classification of drinking water sources does not include any water quality criteria but mere physical nature of the water source and its location. Since there is no formal statistics available to estimate the degree of water safety of the water sources in *Table 2.1* it is worth looking at the water treatment options and quality verification associated with each source, as shown in *Table 2.2*, as an extension to the 2012 Census data.

Table 2.2 – Water safety aspects of classified water sources of Sri Lanka

Water Source	Description	Treatment	Quality Verification	Households Covered %
Protected Well	Shallow ground water aquifer, Parapet wall and apron	Household treatment only if the consumer is willing	No Only on demand	46.4
Unprotected Well	Shallow ground water aquifer, No parapet wall and apron			4.4
National Pipe Grid	Conventional water supply by NWS&DB with professional staff	Mandatory treatment with varying capacities depending on scheme	Yes With regular frequency	30.5
Rural Water Supply Project	Conventional small water supply managed by community	Basic treatment varying from zero to full depending on scheme	Yes Limited with much less frequency	9.5
Tube Well	Deep ground water aquifer, Hand pump and apron	Household treatment only if the consumer is willing	No Only on demand	3.2
Bowser	Topping up water transported with bowser from varying sources	Household treatment only if the consumer is willing		0.5
Bottled Water	Commercially produced with a higher rate	Basic treatment depending on the source	Yes with less frequency	0.2
Surface Water	Naturally available, Multi-purpose	Household treatment only if the consumer is willing	No Only on demand	5.3

While water safety needs to be assessed with respect to the criteria defined for WSPs ,the water sources in *Table 2.1 and 2.2* are yet to be rated on such comprehensive basis. Furthermore *Table 2.2* clearly shows that only 40.2 % of households (highlighted) can have confidence that their water is complying with at least “some elements” of water safety. With fluctuations of the raw water quality, treatment option and verification measures there are discrepancies even within this 40.2%. On the other hand a water source even with risks may not always cause hazardous events at a noticeable level. Thus the balance 59.8% households may not be immediately convinced of the risks associated with their drinking water. This challenge related to interpretation and perception between theoretical and practical applications of water safety needs to be dealt cautiously by clearly differentiating the "risk" and "hazard".

The above 59.8% households do have the option of practising household water treatment methods so that they could make their water reasonably safe at the point of use. Census of Population and Housing in 2012 has not captured this information. However Sri Lanka Demographic and Health Survey in 2009 (Department of Census and Statistics Sri Lanka, 2009) had reported on household water treatment from a limited sample, studied between year 2006 and 2007. *Table 2.3* summarizes its findings.

Table 2.3 - Household water treatment of Sri Lanka, 2006 - 2007

Household Treatment Method	% Households
Boiling	50.5
Bleaching / Chlorination	1.8
Straining through cloth	11.0
Filtration (ceramic, sand or other)	2.6
Solar disinfection	0.0
Other	0.5
No treatment	40.4

Source: Sri Lanka Demographic and Health Survey 2006-07, Department of Census and Statistics (http://www.statistics.gov.lk)

Total house households surveyed – 19,862

Basically all household water treatment methods have addressed only the microbial and acceptability aspects of water contamination. *Table 2.3* shows an alarming situation of 40.4% households without any water treatment while the 11% practicing straining through cloth are still vulnerable to microbial contamination. Thus effectively 51.4% of households can be considered as vulnerable to microbial contamination. Vulnerability to chemical contamination is hardly available in terms of credible data. Assuming that 2006 – 07 household water treatment patterns were still valid in 2012 (as there are no latest statistics), an approximate profile of drinking water safety in Sri Lanka can be summarized as below.

a) Only 40.2% households access drinking water from sources with varying degrees of treatment and quality verification

b) 59.8% households access drinking water from sources with no treatment and quality verification unless opted by the consumer

c) 51.4% households do not practice any water treatment for microbial and chemical contamination of water

These 3 factors together strongly indicate the need for adaption of Water Safety Plans in Sri Lanka with thorough attention on its basic concepts particularly paying more attention to short and medium term actions customized to local scenarios.

2.3 Perceptions and policies on catchments and drinking water

In Sri Lanka's context, catchment remains the most complicated element of water supply particularly in assuring water safety. Certain policies do exist to support catchment management yet public perceptions on catchments as well as the policies themselves is not always complying and consistent. Hence research in this regard is of great importance when understanding where to put resources.

Regardless of the type of public perception, it is important to understand the experience in other contexts on how compromise was reached between perceptions and policies when it comes to catchments and drinking water. In the study on perceptions and policies with special focus on recreations Geoffrey et al (2012) concludes following vital punts in this regard:

- While this study focused on a particular case (recreation), the general conclusions are that attitudinal studies of policies would benefit by more regular use of alternatives to traditional attitudinal measurement.
- By exhibiting the range of acceptance rather than a single mean value, the basis for negotiation, ongoing policy development and the potential for compromise can be established.
- The research on the current policy also shows the importance of measuring the ethical and knowledge bases of peoples' latitude of inclusion and also the centrality of their attitudes. We need to know not only the direction of the attitudes which are most commonly measured in environmental attitudinal studies, but also their strength, and on what basis they may affect social judgements if attitudinal surveys are to have value in collaborative planning processes.

2.4 Evidence based cost effectiveness & risk reduction of water safety

Unlike hazards which are apparent, all the risks are not apparent as well as not perceived in the same manner even if they are apparent. Therefore investing on risk reduction itself may be seen as risky from resource allocation and decision making point of view. Hence resource allocation supported by solid evidence would help decision makers to be more confident and focus. In their study on Cost Effective Analysis (CEA) pertaining risk reduction measures on water safety Lindhe et al (2010) concludes following:

- The fault tree method enables comparison of risk-reduction alternatives in the same quantitative unit and for an entire drinking water system from source to tap. Interactions between events and components of the system can be modelled in a realistic way. Furthermore, the probabilistic approach enables comparisons with safety targets and the probability of exceeding these target values can be calculated.

- CEA provides useful information by combing the effect and cost. However, it is important to understand existing pitfalls when interpreting the results. For example, alternatives may provide additional benefits not considered in the CEA and alternatives cannot be evaluated solely based on cost-effectiveness ratios.

- CEA requires a safety target representing the acceptable level of risk. In addition to the target value it is also important to consider the highest acceptable probability of not meeting the target value, i.e. a certainty criterion.

- Combining quantitative risk analysis tools, such as the applied fault tree method and economic evaluation, provides a powerful tool for decision-makers. A combined quantitative risk assessment and economic evaluation can provide a structured and thorough analysis of risk-reduction measures that facilitates transparency and long-term planning of drinking water systems in order to avoid sub optimisation of available resources for risk reduction.

Risk management on water safety is based on universal standards. Yet due to complex parameters associated, its adaptation in varying contexts needs serious course corrections and adjustments. Especially developing and middle income level countries as well as rural and urban sub sectors seem to need customized applications. In his paper on applying risk management to improve water safety Jayaratne (2008) has recommended the following:

Implementing Hazard Assessment and Critical Control Points (HACCP) based Water Safety Plans in urban systems in developing countries would require a strong commitments and resources as follows;

- A strong commitment to Water Safety Plan implementation by the most senior executives

- Dedicated person to coordinate and actively manage the Water Safety Plan preferably on full time basis
- Development of a long term Improvement Action Plan
- Increase in process performance monitoring.

2.5 Soil erosion quantification and catchment management

Research in this regard are extremely important when investing on long term improvements on catchment management pertaining to water quality. In their study on reforestation and its effects on soil erosion, Marden et al (2013) have concluded that reforestation in the study basin resulted in a ~62% reduction in erosion-affected area, a ~51% reduction in the erosion rate, and an estimated ~12% reduction in sediment yield of the concerned River from ~6% of its catchment area.

Focusing on effects of catchment erosion on the water sources (streams) Rodríguez-Blanco et al (2013) has pointed out that the effective areas of sediment production are only a small percentage of the total catchment area. It was also concluded that sediment delivery to the catchment outlet was dependent on the spatial organization of land use, as well as on the connectivity between sediment-producing areas and the stream and soil loss measured at the field scale cannot be used to predict soil loss at the catchment outlet.

Hankcock et al (2014) have concluded several important points on soil erosion and realities in quantification as follows:

- Even a well-managed land property with relatively low erosion rates is losing soil at a faster rate than it is being produced. Improved land management strategies are needed to better conserve the soil resource. Evaluation and improved understanding of erosion and soil formation processes using both field data and models will allow better application and resultant prediction of erosion and sediment transport and provide robust data with which to calibrate and evaluate numerical models.

- Quantitative studies are needed as land use and land use change assessments can allow predictions to be made about the effects of land use and climate variability on catchment processes. This is of particular relevance in an era of real or perceived climate change and the adaptation required.

- It should be recognised that depending on the scale of the system, climate, topography, biotic activity and geology vary with time and their impact on soil processes is likely to be nonlinear and differ in space and time. These potential environmental changes suggest that soils may always be evolving and that the notion of equilibrium soils may not be realistic but given the difficulties of process quantification only simple approaches are possible.

- To advance our understanding a landscape-paedogenesis approach is needed to realistically capture soil dynamics and predict their spatial distribution. This is particularly relevant in long-term simulations of environmental processes such as landform evolution modelling.

2.6 Agro chemical usage and catchment management

Ideally modern agricultural zones should not be located within the effective range of catchments or river basins. However this is yet to be a reality when it comes to balancing livelihoods and environment. This is a burning issue in developing countries where agriculture has been traditionally associated with water sources while embracing modern use of agro chemicals and fertilizer in recent past. Hence the studies on minimizing the damage is of great importance since complete turnaround of the situation seems to be far from reality due to complicated socio economic repercussions.

European Union has introduced Nitrogen Vulnerable Zones (NVZ) to reduce the maximum level of Nitrate level in drinking water to be 50mg/l. In their study on the interesting topic of farmer perspectives and practices regarding such water pollution control programmes Barners et al (2008) have revealed the following:

- Farmers operating within Scottish NVZs have not unduly changed their behaviour to accommodate the greater restrictions imposed after designation. Coupled with the fact that benefits in water quality only emerge over a number of years (Nimmo Smith et al., 2007), it may be difficult for producers to accept perceived constraints on their activity.

- A more integrated approach to water management is needed and clear indicators of water quality should be developed. This may start to embed nitrogen saving goals within the farmer's cultural framework of decision-making and lead to greater adoption of these regulations.

- Effort should be made towards emphasising the links between farming activities and nitrate pollution, any positive impact of the regulations and the science behind the nitrate limits imposed on farmers.

Another approach of research in this regard is to focus on a specific crop and associated agro chemical influence on the water.

2.7 Accountability associated with water safety planning

Accountability remains a key challenge in Water Safety Planning. Organizational culture and leadership are two out of many parameters that may govern the level accountability from a given stakeholder. During their study on these two parameters, Summerill et al (2010) have concluded the existence of enablers and blocking features associated with water safety plan implementation as presented in *Table 2.4.*

Table 2.4 – Effects of organizational culture and leadership in WSP

Enablers	Blocking Features
• Continual improvement culture	• Poor communication
• Community focus	• Inflexibility
• Internal accountability	• Complacency
• Camaraderie	• Lack of awareness
• Customer service mentality	• Lack of interest
• Transparency	• Lack of reward
• Competitiveness	• Coercion from senior staff
• Proactive and involved leaders	
• Competent workforce	
• Empowerment of workforce	
• Appreciation	

2.8 Tools for analysing health service coverage bottlenecks

Water safety is a derivation of public health thus rationales and tools pertaining to health services can ideally be applied in supplying safe drinking water. T. Tanahashi has introduced a milestone concept based on "specific coverage" of health services. In his famous paper on health service coverage and its evaluation, Tanahashi (1978) has come up with the following thought provoking questions as the fundamental issues in the management of a basic health service:

a) How should resources be allocated and the service organized in order to serve as many people as possible?
b) Is the service reaching the people it should serve?
c) Has the service been effective in meeting the people's needs?

In answering these questions Tanahashi (1978) has come up with an approach on the development of a coverage evaluation scheme based on three requirements.

1. Information (demographic, epidemiological, and socioeconomic) on the population with which the service is concerned
2. Knowledge of the health problem that the service is intended to deal with and of the activities of the service
3. Ability to gather information on the operation of the service

His recommendations on materializing these requirements are as follows:

- Under probably common circumstances (lack of data, lack of systems etc.), the evaluation scheme may first be developed for a limited pilot area and later expanded as practical methods become established.

- For coverage evaluation, demographic and epidemiological information on the population is essential, but it is rarely readily available. The approach facilitates the gathering of such information by focusing attention on a population of manageable size.

- Sometimes, knowledge of the health problem and also of the ways in which the service intervenes in it needs to be gained from experience; a pilot operation gives an opportunity for this, thus facilitating selection of the appropriate target and coverage measures.

- If the coverage evaluation is meant for the service management, continuous gathering of information on the operation of the service is necessary; hence it is important to make this activity as simple and practical as possible.

Tanhashi's concept led to 6 determinants associated with a given health service coverage under supply and demand categories as shown in *Table 2.5*.

Table 2.5 – Tanahashi model for analysing health service bottle necks

Category	Service Coverage Determinants
Supply	• Availability – Essential health commodities • Availability – Human Resources • Accessibility – Physical access of services
Demand	• Initial utilization – First contact of multi contact services • Adequate coverage - continuity • Effective coverage - quality

(**Note:** Each determinant to be evaluated with a tracer indicator)

With the complexity of health services increased, the Tanahashi model has now been improved by adding two more categories; Enabling Environment and Quality.

Table 2.6 – Enhanced Tanahashi model for health service bottlenecks

Category	Service Coverage Determinants
Enabling Environment	• Social Norms • Legislation / Policy • Budget / Expenditure • Governance / Partnership
Supply	• Availability of essential commodities / inputs • Access to adequately staffed services and information
Demand	• Financial access • Social cultural acceptability • Continue of use
Quality	• Quality

Source: Centre for Global Safe Water, Rollins School of Public Health, Emory University

3. RESEARCH METHODOLOGY AND DATA

Water safety associates with a wide range of implementation levels due to its importance for public health as well as its demand as a commodity. On the other hand the scope of the research also demands exploration of actual dynamics at both decision making and operational levels when rolling out Water Safety Plans (WSP) in Sri Lanka. For this reason the research touched based a diverse scope of domains from national to subnational levels associated with both planning and implementation of WSPs in Sri Lanka.

3.1 Process of conducting the research

From national to subnational level, each domain and stakeholders had their own hierarchical, social and professional norms to be complied with when having their involvement in the research. Besides the study, the Researcher engages with almost all the stakeholders in his official capacity as well. Hence it was thought to incorporate these formal avenues as a part of the research methodology to study the policy level dynamics related to WSP implementation in Sri Lanka. Then at sub national level, the WSP at the Eheliyagoda water supply scheme was selected to study the dynamics of WSP implementation at the operational level. Eheliyagoda WSP is important as it is the first pilot WSP under NWS&DB that had reached implementation phase. Although small, it comprised of standard systems and issues associated with any larger conventional water supply scheme in a smaller and manageable boundary. Hence this research may belong to the category of **descriptive and interpretative case study**.

Due to limitations in research capacity, the methodology mainly counted on the raw data available with the relevant stakeholders when it came to quantitative information. On the other hand interviews, observations and interactions such as formal meetings were used to gather qualitative data. Auxiliary information such as rainfall was directly obtained from the mandated institutions. The outline of the research process is summarized in *Table 3.1*.

Table 3.1 - Process of conducting the research

Interaction Level & Stakeholders	Target	Methodology
Academic Level Dept. of Civil Engineering, University of Motatuwa NWS&DB WSP Cell	1. Research planning, verification and review of progress	a) One to one meetings with the Supervisor and Co Supervisor
	2. Latest information; Recent trends and research on the water safety and water safety plans	b) Literature Survey (Standards, Guidelines, Policies, Research, Routine Statistics, Online knowledge)
National Level Min. of Urban Development, Water Supply and Drainage NWS&DB (Corporate Planning Section) World Health Organization Central Environmental Authority	3. Assessing the enabling environment; Policies, national plans, Sri Lanka's commitments to the international forums, water sector coordination	a) Participation in water sector high level meetings and forums b) One to one discussions with key decision makers c) Analysis of policy documents
Sub National Level NWS&DB Regional Support Centre (Sabaragamuwa) NWS&DB Regional Laboratory (Kegalle and Rathnapura) NWS&DB Water Treatment Plant (Eheliyagoda)	4. Studying stakeholder dynamics; Roles, interactions, coordination and social dynamics related to WSP implementation	a) Participation in WSP implementation, stakeholder meetings and progress reviews
	5. Collection of field data; Plant operations, water quality, demographics, land use, rain fall etc related to Eheliyagoda WSS	b) Capturing routine data collected by NWS&DB water treatment plant staff and regional laboratory staff c) Field observations (catchment and treatment) d) One to one discussions with stakeholders

Elaboration on the Targets 3, 4 and 5 are as follows;

3.1.1 National level – Assessing the enabling environment

Two high level national forums attended in researcher's official and professional capacity were the key entry in achieving this Target as explained below.

1. Water Safety Plan Steering Committee (Chaired by NWS&DB)

This committee is the current apex body for implementing WSPs for the conventional water treatment plants of the NWS&DB. Its participation consisted of higher management of NWS&DB, trained WSP Champions, WSP teams of the 6 water treatment plants being piloted, WHO, UNICEF and academia. Networking at this meeting helped compiling policy level initiatives of the WSP while creating entry points to the grass root level implementation.

2. National WATSAN Coordination Meeting

(Chaired by the Ministry of Water Supply and Drainage)

This forum functions as the apex coordination body for both water and sanitation sectors in Sri Lanka. Key line Ministries and lead institutions representing Water, Health, Education, Disaster Management and Environment sectors participate in the forum. Furthermore UN agencies (UNICEF & WHO) and many reputed INGOs, local NGOs and Civil Society Organizations engaged in water and sanitation take part. In addition the forum is also attended by research agencies, think tanks and individual professionals. Researcher's participation in this forum in official capacity helped interacting with the highest level discussions and follow ups leading to water safety.

3.1.2 Subnational level – Studying stakeholder dynamics

Eheliyagoda WSP Team convened meetings with the participation of multiple stakeholders from various disciplines that has relevance to the WSP though various commitments. These stakeholders represented professionals from water supply, public health, environment, agriculture, sociology, water quality as well as senior public administrators, community level government officers, police, community leaders, religious leaders, school children and community members. These meetings and subsequent networks were extremely useful in understanding the dynamics in transforming a documented WSP into action at the grass roots level.

3.1.3 Subnational level – Collection of field data

Direct partnership was built with the team leader of the Eheliyagoda WSP thus getting real time updates on how they proceeded with the implementation. Accordingly field visits to the scheme and relevant areas were made jointly with the WSP team members. The locations covered during the field visit were as follows.

- Catchment area of the water source
    - Residential areas
    - Rubber plantation and rubber factory
    - Temple
    - Natural forest area
    - Upstream water intake
- NWS&DB Regional Support Centre (Sabaragamuwa)
- Eheliyagoda water treatment plant
- Office of the Medical Officer of Health, Eheliyagoda

Figure 3.1 shows the map of the area and locations involved in field data collection.

Figure 3.1 – Field data collection area map

3.2 Summary of data collected

Both quantitative and qualitative data was collected as summarized in the *Table 3.2*.

Table 3.2 – Summary of data collection

	Description of data category	Source (s)	Method(s) of Collection	Remarks
1	Policy and legislative milestones pertaining to water safety	CEA, Web, Eheliyagoda WSP team	Interviews, Browsing, Documents	16 milestones found with complete documents for 7
2	Chronology of WSP implementation in NWS&DB	NWS&DB	Interviews, Documents	From the chairperson of WSP steering committee
3	Eheliyagoda Water Supply System (Catchment and Treatment)	Eheliyagoda WSP team	Interviews, WSP Documents, Observations	Including geographical, demographical and infrastructure related data
4	Water quality data of Eheliyagoda WSS • Daily - raw & treated – on Turbidity, pH and RCl • Monthly – raw & treated – on Colour, pH, Turbidity, Chloride, Alkalinity, Hardness, TDS and Iron	NWS&DB Eheliyagoda water treatment plant and Rathnapura laboratory	Operational logs Water quality reports	The laboratory has not tested fertilizer residues and agro chemical residues due to limitations of capacity Daily records were found only for 2014 while monthly reports were available for 2013 and 2014
5	Water pollution data of Eheliyagoda catchment • Fertilizer and agrochemical usage in rubber plantation • Waste water quality analysis of rubber processing	Superintendent of Eheliyagoda watta Estate NWS&DB regional laboratory, Rathnapura	Interviews Water quality reports Observations	Rubber industry related data collection can be made a research on its own
6	Socio – Economical data of catchment inhabitants	NWS&DB Sociologist	Raw data	Reports generated with SPSS
7	Monthly rain fall data for Eheliyagoda	Department of meteorology		From 2004 to 2014

3.3 Presentation of Data

3.3.1 Policy and legislative milestones towards water safety

Table 3.3 – Policy and legislative milestones towards water safety

Year	Milestone
1935	Land Development Ordinance No: 19
1946	Irrigation Ordinance No. 32
1951	Act No. 1
1951	Soil Conservation Act
1959	Electricity Board Act
1964	Water Resource Board Act
1965	River Valleys Development Board Act
1979	Mahaweli Authority Act
1980	National Environment Act (NEA) No. 47
1988	NEA Amendment Act No. 56 (Regulatory tools such as EIA, EPL etc)
1990	Gazette Extraordinary No. 595/16 on Waste Water Discharge Standards
2000	NEA Amendment Act No. 53 (Prescribing EPL requiring activities)
2008	Gazette Extraordinary No. 1534/18 on revised waste water discharge standards
2009	National Policy on Drinking Water (updated)
2009	Cabinet paper on establishment of a Water Quality Surveillance System
2014	National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka

3.3.2 Chronology of WSP implementation by NWS&DB

This has been already presented in detail in Chapter 1 – INTRODUCTION under the sub title; 1.1.5 - Sri Lanka's Progress towards drinking water safety. Yet it is repeated concisely for the completion.

a) Cabinet Memorandum between the Ministry of Water Supply and Drainage and the Ministry of Health (2009)
b) Pilot implementation of Water Safety Plans by NWS&DB under the support of WHO with the following actions (2014 onwards)

i. Building institutional capacity of NWS&DB on water safety (in terms of knowledge and human resources)
ii. Piloting WSPs at 6 water supply schemes
iii. Development of regional WSP models from pilots to be replicated
iv. Establishment of WSP coordination mechanism
v. Integration of WSPs with catchment management programs
vi. Inclusion of WSPs in university short courses and post graduate courses
vii. Upstream advocacy at Ministerial level (both water supply and health)
viii. Establishment of internal monitoring cell
ix. Emergency preparedness and response related to WSPs
x. Quality assurance mechanism for WSPs

3.3.3 Eheliyagoda Water Supply System

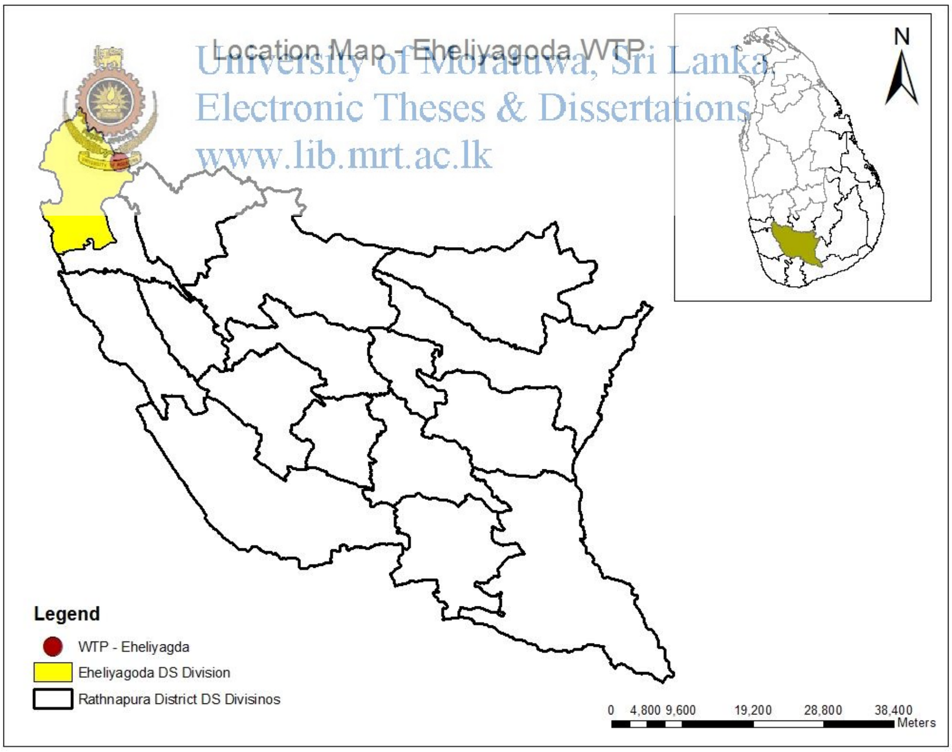


Figure 3.2 – Location map of the Eheliyagoda Water Supply System

Table 3.4 – Overview of Eheliyagoda Water Supply System

Category	Description	Data
Administrative and Geographical boundaries	Province	Sabaragamuwa
	District	Rathnapura
	Divisional Secretariat	Eheliyagoda
	Water treatment plant location	2km away from Eheliyagoda town along Eheliyagoda – Dehiovita main road
Quality of Service	Capacity	1400 m^3/day
	Service Population	15,667 persons
	Treatment category	Partial
	Service duration	24 hrs.
	Water transportation (raw and treated water)	Under gravity
Water Source	Main water source	Stream – Biso Dola
	Main source raw water tapping location	1.5 km upstream of treatment plant
	Secondary source (for drought period)	Dug well
Catchment (main source)	Catchment area	3.1 km^2
	Primary land use	Rubber plantation
	Secondary land use	Household tea plantation and gardening
	No. of inhabitant families	300
Distribution	No. of Connections	2583 (Domestic 2184, Commercial 334, Industrial 1, School 7, Other 57)
	No. of Valves	47 (Air valves 14, Section valves 33)
	Total pipe length (m) (transmission and distribution)	33,251
	No of Grama Niladari Divisions Covered (GND)	15 (Coverage share in each GND ranges from 1.8% to 90.5%)

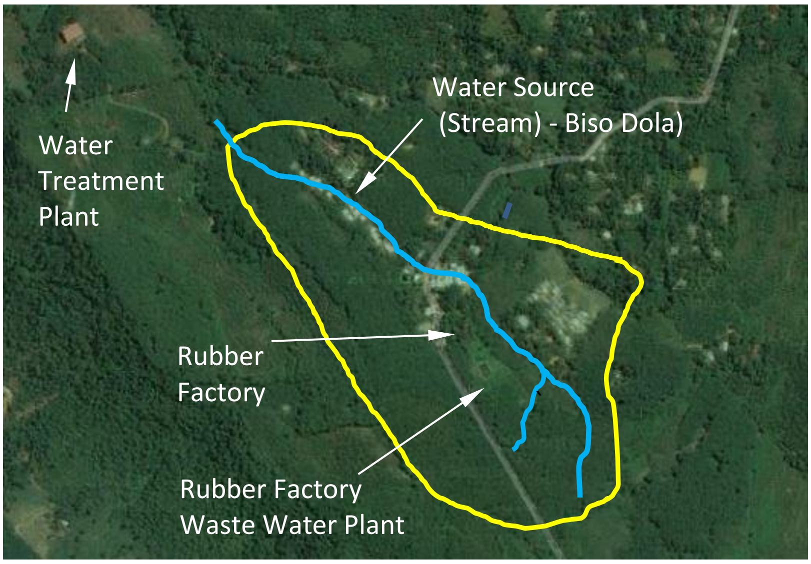


Figure 3.3 – Google map of Eheliyagoda Water Supply System

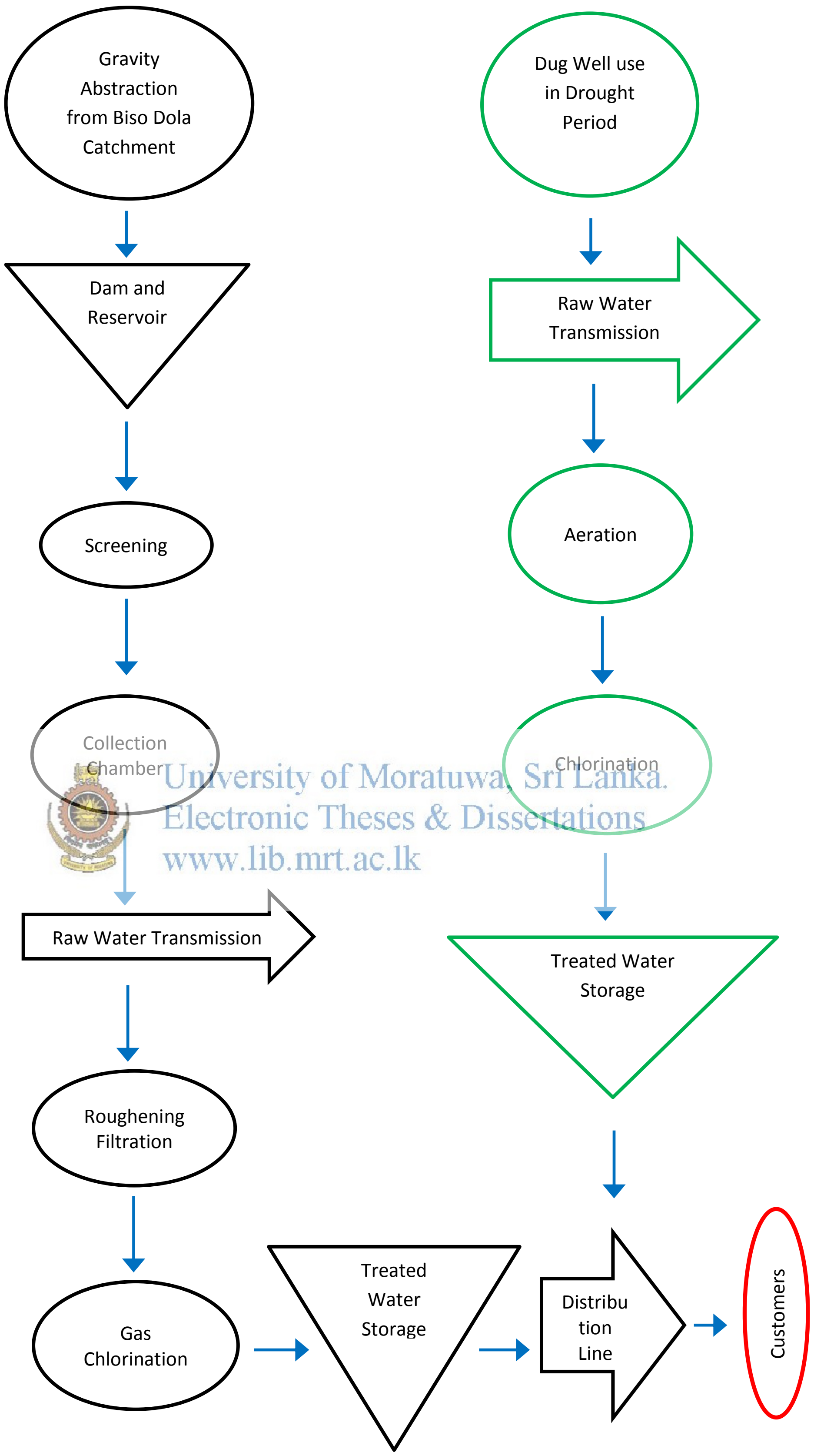


Figure 3.4 – Process diagram of Eheliyagoda Water Supply System

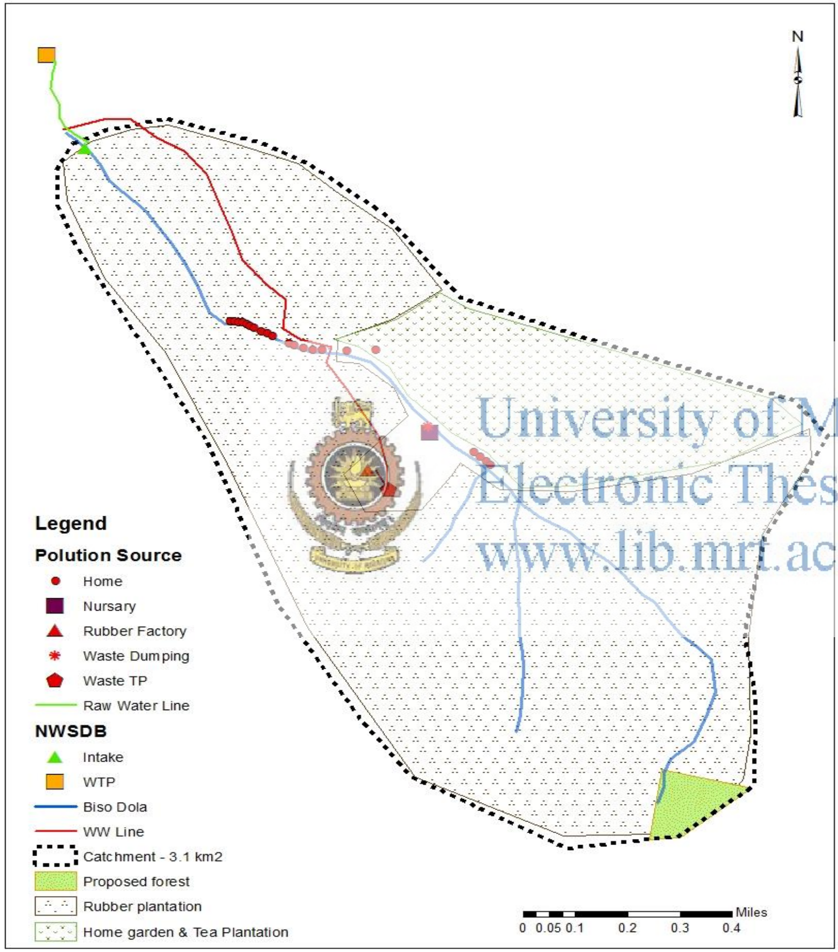


Figure 3.5 – "Biso Dola" catchment map of Eheliyagoda WSS

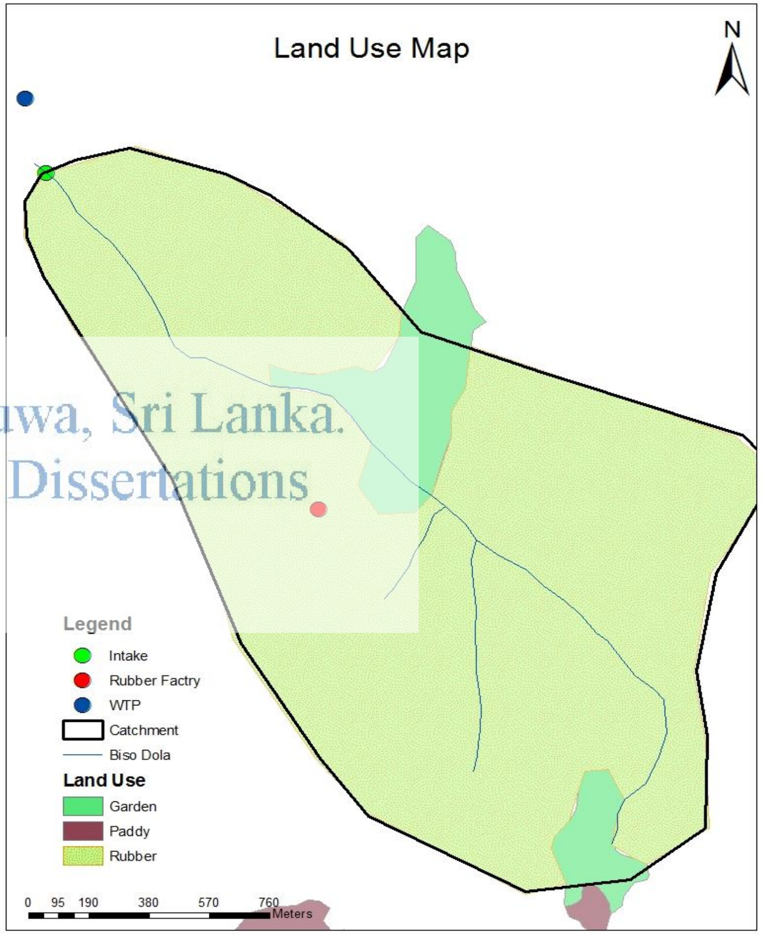


Figure 3.6 – Catchment land use map of Eheliyagoda WSS

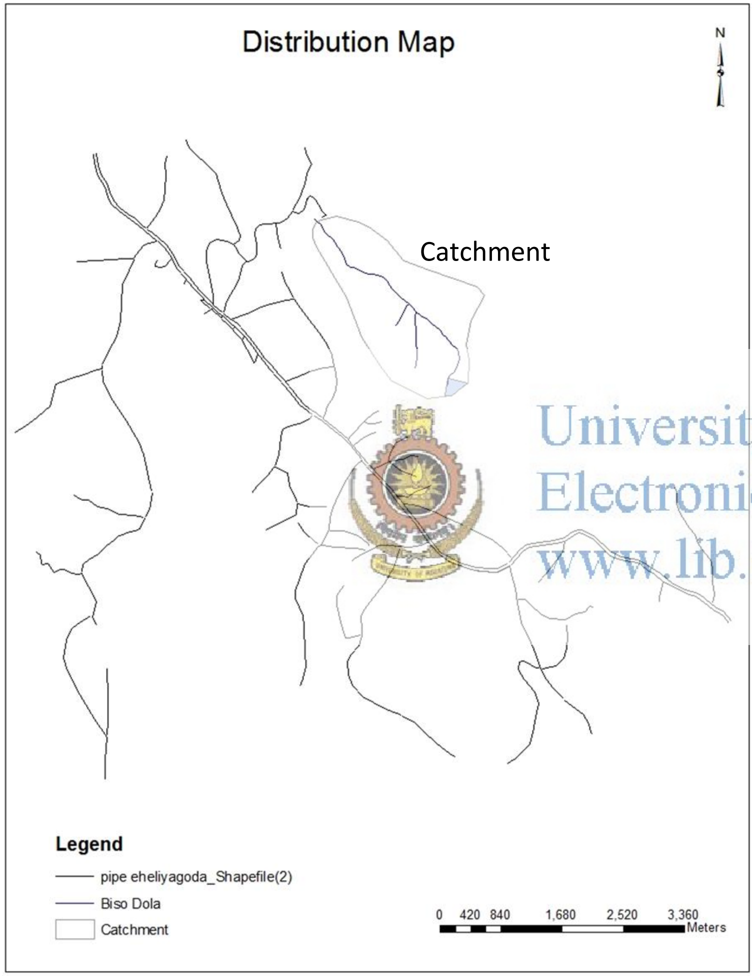


Figure 3.7 – Distribution map of Eheliyagoda WSS

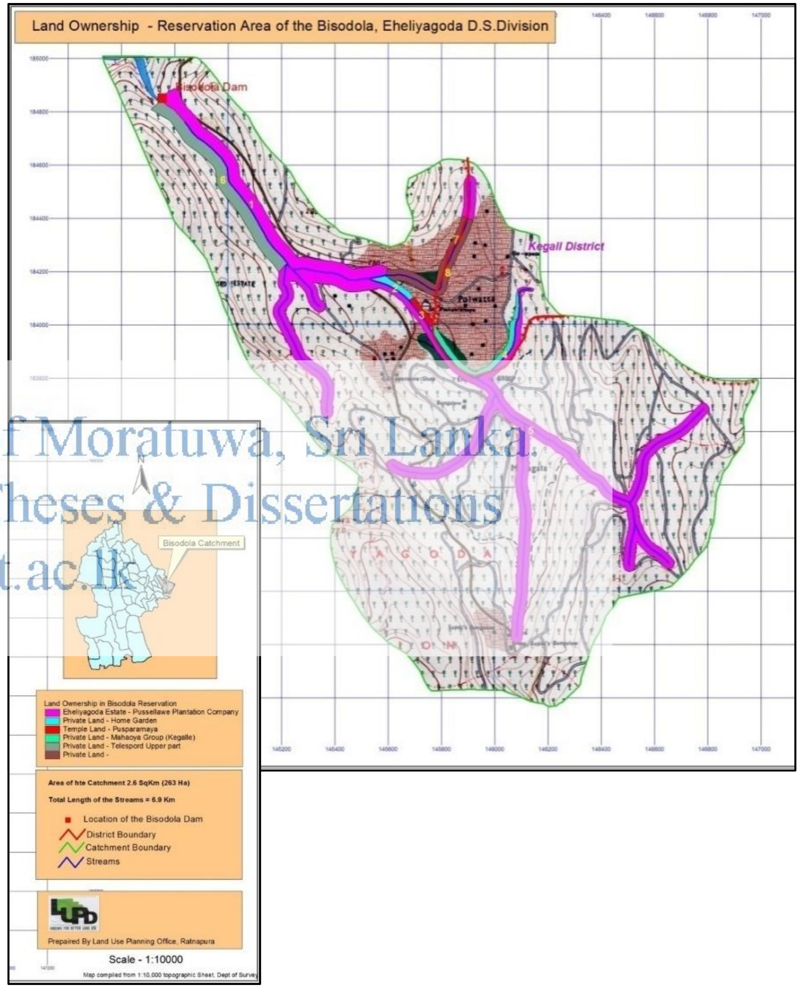


Figure 3.8 – Eheliyagoda catchment reservation and land ownership map

Rubber cultivation & Main road

Rubber nursery and Inhabitants

Rubber processing factory

Home tea gardens

Figure 3.9 – Observations of Eheliyagoda catchment

Intake

Roughening filter

Gas Chlorinator

Figure 3.10 – Observations of Eheliyagoda water treatment plant

3.3.4 Water quality data of Eheliyagoda Water Supply System

Table 3.5 - Daily treated water quality analysis (eg. August, 2014)

(Data collected at the water treatment plant for 11 months in 2014 in a similar format)

Date	Time	Raw Water		Treated Water			Date	Time	Raw Water		Treated Water		
		Tur. (NTU)	pH	Tur. (NTU)	pH	RCl (mg/l)			Tur. (NTU)	pH	Tur. (NTU)	pH	RCl (mg/l)
1	8.00	2.05		1.74	7.8	1.0	18	8.00	3.88		1.24	7.8	1.0
	16.00	11.7		5.99		1.0		16.00	2.22		1.45		1.0
4	8.00	15.7		10.30	7.8	1.0	19	8.00	24.4		16.90	7.8	1.0
	14.00	7.31		6.47		1.0		18.00	5.31		4.03		1.0
	18.00	5.41		3.21		1.0	20	8.00	2.42		2.01	7.8	1.0
5	8.00	4.87		2.44	7.8	1.0		14.00	2.21		1.47		1.0
	14.00	16.7		2.30		1.0	21	8.00	2.56		1.60	7.8	1.0
	18.00	4.81		2.92		1.0		16.00	4.81		3.56		1.0
6	8.00	8.36		5.04	7.8	1.0	22	8.00	85.7		17.50		1.0
	16.00	3.92		2.70		1.0	25	8.00	2.57		1.75	7.8	1.0
7	8.00	2.01		1.53	7.8	1.0		14.00	2.41		1.45		1.0
	16.00	1.67		1.38		1.0	26	8.00	1.59		1.04	7.8	1.0
8	8.00	2.28		1.27	7.8	1.0		18.00	1.9		1.18		1.0
	16.00	38.05		6.56		1.0	27	8.00	2.11		1.31	7.8	1.0

Table 3.6 - Monthly treated water quality analysis (eg. October, 2014)

(Data collected at 6 sampling locations for 11 months in 2014 in similar format)

No.	Date	Time	Lab. No.	Sampling point	Hw / Dis.	RCl (mg/l)	Coliforms at 44^{0}C/100ml	E-coli at 44^{0}C/100ml	Colour	Turbidity (NTU)	pH	E.C. (µs/cm)	Chloride	Total Alkalinity as $CaCO_3$ (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Sulphate (mg/l)	Total Iron (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	TDS (mg/l)
1	15	14.15	2014/11 87	Tap at Edirisinghe shop	D	0.1	0	0	2.5	1.10	7.31	32.2	8	16.0	24.5	16.0	<0.01	-	-	21.2
2	15	14.30	2014/11 88	Tap at the town Petrol shed	D	0.4	0	0	2.5	0.90	7.32	32.4	8	16.6	24.0	16.0	<0.01	-	-	21.4
3	15	14.45	2014/11 89	Tap at Nendurana road	D	0.3	0	0	2.5	1.60	7.35	32.6	8	16.2	24.8	16.0	<0.01	-	-	21.5
4	15	14.55	2014/11 90	Tap at Moragala Muslim hotel	D	0.1	0	0	2.5	1.40	7.33	32.4	8	16.4	24.2	16.0	<0.01	-	-	21.4
5	15	15.10	2014/11 91	Tap at Panawala road	D	0.2	0	0	2.5	1.40	7.35	32.2	8	16.6	24.0	16.0	<0.01	27.8	0.476	21.2
6	15	15.45	2014/11 93	Clear water Tank (Sump)	H	1.0	0	0	2.5	1.00	7.38	32.4	12	16.0	24.0	16.0	<0.01	28.1	0.972	21.4

Table 3.7 - Monthly raw water quality analysis (2014)

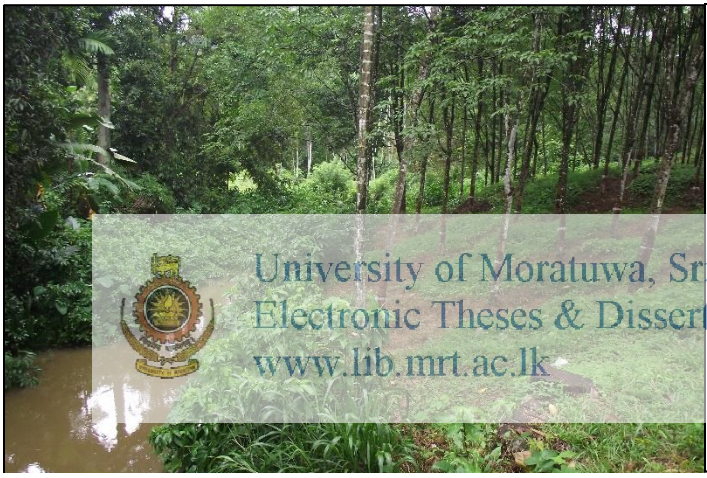
(Data collected at 3 sampling locations for 10 months in 2014)

Month	Date	Time	Color (Hazen unit)	Turbidity (NTU/FTU)	pH	EC (µs/cm)	Chloride as Cl (mg/l)	Total Alkalinity as $CaCO_3$ (mg/l)	Total Hardness as $CaCo_3$ (mg/l)	Sulphate (mg/l)	Total Iron (mg/l)	Calcium as $CaCO_3$ (mg/l)	Magnesium as Mg (mg/l)	Total Coliform at 35^0C/100ml	Escherichia Coli at 44^0C/100ml	BOD (mg/l)	COD (mg/l)
January	16.01.2014	12.00	2.5	1.0	6.90	89.4	10.0	32.0	46.0	36	<0.01	32	0.243	TNC	TNC	-	-
February	18.02.2014	15.45	5	1.5	6.90	176.8	16.0	20.0	28.0	36	<0.01	18	0.480	TNC	TNC	-	-
March	18.03.2014	17.30	10	1.6	6.80	172.6	16.0	52.0	68.0	16	<0.01	48	0.480	TNC	TNC	-	-
April	01.04.2014	17.45	2.5	1.4	6.66	57.6	12.0	28.0	36.0	16	<0.01	22	0.360	TNC	TNC	-	-
May	19.05.2014	17.45	20	6.8	7.12	38.5	12.0	18.0	26.0	16	<0.01	8	1.940	TNC	TNC	3.2	9.6
June	16.06.2014	15.45	2.5	1.4	6.83	30.7	12.0	18.0	20.0	16	<0.01	16	0.486	TNC	TNC	3.8	9.8
July	14.07.2018	15.45	2.5	2.8	6.96	30.3	8.0	16.0	18.0	16	<0.01	12.0	0.970	TNC	TNC	4.2	12.5
August	18.08.2014	15.45	2.5	2.6	6.65	27.3	8.0	16.0	20.0	16	<0.01	12.0	1.621	TNC	TNC	3.6	9.3
September	16.09.2014	15.45	7.5	1.2	6.97	25.0	12.0	18.0	21.0	16	<0.01	16.0	0.243	TNC	TNC	6.2	15.8
October	15.10.2014	15.55	7.5	2.4	7.49	29.9	12.0	20.0	24.0	16	<0.01	18.0	0.972	TNC	TNC	5.6	16.2

3.3.5 Water pollution data of Eheliyagoda catchment

Table 3.8 – Analysis of waste water from rubber processing plant (2014)

Parameters	Unit	14th Jul.	18th Aug.	15th Sept.	15th. Oct.	17th Nov.
		14.35 hrs.	18.00 hrs.	17.50 hrs.	16.20 hrs.	15.45 hrs.
Total Suspended Solids	**mg / l**	6.5	8.4	7.2	8.2	4.0
BOD	**mg / l**	8.0	12.0	8.0	8.0	6.0
COD	**mg / l**	72.0	28.0	26.0	12.0	18.0
pH		7.5	7.4	7.5	7.4	7.1
Colour	**Hazen**	25.0	30.0	25.0	20.0	7.5
Turbidity	**NTU**	42.0	84.0	62.0	54.0	40.0
Temperature	**^{0} C**	28.8	28.0	28.4	27.6	26.0



Observation *– Large patches of eliminated ground vegetation is seen due to application of "Glyphosate" to clear paths between rubber trees. Close proximity of this agro chemical to the water source poses an extreme risk.*

Figure 3.11 – Application of weedicide near the water source

Observation *– High soil erosion within the catchment transports loads of sediments to the water source. The sediment carries "adsorbed" agro chemicals and fertilizer used in the rubber plantation. This is an extreme risk.*

Figure 3.12 – Soil erosion in the catchment

3.3.6 Socio economic data of catchment inhabitants of Eheliyagoda

The WSP team had undertaken a socio – economic study among the catchment communities pertaining to their background and understanding on catchment management. The sample had consisted of 85 households. The study carried a total of 31 questions out which 27 were closed ended and only a 4 were open ended. The questions belonged to the following key categories.

- Administrative and geographical information of the housing unit
- Personal data of the inhabitants of the housing unit
- Land use of the home garden
- Knowledge, attitudes and practices related to organic farming
- Income generation and level of expenditure
- Water, sanitation, hygiene and solid waste management
- Knowledge and attitudes on catchment demarcation

Table 3.9 – Parameters related to community catchment management

Monthly Income (Rs)	No. of Households	Practicing Organic Farming	No. of Households	Like ? Catchment Management	No. of Households
Below 20,000	57	Yes	20	Yes	85
Above 20,000	28	No	65	No	0

Figure 3.13 – WSP team with community leaders

Land boundaries and the method of demarcation can be a serious concern for communities when it comes to development initiatives that spread over a large geographical area cutting across private properties. There has been a tendency of people becoming skeptical of development initiatives due to the fear of losing their living space and livelihoods regardless of the legal ownership of the lands.

In the case of Eheliyagoda water supply system, the demarcation of the catchment boundary and reservation of the water stream had been methodically done by the Waster Safety Plan team thus preventing possible speculations and unrest among the inhabitants. The services of **Land Use Planning Officer** attached to the Eheliyagoda Divisional Secretary's office has been obtained thus leading a professional output.

The mandate of this Officer is only limited to government owned lands that, in some rural cases, encroached by the neighboring communities knowingly or unknowingly. Stream reservations and land use maps of the area have been professionally developed by this Officer using GIS mapping thus making the process transparent and evidence based to all. These maps and boundaries had been quite helpful to get community participation to negotiate on how best they could contribute the demarcation and management of the catchment. For example one consensus has been to plant durable trees along the stream reservation instead of concrete land posts thus avoiding emotional feeling of hostility among neighboring inhabitants.

In addition the maps developed in the exercise have been extremely useful in visualizing domains of different elements of the water supply system and assigning accountability for professional contributions. For example the rubber plantation owners and management have been logically convinced on the effects of plantation on the water supply system as well as their accountabilities to take certain precautions and actions of mitigation.

4. ANALYSIS & DISCUSSION

4.1 Rationale of the Analysis

Water Safety Plan (WSP) cuts across 4 elements of a conventional Water Supply System (WSS); Catchment, Treatment, Distribution and Consumer. Thus it comprises of a substantial diversity in terms of domains and stake holders as shown in *Figure 4.1*.

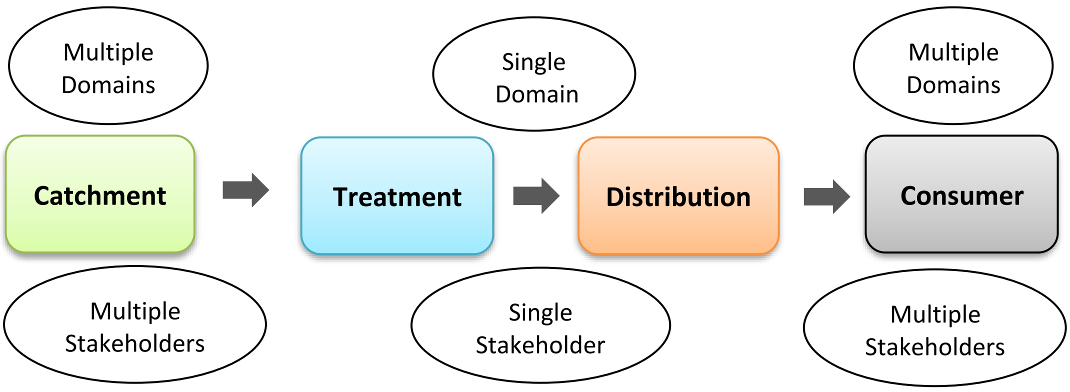


Figure 4.1 – Diversity associated with conventional Water Supply System

Water suppliers solely dominates the elements Treatment and Distribution that largely associate with professional components of water supply such as technology, administration and finance. However the elements Catchment and Consumers consist of a large number of stakeholders from multiple domains who don’t necessarily play any direct role with respect to water supply. However directly or indirectly they are able to influence water safety in a big way. Dynamics of stakeholders in a catchment are linked with intake water quality for Treatment as well as drinking water safety at the point of use is linked with the dynamics of the very Consumers (WHO, 2011, pp36).

For these reasons a study on WSP has to associate with both nonprofessional human dynamics, such as attitudes and behaviour, as well as professional systems and procedures. As a result an analysis on WSP would come across both qualitative and quantitative data that apparently has no correlation by any means.

While the research Question reflects more qualitative aspects the research Aim and Objectives are supposed to generate rational and credible evidence largely based on quantitative information. Hence the approach of this analysis was planned with a view to deriving a *qualitative rationale with quantitative evidence* by analysing the Water Safety Plan of the Eheliyagoda Water Supply System. The analysis was confined only to the major part of the System with the stream (Biso Dola) as its water source. The alternative water source (Dug Well) was not considered in this case due to the unique nature of the 2 sources. *Table 4.1* presents the outline of the analysis.

Table 4.1 - Summary of analysis of Eheliyagoda Water Safety Plan

Analytical Step		Methodology
4.2	Identifying the critical Modules of Eheliyagoda WSP	Checking actual progress and compliance of WSP with WHO WSP Manual for drinking water suppliers
4.3	Analysing Risk Re-assessment under WSP Module 4	Graphical analysis comparing Risk Assessment and Risk Re - assessment
4.4	Analysing improvement plan under WSP Module 5	Qualitative analysis on improvement plan against Risk Re-assessment
4.5	Generating evidence beyond risk matrix	Graphical and qualitative analysis of water quality parameters associated with extreme risk ratings
4.6	Quantifying evidence on risks beyond the risk ratings	Sample quantification and qualitative analysis on soil erosion and chemical pollution within catchment
4.7	Understanding resource allocation and accountability in Water Safety Planning	Qualitative analysis on stakeholder interactions and resource categories
4.8	Deriving the need to rationalize resource allocation for WSP	Qualitative analysis on proposed resources and associated perceptions
4.9	Deriving a model for rationalizing resource allocation	Application of bottleneck analysis based on Tanahashi model

4.2 Identifying critical modules of Eheliyagoda WSP

As a document Eheliyagoda WSP was found to be complete. It had been developed through a consultative and participatory process. As the first step the compliance of this WSP was analysed with respect to the guidelines presented in WHO WSP Manual for drinking water suppliers as shown in *Table 4.2*.

Table 4.2 – Compliance of Eheliyagoda WSP with WHO WSP Manual

WSP Module		Strengths	Challenges
1	Assemble the WSP team	Diverse group	Coordination mechanism not clear
2	Describe the water supply system	Comprehensive	
3	Identify hazards, hazardous events and assess the risks	Comprehensive	Consumer element missing
4	Determine and validate control measures, reassess and prioritize the risks	Comprehensive	29 Hazardous events with 7 extreme and 10 very high risks
5	Develop, implement and maintain an improvement / upgrade plan	Priorities justified	Long term activities consuming a lot of resources while no short or medium term actions
6	Define monitoring of the control measures	Comprehensive	
7	Verify the effectiveness of the WSP		Only compliance monitoring by the NWS&DB is available. No External auditing and consumer satisfaction measures
8	Prepare management procedures		No compliance with guidelines with no reference to regular and emergency procedures
9	Develop supporting programs	Sufficient enough	
10	Plan and carry out periodic review of the WSP	Sufficient enough	
11	Revise the WSP following an incident	As an when needed	

Challenges within Modules 4, 5, 7 and 8 are critical. By the time of research the WSP team was engaged on rolling out Modules 5 and 9. Modules 6, 7 and 8 can be improved slowly and they largely depend on the way Modules 4 and 5 are rolled out. Hence obviously the Modules 4 and 5 are critical and deserve further analysis on their compliance and improvements. This explanation is visualized in *Figure 4.2*.

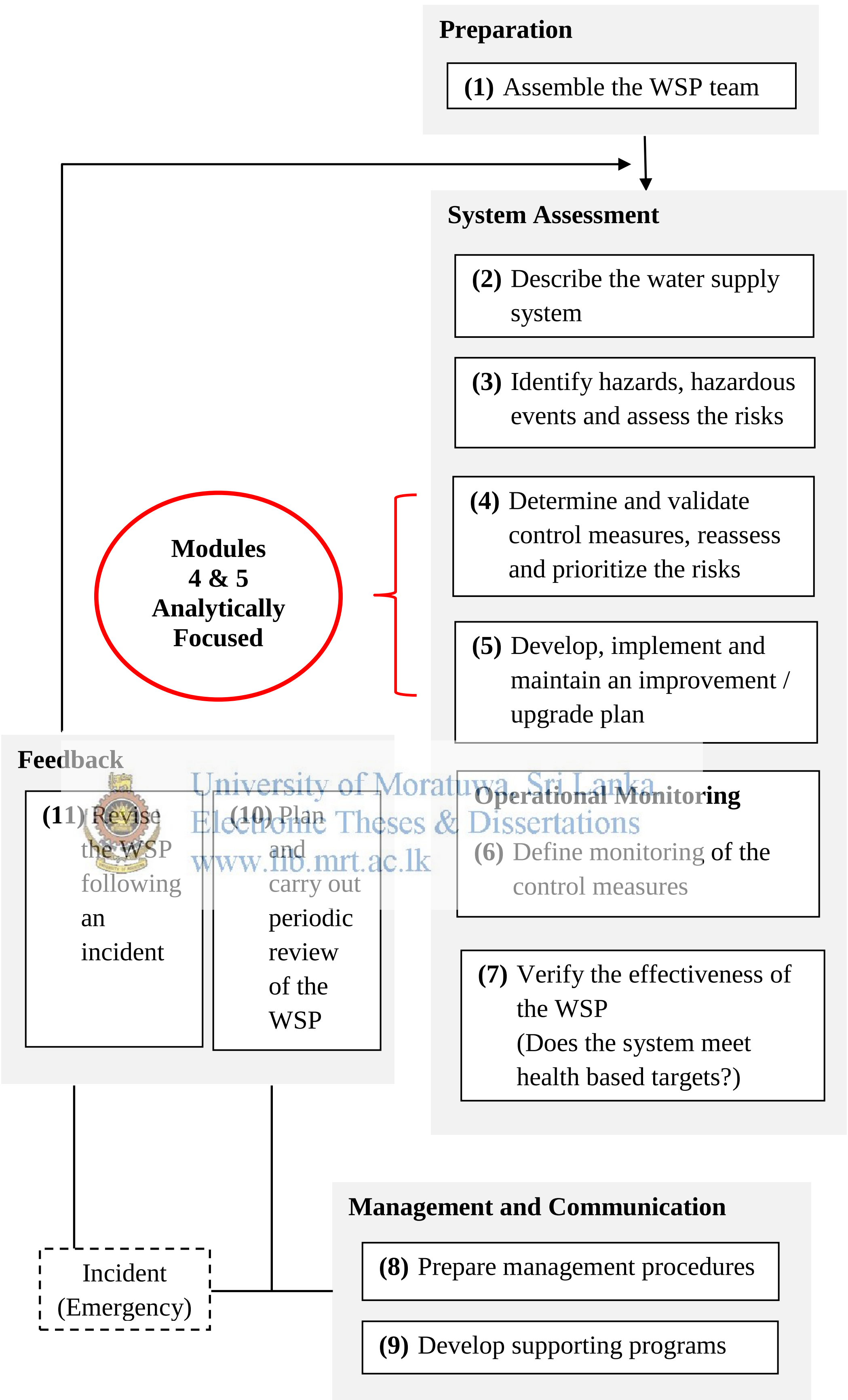


Figure 4.2 – Critical Modules in analysing Eheliyagoda WSP

4.3 Analysis of risk re-assessment (Module 4)

Risk assessment of the Eheliyagoda WSP has been based on the following criterion of the WHO Water Safety Plan Manual (Bartram et al., 2009, pp. 27 -28).

Hazard (Contaminant): Physical, biological, chemical or radiological agents that can cause harm to public health

Hazardous Event (Cause): An event, practice or outcome that introduces hazards to or fails to remove them from water product

For a given hazardous event
Risk = Likelihood (Frequency) × Consequences (Severity)

Risk assessment has been based on the semi – quantitative risk matrix approach, an adaptable guideline by WHO, as shown in the *Table 4.3*.

Table 4.3 – Semi quantitative risk matrix approach

		Consequence or Severity				
		Catastrophic Public Health Impact (Epidemic) Rating 5	Major Regulatory Impact (Wide spread illness) Rating 4	Minor Regulatory Impact (Isolated cases of illness) Rating 3	Aesthetic Impact Rating 2	No Impact or Not Detectable Rating 1
Likelihood or Frequency	Once a day Rating 5	**25**	**20**	**15**	**10**	**5**
	Once a week Rating 4	**20**	**14**	**12**	**8**	**4**
	Once a month Rating 3	**15**	**12**	**9**	**6**	**3**
	Once a year Rating 2	**10**	**4**	**12**	**4**	**2**
	Once in 5 yrs. Rating 1	**5**	**4**	**3**	**2**	**1**
Risk Score		< 5	> = 5	> = 10	> = 15	> = 20
Risk Rating		Low	Moderate	High	Very High	Extreme

4.3.1 Vulnerabilities within Eheliyagoda Water Supply System

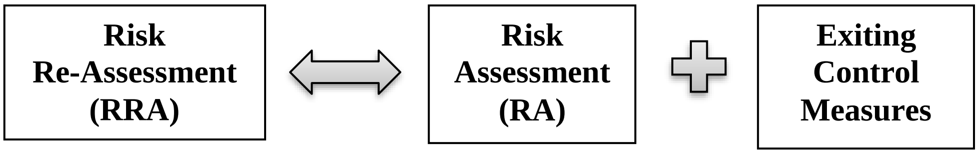


Figure 4.3 – Risk Re-Assessment of Eheliyagoda WSP

“Risk Assessment” had been performed under the Module 3 of the WSP covering 3 water supply system elements; Catchment, Treatment and Distribution. “Risk Re-Assessment” had been then followed under the Module 4 of the WSP by incorporating the existing control measures on the identified hazardous events as in *Figure 4.3*. There are 7 types of hazards identified for Eheliyagoda Water Supply System as shown in the text box. Before and after scenario of the Risk Re-Assessment are shown in the *Figures 4.4, 4.5 and 4.6* respectively for the elements Catchment, Treatment and Distribution.

Type of hazards identified in Eheliyagoda WSS

Single
M – Microbial
C – Chemical
P – Physical

Combined
M/C – Microbial & Chemical
P/C – Physical & Chemical
M/P – Microbial & Physical
M/C/P – Microbial, Chemical & Physical

Fig. 4.4 - Variation of risk rating in Catchment (RA to RRA)

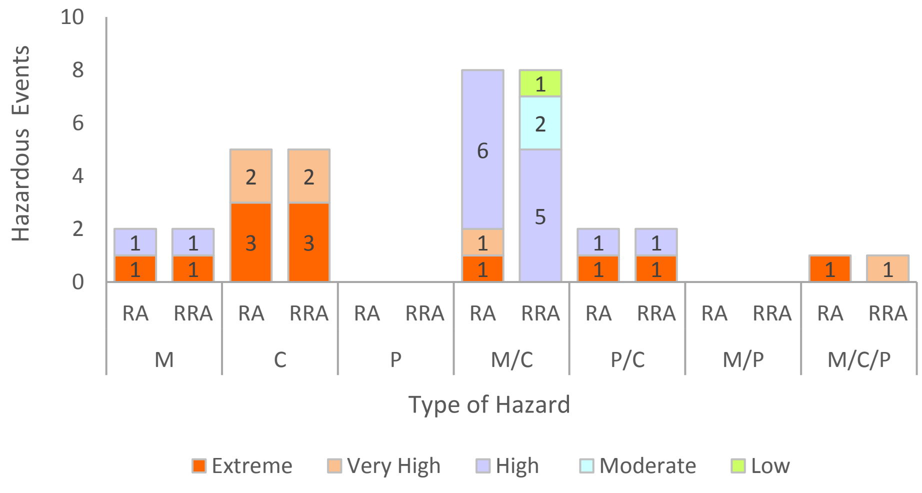


Fig. 4.5 - Variation of risk rating in Treatment (RA to RRA)

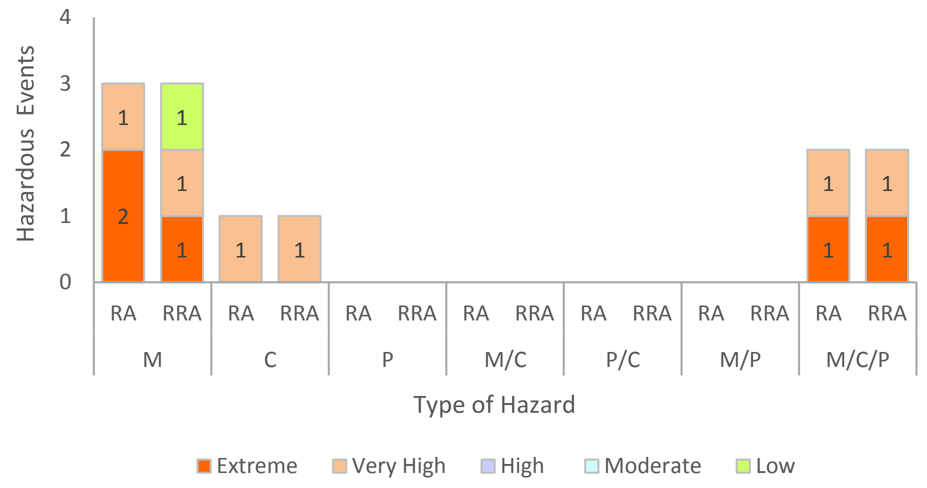
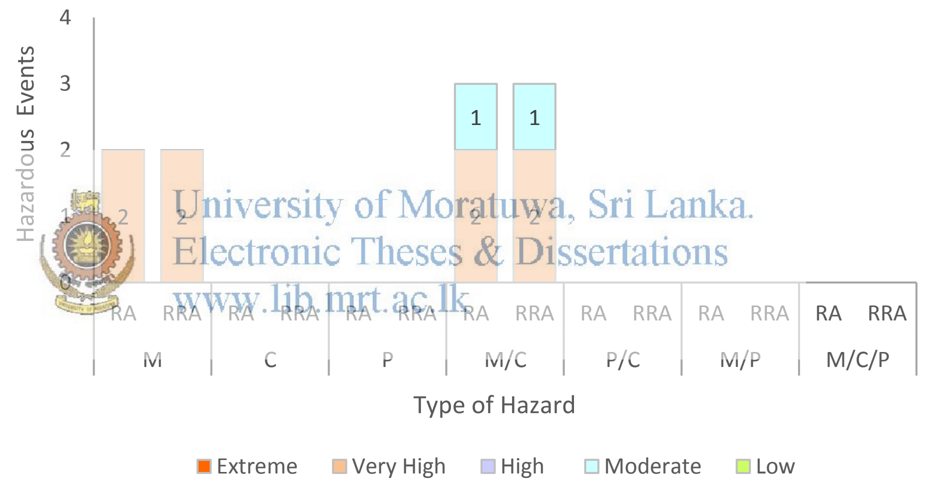
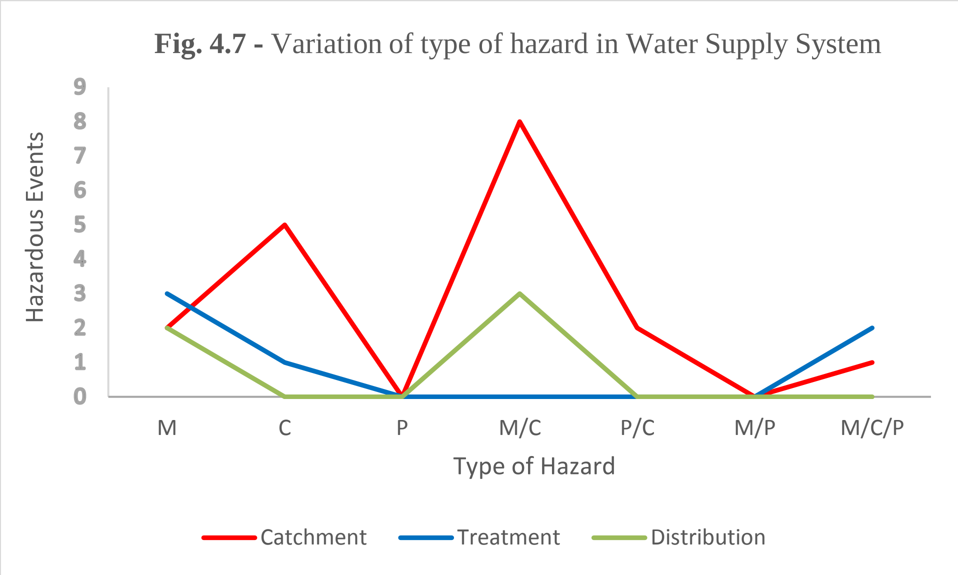
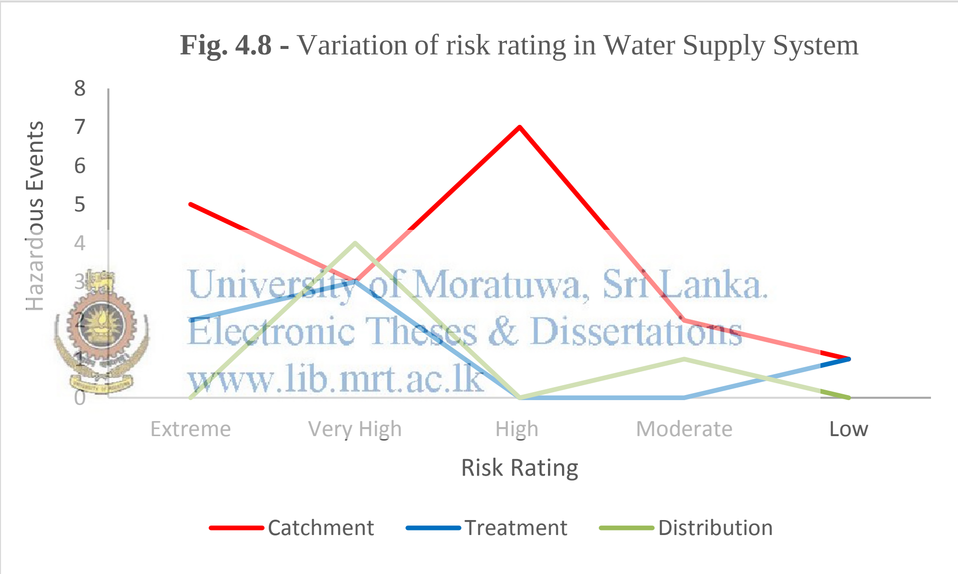


Fig. 4.6 -Variation of risk rating in Distribution (RA to RRA)



The risk rating is a measure of the vulnerability that each of water supply system element is inherited with. **Vulnerability** can be defined as the combination of factors determining the degree to which people's life and livelihood are put at risk by a discrete and identifiable event(s) in nature or society (Red R India, 2012). When it comes to water safety, the vulnerability is on the public health.Vulnerability of each element of the Eheliyagoda Water Supply System with respect to the 5 risk ratings and 7 types of hazards are shown in the *Figures 4.7 and 4.8* respectively.





Hence the vulnerability of the Water Supply System, even with the existing control measures in place, can be interpreted as follows.

- Catchment is the most vulnerable element (18 hazardous events – with 5 extreme, 3 very high and 7 high risk ratings)
- Treatment is the second most vulnerable element (6 hazardous events – with 2 extreme and 3 very high risk ratings)
- Distribution is the least vulnerable element (5 hazardous events - with 4 very high with risk ratings)
- Chemical hazard is the most critical while Microbial follows next.

4.4 Analysis of upgrade & improvement (Module 5)

Out of the 29 hazardous events, there were 7 events with extreme risk rating. This part of the analysis will be confined to those 7 extreme risks shown in the *Table 4.4*.

Table 4.4 – Eheliyagoda WSP extreme risks with no existing control measure

System Element	Hazardous Event (= Extreme Risk)		Hazard Type	Score	Validation Basis
Catchment	**1**	Microbial contamination of raw water due to leachate accumulation from toilet pits	Microbial	25	*E.coli* in Raw water at three locations
	2	Chemical contamination of Raw water due to accumulation of latex from latex collection centre in catchment	Chemical	20	Visual observation and testing BOD, COD, pH of pollutant at accumulation point
	3	Chemical contamination of Raw water due to accumulation of Agro chemical residues from Eheliyagoda Estate	Chemical	20	Pesticide residue analysis of raw water for tolerance limits
	4	Chemical contamination of Raw water due to accumulation of fertilizer residues from Eheliyagoda Estate	Chemical	20	Fertilizer residues analysis of raw water for tolerance limits
	5	High turbidity in river water after rain event due to soil erosion	Physical / Chemical	20	Turbidity measurement of raw water at intake
Treatment	**6**	High turbidity in filtered water due to inefficient filtration	Microbial/ Chemical/ Physical	25	Visual observation and turbidity measurement
	7	Microbial Contamination of filtered water due to back washing the filters with raw water	Microbial	25	Microbial analysis of filtered water

The WSP team had articulated an upgrade and improvement plan for the risks associated with all the 29 hazardous events. The *Table 4.5* contains the proposed improvements that correspond with the 7 events with extreme risks except the hazardous event No. 2 which comes under the purview of the rubber processing factory.

Table 4.5 – Eheliyagoda WSP improvement plan for extreme risks

	Action	**Hzds. Event** (Table 4.4)	**Identified Improvement**	**Accountability**	**Due**	**Status**
1	Prevent backwashing of filters by raw water	7	Install back washing pump	Regional Manger (NWS&DB)	Within six months	No action
2	Implement measures to control Microbial contamination in final water produced	6	Install and validate sedimentation and rapid sand filtration system to WTP	Additional General Manager (NWS&DB)	Within one year	On going
3	Implement measures to prevent accumulation of toilet leachates to the river	1	Introduce septic tanks to each toilet for 20 houses	WSP Committee	Within one year	On feasibility stage
4	Prevent accumulation of agro chemical and fertilizer and minimize hi turbidity in rain event in river water due to soil erosion	3 4 5	Implement comprehensive Catchment Management Plan	WSP Committee	Within three years	On going

Both extreme risk rating matrix *(Table 4.4)* as well as proposed improvements *(Table 4.5)* are direct products of the semi quantitative risk matrix approach from the WHO Water Safety Plan Manual. However the Manual itself has acknowledged the limitations of it as a tool. When discussing on "broadening the application of risk assessment" it is mentioned that many water suppliers restrict hazard identification and risk analysis to those that relate directly to their own compliance parameters (which may be due to WSP team capacity). Although issues outside their purview are well documented in the WSP those are unlikely to be considered as a part of implementation (Bartram et al., 2009, p. 36).

Despite the fact that there has been lack of examples on how a water supplier may implement a WSP beyond their domain, Eheliyagoda NWS&DB officials have taken commendable initiatives in this regard as shown in the improvement plan. Particularly the Action 4 on catchment management is significant since it attempts to cater 3 hazardous events with extreme risk ratings. On the other hand the Actions 1 and 2 are clearly under NWS&DB's (water supplier) purview.

4.5 Evidence generation beyond the risk matrix

Limitations of the semi quantitative risk scoring matrix have been known since the inception of WSP implementation. It is hard to find reasonable quantifications for certain hazards where time is wasted on hypothetical situations to reach consensus. The situation becomes more complex when risks are re-assessed with respect to existing control measures. Hence the WHO WSP Manual itself encourages WSP teams to have customized the risk re-assessments to generate more quantitative evidence (Bartram et al., 2009, p. 36). Quantified evidence has much weight and value in convincing decision makers rather than a ranking score results from a qualitative approach. Rational decisions would make resource allocation much valid and make investments more relevant to the prevailing ground conditions.

According to the analysis done so far, semi-quantitative risk matrix of the Eheliyagoda WSP can be re-interpreted with water supply elements, hazard types and water quality parameters in order of vulnerability and severity as shown in the *Table 4.6*.

Table 4.6 – Most vulnerable & severe entities within Eheliyagoda WSP

Vulnerability & Severity	Water Supply Element	Hazard Type	Water Quality Parameters
1	Catchment	Chemical	E.coli
2	Treatment	Microbial	Agrochemical residues
3			Fertilizer residues
4			Turbidity

The semi-quantitative risk matrix and improvements & upgrade plan have attempted to relate the above entities towards achieving water safety. However presentation through the standard WHO formats does not seem to be comprehensive and rational enough to impress decision makers as well as other stakeholders with no formal commitments in water supply. Hence it was thought of interpreting the extreme risks in terms of routine water quality data collected by the Eheliyagoda water supply scheme staff. Depending on the sampling frequency the analysis was based on 2 categories. Data is pertaining to both raw and treated water.

1. Monthly sampling for full analysis (One day fixed in the middle of the month) from the sampling points shown in *Figure 4.9*.
2. Daily sampling for analysis of Turbidity, pH and RCl from samples collected at the water treatment plant

4.5.1 Risk interpretation based on monthly water quality parameters

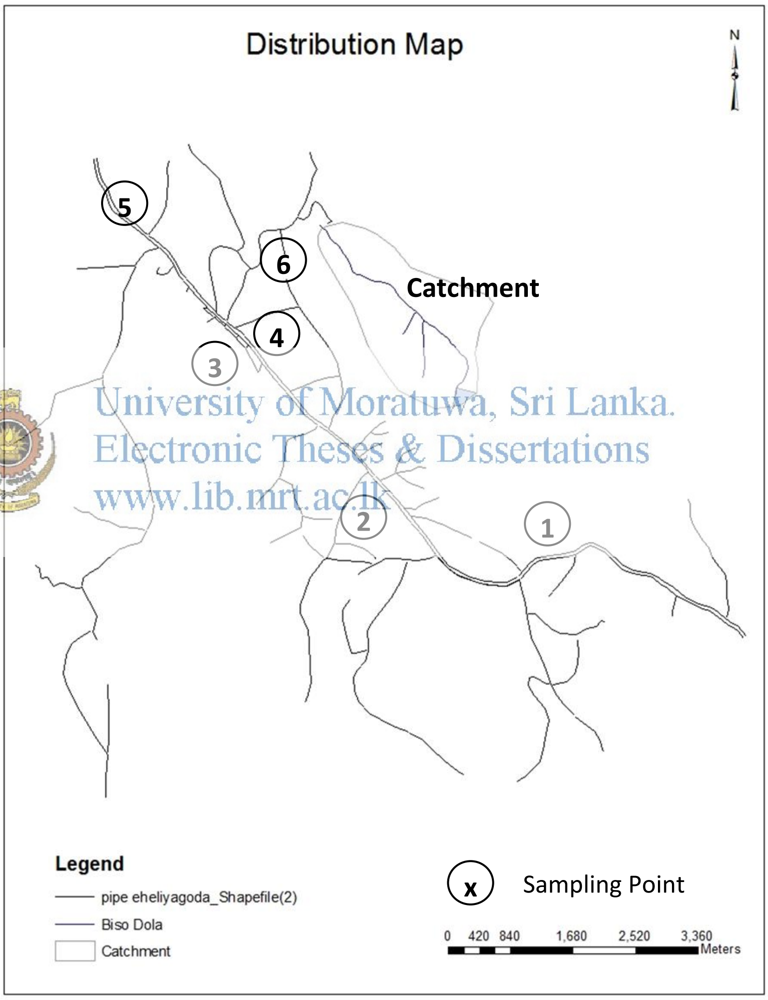


Figure 4.9 – Monthly treated water sampling locations

Note: - Average of the 6 samples (once a month) was taken to represent each water quality parameter during the analysis

Figure 4.10 to 4.17

Fluctuation of monthly water quality parameters of raw water and treated water

(From January to October, 2014)

Fig. 4.10 - Colour fluctuation

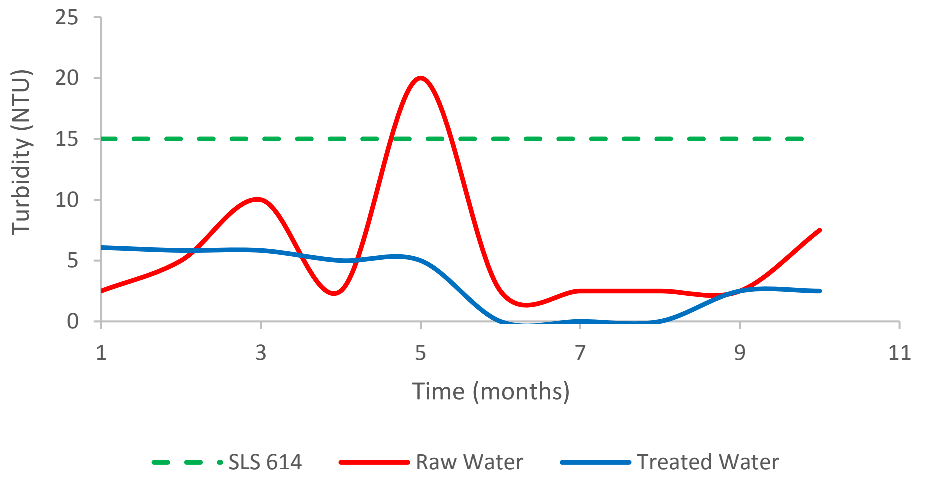


Fig. 4.11 - Turbidity fluctuation

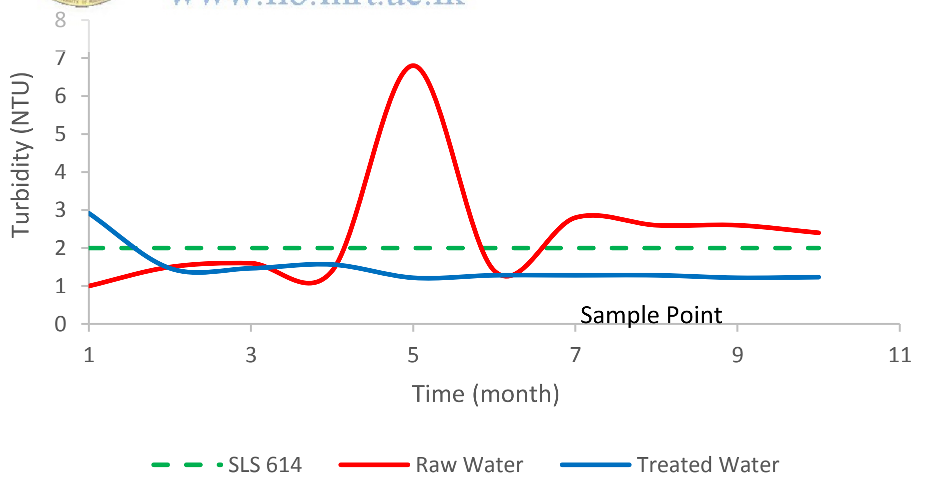


Fig. 4.12 - pH fluctuation

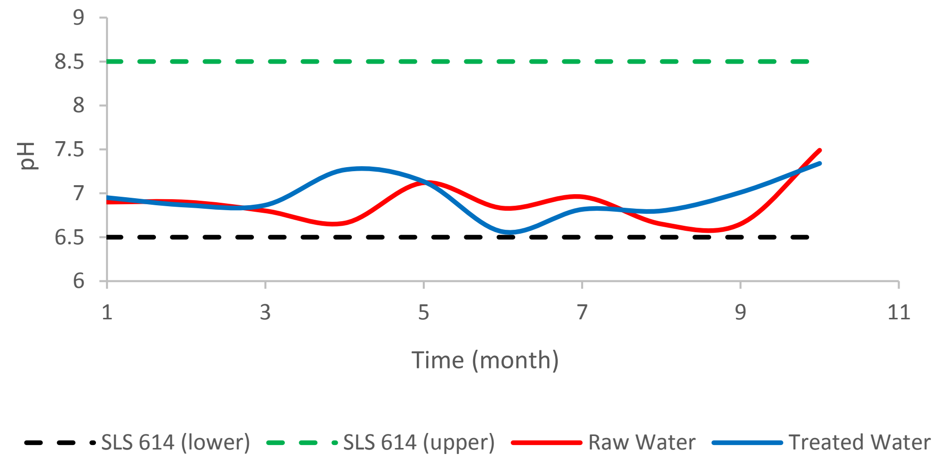


Fig. 4.13 - Choride (as Cl) fluctuation

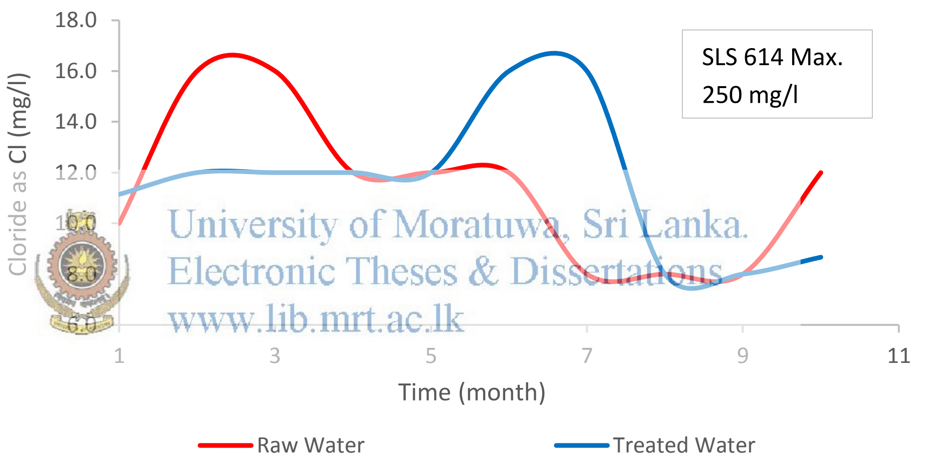


Fig. 4.14 -Total Alkalinity (as $CaCO_3$) fuctuation

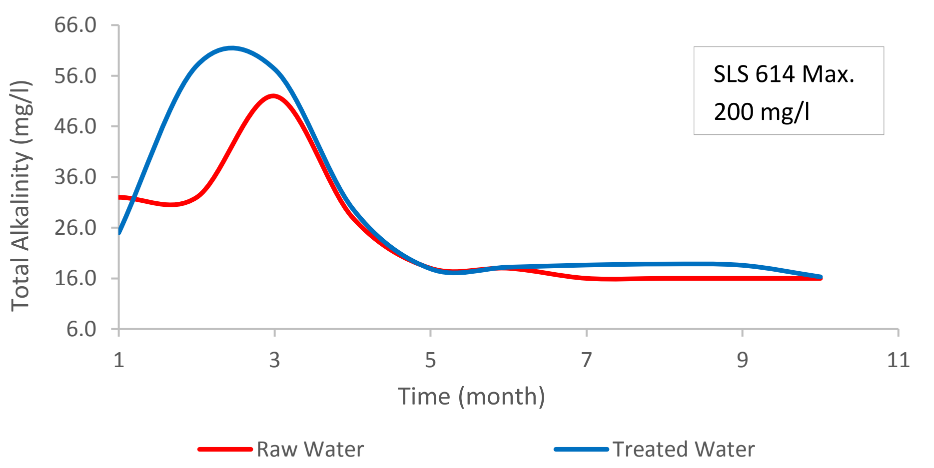


Fig. 4.15 - Total Hardness (as $CaCO_3$) fluctuation

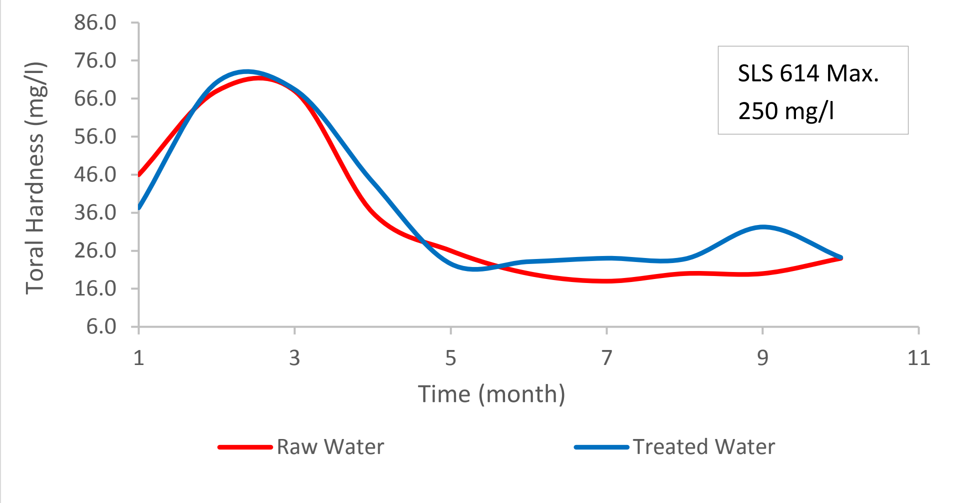


Fig. 4.16 - Sulphate (as SO_4) fluctuation

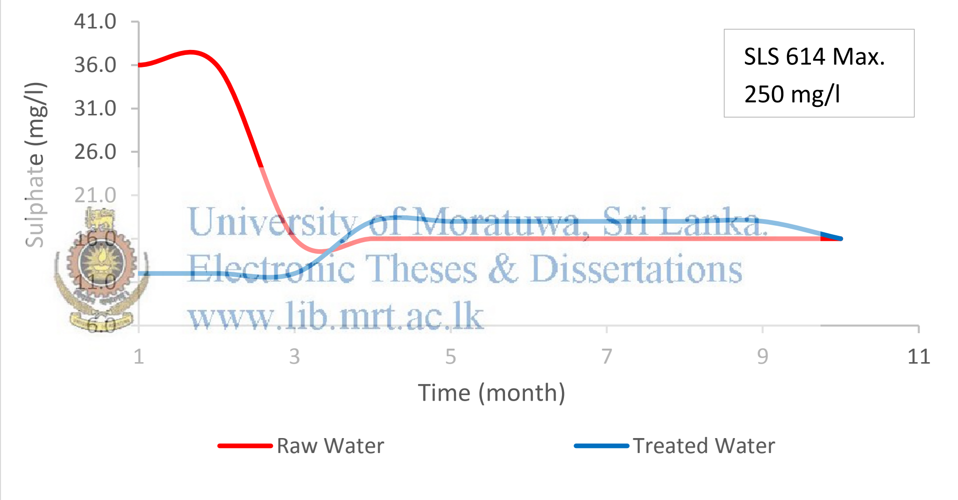
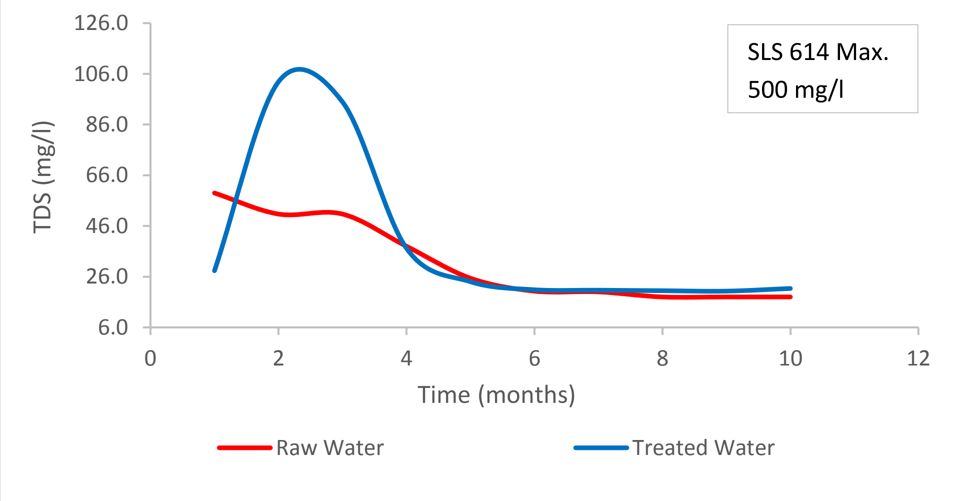


Fig. 4.17 - Total Dissolved Solids fluctuation



For the whole period both Total Coliform and E.coli counts and Residual Chlorine (RCl) values of raw and treated water are summarized in the *Table 4.7*.

Table 4.7 – Total Coliform, E.coli and RCl values (from January to October, 2014)

Parameter	Raw Water	Treated Water
Total Coliform Count (35^0C/100ml)	Too Numerous to Count (TNC)	Zero
E.coli Count (35^0C/100ml)	Too Numerous to Count (TNC)	Zero
RCl (mg/l)	Inapplicable	0.2 – 1.0

Critical interpretations on Figure 4.10 to 4.17 and Table 4.7

a) Microbial contamination of raw water is extremely high and extreme risk no. 1 in Catchment is totally out of control. However results after treatment shows that still this risk does not affect the point of use drinking water safety.

b) In relation to the extreme risks no. 3 and 4, the regional laboratory has been unable to test the parameters for agro chemical residues and fertilizer residues including Nitrate, Nitrite and Phosphates. This is a critical factor missing in the upgrade and improvement plan.

c) In relation to the extreme risk no. 5, raw water Turbidity at intake was reasonably under control with a maximum value 6.8 NTU during the 10 month period.

d) E.coli and Turbidity fluctuation in treated water from “once a month full analysis” validates that the extreme risks no. 6 and 7 in the *Table 4.4* are fully under control following Treatment.

Since the above analysis is based on monthly sampling there needs to be further understanding on how critical parameters fluctuate daily. Out of the 4 critical parameters of the *Table 4.6*, daily sampling data was available only for Turbidity.

4.5.2 Risk interpretation based on daily Turbidity

Daily Turbidity, RCl and pH data were available for treated water from January to November, 2014. On certain days Turbidity has been recorded several times depending on the fluctuation of stream water quality based on visual observations. Unlike in monthly sampling, daily sampling has revealed considerable fluctuation of Turbidity of "treated water" within a given month. *Figures 4.18, 4.19 and 4.20* show the fluctuation of monthly maximum and minimum Turbidity over above duration.

Fig. 4.18 - Fluctuation of maximum and minimum monthly Turbidity of treated water in 2014

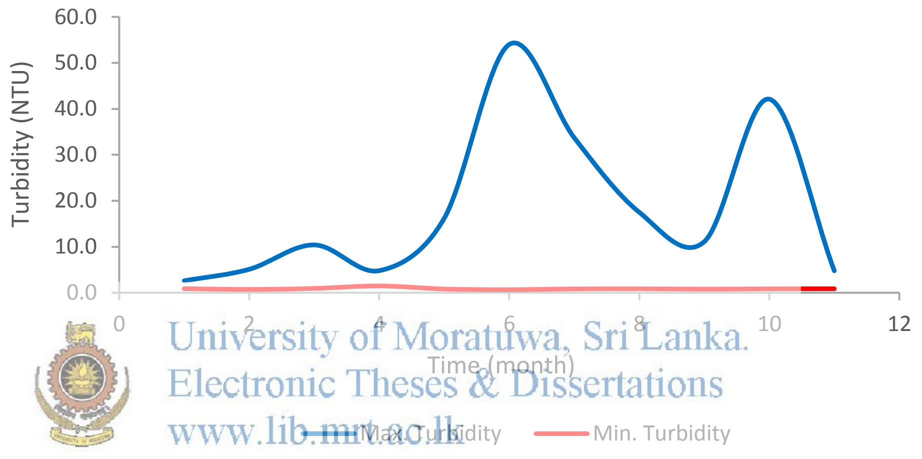


Fig. 4.19 - Fluctuation of minmimum monthly Turbidity of treated water in 2014

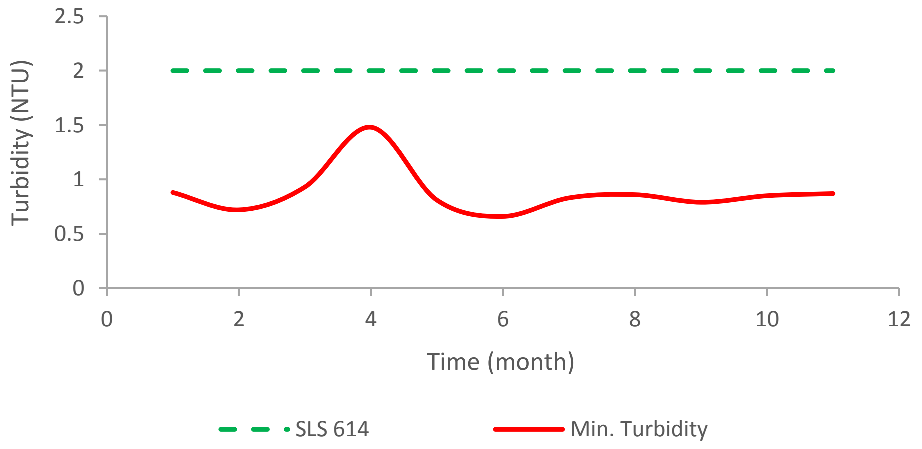
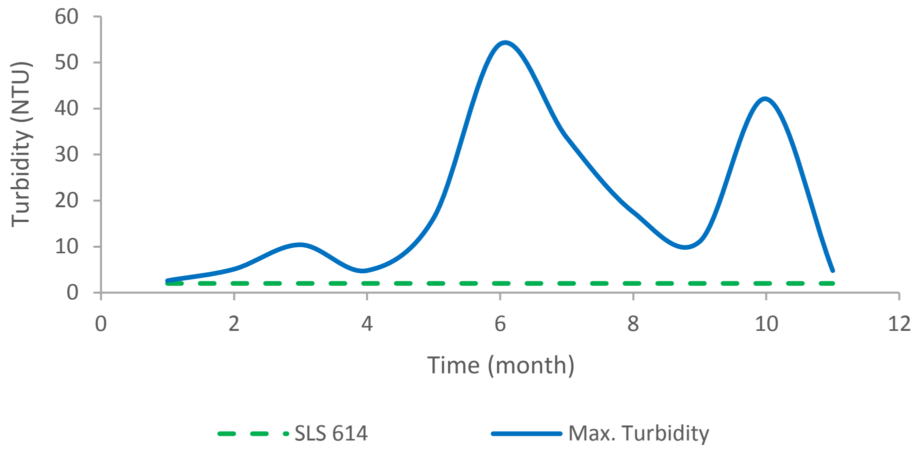
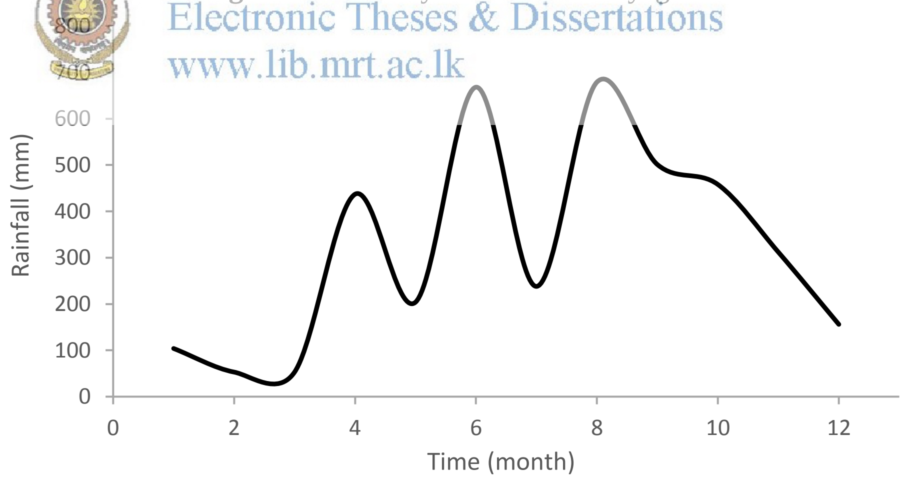


Fig. 4.20 - Fluctuation of maximum monthly Turbidity of treated water in 2014



Therefore it is evident that Turbidly of treated water has exceeded the SLS 614 maximum limit in every month while reaching dangerously high values during the months from May to July as well as September to November.

Fig. 4.21 - Monthly rainfall of Eheliyagoda in 2014



Source: Department of meteorology – Eheliyagoda Station

While the monthly average rainfall may be too generic to see the rain fall pattern, still a visual correlation can be observed in the rainfall fluctuation and monthly maximum Turbidity fluctuation in “treated water”. This is quite apparent in 2nd and 4th quarter of the year when *Figures 4.20 and 4.21* are compared.

Water treatment plant operators had started to document daily Turbidity of both raw and treated water since June 2014 with average 40 readings per month. To observe more realistic Turbidity fluctuation the whole data set is plotted in *Figure 4.22*.

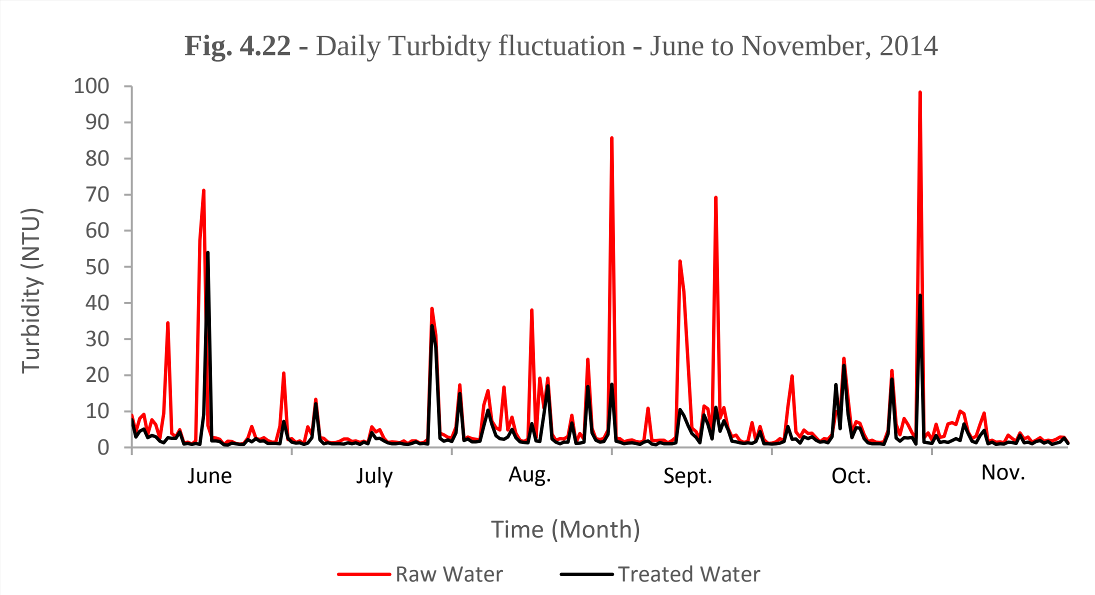


Figure 4.22 also reflects elevated Turbidity in both raw and treated water corresponding to the peaks in *Figure 4.21*. Furthermore much larger data set of *Figure 4.22* shows much realistic picture of Turbidity fluctuation than *Figures 4.18, 4.19 and 4.20*. It also gives the opportunity to compare Turbidity of both raw and treated water fluctuations at a glance. Most of the times Turbidity of treated water seems to have been proportional to that of raw water. In the absence of flocculation and coagulation the scenario is not unlikely and diverts urgent attention on the existing filtration.

Critical Interpretations of from Figure 4.18 to 4.22

a) High Turbidity in both on raw and treated water is proved to be the most critical water quality parameter with respect to the available data.

b) Turbidity is apparently proportional to the intensity of rainfall thus catchment soil erosion is proved to be a substantial component of Turbidity.

c) Though agrochemicals and fertilizer residues have not been tested, soil erosion and surface runoff can most probably transport them to the stream.

4.6 Quantifying evidence on risks beyond risk ratings

Existing treatment has so far been able to prevent the propagation of microbial contamination (E.coli) beyond the Treatment element towards the Consumer element. However the existing treatment has failed to prevent the impact of **soil erosion** propagating towards consumers. Though not tested the same path would carry the **chemical pollution (mainly from rubber industry)** towards the consumers, particularly when associated with soil erosion. This part of the analysis is dedicated to arrive at a reasonable quantification of these two pollution factors that cause several hazardous events in this Water Treatment System.

4.6.1 Quantifying soil erosion

It is assumed that the soil erosion in Eheliyagoda catchment comprises of 4 erosion types namely; impact, sheet, rill and channel erosion. (Rusle, 2012)

Extensive review of literature on the topic revealed that "Universal Soil Loss Equation (USLE)" can be applied in this case as follows: (Stone et al., 2012, p.1)

$$\mathbf{A = R \times K \times LS \times C \times P}$$

A - Potential long-term average annual soil loss in tonnes per hectare per year

R - Rainfall factor by geographic location

K - Soil erodibility factor (average soil loss) in tonnes per hectare

LS - Slope length-gradient factor

C - crop/vegetation and management factor

P - Support practice factor (erosion control practices)

Figure 4.23 shows the catchment map of the Eheliyagoda Water Supply System. The rest of the parameters were calculated with certain assumptions based on this map.

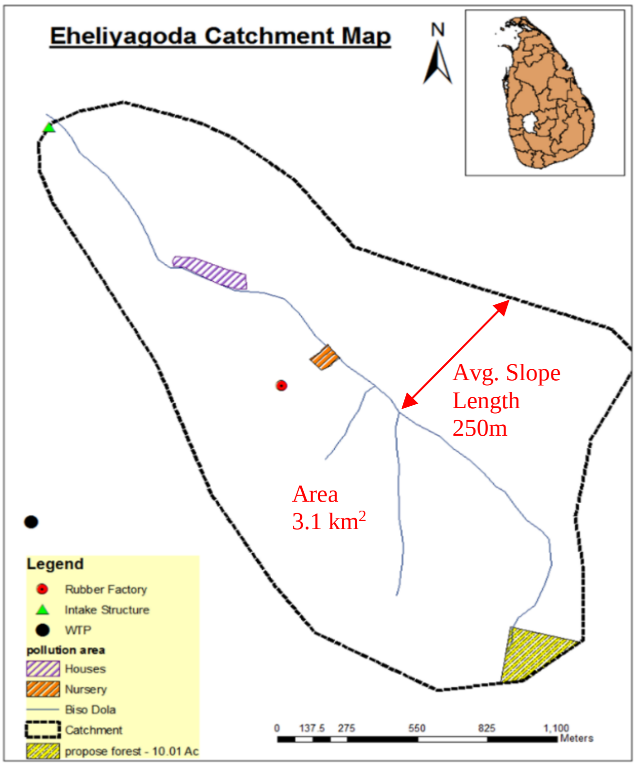


Figure 4.23 – Eheliyagoda catchment map

Study by W. D. Joshua on *"Soil erosive power of rainfall in different climatic zones of Sri Lanka"* contains wealth of information on applying the USLE in Sri Lanka. One of its data point has been Rathnapura where the results are quite reasonably applicable to Eheliyagoda. Accordingly the area has Red-yellow podzolic soil with K = 0.22 (Joshua, p. 59).

R = 100

(Stone et al., 2012, p.2)

Assuming average slope length to be 250m and slope to be 6%

LS = 1.91 (Stone et al., 2012, p.3)

C = Crop type factor × Tillage method factor (Stone et al., 2012, p.4)

Crop type factor = 0.1 (assuming for Rubber)

Tillage method factor = 0.25 for No till (Stone et al., 2012, p.4)

C = 0.1 × 0.25 = 0.025

P = 0.37 (Stone et al., 2012, p.4)

A = 100 × 0.22 × 1.91× 0.025 × 0.37 = 0.39 tonne/hectare/year

A = 39 tonne/ km^2/year

The total potential average soil loss (erosion) in the catchment = **121 tonnes/year**

(= 39 × 3.1 assuming homogenous erosion across the catchment)

4.6.2 Quantifying chemical pollution from rubber industry

Eheliyagoda watta rubber estate within the catchment covers 75% of catchment area. Rubber cultivation and production associates with 3 apparent pollutants that contribute to the hazardous events with extreme risk rating in the catchment.

1. Fertilizer use in the estate and nursery
2. Weedicide use in the estate
3. Waste water discharged from latex rubber processing factory

Table 4.8 – Rubber industry related chemical pollutants in the catchment

Pollutant Type	Product	Constituents	Load utilized within catchment
Fertilizer	RSA 799	NH_3	11.6 tonne/year
	RU121414	N, P, K	
	Rock Phosphate	P	
Weedicide	Glyphosate	-	31 l/month (to be discontinued)
Waste from Rubber Processing	Waste Water	Acetic Acid Water Solids	Functions when required, No data available

At present there are no tests conducted to measure fertilizer residues (N and P). Yet with evidence of soil erosion and high Turbidity in both raw as well as treated water, the possibility of fertilizer residues being present in drinking water is likely. Out of the average total 11.6 tonnes / year of fertilizer RSA 799 shares 4.35 tonnes / year. Proportion of other 2 types depends on the Foliar Analysis by the Rubber Research Institute (RRI). Depending on the nutrients in soil as well as the age of the plant there are 5 prescribed mix proportions of fertilizer to be applied.

Glyphosate is one of the most widely used weedicides in agriculture, forestry, industrial weed control, lawn, garden, and aquatic environments. “Signal words” for products containing Glyphosate may range “from Caution to Danger”. The U.S. EPA does not consider Glyphosate to be a human carcinogen based on studies of laboratory animals that did not produce compelling evidence of carcinogenicity. Yet in Sri Lanka there has been sensitive and controversial discussions going on regarding Glyphosate. Hence in relation to soil and water the following facts worth noting (National Pesticide Information Center, 2015):

- Glyphosate adsorbs tightly to soil
- Glyphosate and its residues are expected to be immobile in soil
- The median half-life of glyphosate in water varies from a few days to 91 days
- Glyphosate has a low potential to contaminate groundwater due to its strong adsorptive properties. However, there is potential for surface water contamination from aquatic uses of glyphosate and soil erosion
- The reference dose (RfD) for glyphosate in humans is 1.75 mg/kg/day
- The maximum contaminant level (MCL) of glyphosate in water is 0.7 mg/L

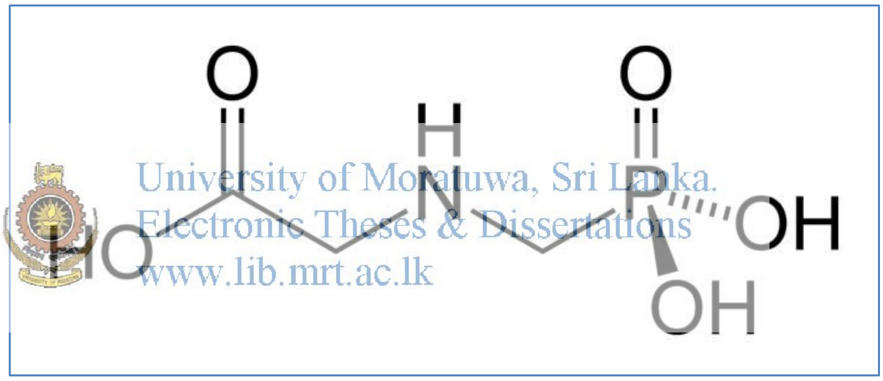


Figure 4.24 – Structure of glyphosate

There are many alternative views on glyphosate interms of health based targets. Bio accumulation of glyphosate has been spotted due to its presence in both urine and breastmilk (Scoopwithmysoup.com, 2015). Most importantly Glyphosate has been concluded to be one of the 3 critical factors that cause the Chronic Kidney Disease in Sri Lanka (Jayasumana et al., 2014).

Waste water generated from latex rubber processing factory is treated in a treatment facility before it is discharged to the catchment. Summary of the critical water quality parameters of the treated effluent is shown in *Table 4.9*.

Table 4.9 – Water quality of treated effluent from latex rubber processing

Parameters	Unit	Tolerance Levels of CEA	Monthly Sampling near intake - 2014				
			July	Aug.	Sept.	Oct.	Nov.
Total Suspended Solids	mg / l	**50**	6.5	8.4	7.2	8.2	4.0
BOD	mg / l	**30**	8.0	12.0	8.0	8.0	6.0
COD	mg / l	**250**	72.0	28.0	26.0	12.0	18.0
pH		**6.0 – 8.5**	7.5	7.4	7.5	7.4	7.1
Colour	Hazen	**N/A**	25.0	30.0	25.0	20.0	7.5
Turbidity	NTU	**N/A**	42.0	84.0	62.0	54.0	40.0
Temperature	^{0} C	**40**	28.8	28.0	28.4	27.6	26.0

The effluent meets the Sri Lanka standards for discharging industrial effluents to inland surface waters. The two pollution factors (soil erosion & rubber industry chemicals) analyzed above need advanced research methodologies for comprehensive interpretations. Yet the above basic mapping would be sufficient to understand their impact on the basic principles of WSP as shown in the *Table 4.10*.

Table 4.10 – Critical pollution factors in Eheliyagoda WSS vs basics of WSP

Pollution Factor	Pollutant	Hazard Type	Hazardous Event in WSP (Table 4.4)	Vulnerable Water Supply Element	Compromised WSP Basics
Soil Erosion	Soil particles with / without adsorbed agro chemicals	Physical Chemical	5, 6	Catchment Treatment Distribution Consumer	• Risk management of all steps of water supply • Multiple barriers • Priority of drinking water aspects
Rubber Industry Chemical Pollution	Fertilizer	Chemical	4		
	Weedicides	Chemical	3		
	Waste Water	Chemical	2	No Impact	No compromise & Reasonable compliance

Critical observations on soil erosion and rubber related chemical pollution

- Quantifications under this analysis need advanced research methodologies for comprehensive interpretations. Yet even sample quantification and mapping of quantities are much stronger in influencing decision makers than standard semi-quantitative risk matrix.

- Chemical aspect of drinking water safety is placed as the 2nd priority since there may be no immediate health problem. Yet this simple priority sequence does not capture "exposure time" as a parameter when it comes to long term exposure to chemical pollutants (even at low doses) that passes through all the 4 water supply system elements. Thus there needs to be a criteria to interpret any cumulative or accumulated health risk over a time.

- In the absence of comprehensive analysis for generating evidence, available quantifications and visual observations may be used as proxies for making decisions for improvements as explained in examples below.

  - Example 1 – While high Turbidity is resulted from many causes, the quantified soil erosion can be used as a proxy to interpret the severity of Turbidity related hazardous events prompting improvements.

  - Example 2 – While there is no available qualitative and quantitative evidence on agro chemical pollution, visual observation of Glyphosate usage near the very edge of the water source can be used to create a concern and prioritize the relevant improvements.

4.7 Resource allocation and accountability in Water Safety Planning

Implementing any plan needs resources as well as a frame work of accountability and so does the implementation of WSP. Unlike a pure infrastructure project, a WSP needs constant reviewing and revising of its own components when time passes. Thus there needs to be serious concerns on its sustainability from the planning stage itself. Based on the observations of Eheliyagoda WSP, the type of resources needed for sustainability can be qualitatively summarized as in *Table 4.11*.

Table 4.11 – Type of resources required for sustaining a WSP

Type of Resource	Examples
Human (H)	Dedicated WSP champions, WSP team members, Staff trained on certain roles of WSP as part of their job description, Volunteers such as community members, Interested parties such as researchers and donors
Knowledge (K)	Concepts on water safety, Guidelines, Hand books, Tools, Case studies, Research papers etc.
Finance (F)	Capital and recurrent budgets for both hard (tangible) and soft (knowledge based) activities
Time (T)	Time that each stakeholder could allocate as a part of implementing the WSP

While activities under all the 11 Modules of WSP associate with all the 4 types of resources, some require certain resources exclusively. For example hazard mapping involve more human, knowledge and time resources while improvements for treatment plant requires more financial resources.

Any type of resource utilization is linked with accountability. However WSP as a whole does not have a single institutional structure or accountability framework. Hence the most appropriate option is to integrate WSP roles with respective stakeholders' accountability frameworks. Even if this is achieved there remains the challenge of mutual accountability between independent and diverse stakeholders. Observations in this regard from Eheliyagoda WSP are presented in *Figure 4.25*.

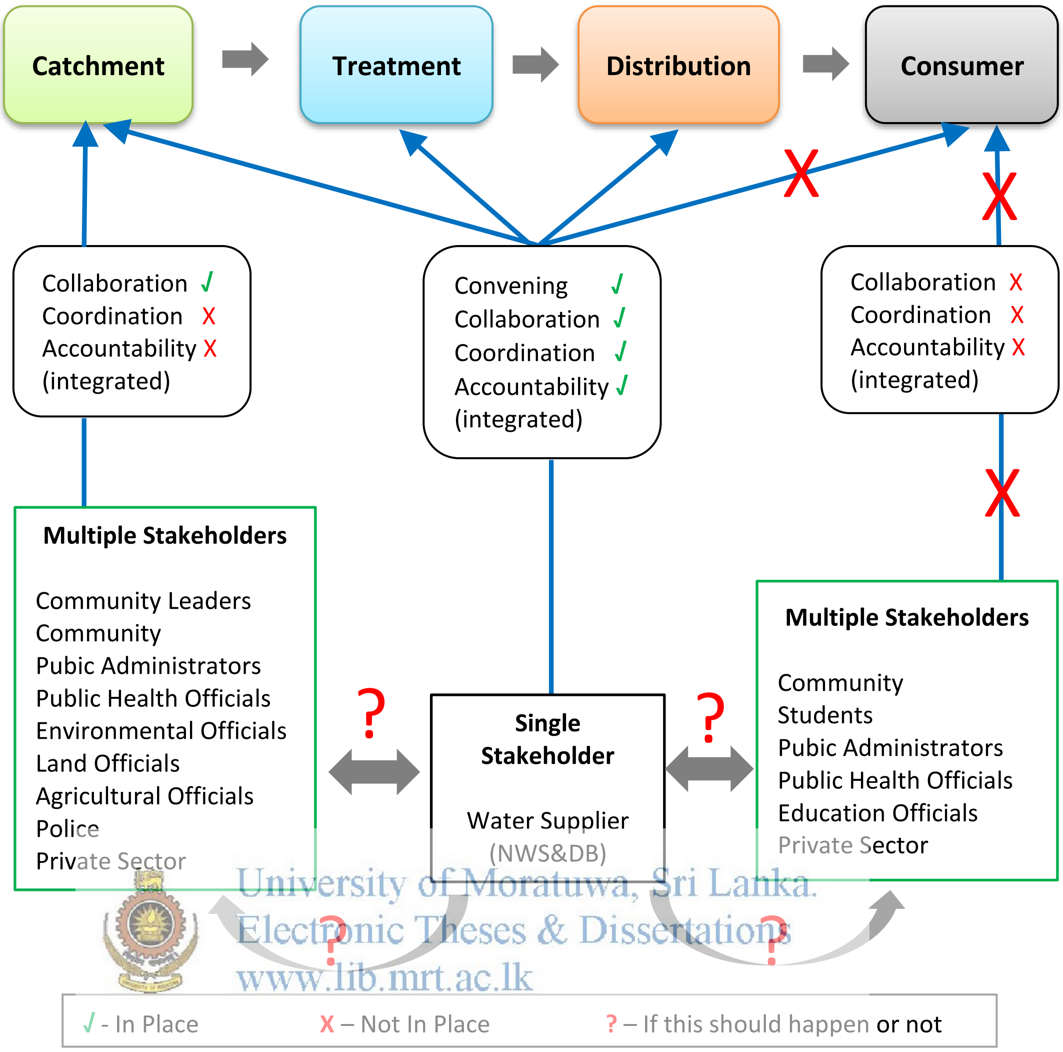


Figure 4.25 – Accountability in Eheliyagoda Water Safety Plan

It is clear that other than the NWS&DB staff, the stakeholders have no accountability except collaboration towards WSP commitments. Accountability is one of the key pre-requisite for sustainability. Hence in relation to WSP in general, the following may need to be raised, clarified and agreed upon by stakeholders.

- Who should create the demand in stakeholders for accountability?
- Should the water supplier push other stakeholders to commit?
- Should there be mutual (lateral) accountability?

4.8 Need to rationalize resource allocation for Water Safety Plans

As WHO WSP guidelines are dedicated for water suppliers, by default they are expected to lead the process. Naturally they seem to be more comfortable on planning and implementing WSP within their own domains, particularly when it comes to resource allocation and accountability.

However the water supply elements outside water suppliers' domain (eg. Catchment and Consumers) comprise of multiple domains and stakeholders with no mutual accountability. Such vagueness adds vulnerability to resource allocation, particular within such water supply elements. In this backdrop how the senior management of water suppliers or other stakeholders would be confident enough to decide on where to allocate resources and in what proportion is a challenge. If there is no rationale for resource allocation, the WSP may not become a management priority in the long run.

WHO WSP Manual clearly identifies this as a key factor under the introduction itself. It is said that *"for successful implementation of the WSP, it is important that senior management support the process. This support is crucial to obtain support for changes in working practices, to ensure sufficient financial resources are available and to actively promote water safety as a goal of the organization. A clear case is needed to show that the adoption of a WSP is important and advantageous to the organization"* (Bartram et al., 2009, p. 9).

Considering the 6 extreme risks prevailing in Eheliyagoda WSS, there has been two major project proposals under the improvement plan of the Eheliyagoda WSP as summarized in *Table 4.12*.

Table 4.12 – Proposed improvement projects under Eheliyagoda WSP

Proposed Activity Scope	Estimated Cost (Rs.)	Relevant Water Supply Element	Domains	Stake Holders
1. Improvements to water treatment plant with • Tube flocculator • Back wash pump (Purely construction)	4,553,109.00	Treatment	Water Supply (Single Domain)	NWS&DB (Single Stakeholder)
2. Comprehensive Catchment Management Plan based on the concepts of • Analog forestry • Organic farming • Fair trade (Knowledge promotion, hands on training, mapping, field testing and consolidating)	19,513,000.00	Catchment	Community Private Sector Environment Agriculture Forestry Public Administration (Multiple Domains)	Community Rubber plantation Consultants Government Officials for water, land, agriculture and admin. (Multiple Stakeholders)

When analysed from water supplier's management point of view, the two proposals would "induce impressions" as summarised in the *Table 4.13*.

Table 4.13 – "Induced impressions" by the proposed improvement projects

Proposed Activity Scope	Impression on Budget	Rationale to Justify	Results Tangible?	Time to See Results	Control over Domain
1. Improvements to water treatment plant	Affordable	Mitigate 2 "extreme" risks	Fully	Short	Full Control
2. Comprehensive Catchment Management Plan	High (4 times the other proposal)	Mitigate 3 "extreme" risks	Partially	Long	No Control

Generally, with limited financial resources, it is highly unlikely for the decision makers to opt for the 2nd proposal as the justification is only based on mitigating just an extra extreme risk than the 1st proposal. The 2nd proposal apparently has the key disadvantage of a higher fund utilization over volatile results in a less reliable domain. In contrary the 1st proposal would be felt much comfortable and confident for a manager of NWS&DB who is accountable for his decision.

When it comes to allocation of resources for certain improvements and upgrades over others there needs to be a clear rationale supported by evidence. Such rationale would create demand among those who have authority. In the absence of such a rationale, mere risk rating of WSP alone may not be sufficient to convince decision makers especially the extent of resources requested and associated accountability are high.

Thus a rationale for resource allocation is critically needed due to the following realistic scenarios;

- When the resources are limited (an obvious case by default)
- When some improvements and control measures need to be prioritized over others
- When the water suppliers have to invest in domains outside their purview
- When it is necessary to convince other stakeholders to utilize their own resources on water safety which is not a part of their mandate (leveraging)
- When it is necessary to make awareness and create demand for non-financial commitments among stakeholders

For a rationale to be successful it needs to have the following characterises;

- Evidence based
- Practically interpreted
- Visual and convincing for a person who has no /less interest on water safety
- Showing both strengths /assets in hand and weaknesses / gaps to attend
- Supporting decision makers to defend resource allocation in case of delayed results or failure (willingness to be accountable)

4.9 Model for rationalizing resource allocation

When looking at safe drinking water with a holistic approach it is finally contributing for the well-being of humans through stable and improved health. Therefore water safety is being integrated and assessed more and more in health sector domains as important as it is being with the water suppliers' domains. For this reason it was thought to test Tanahashi model for water safety planning. This model has been well recognized for "Marginal Budgeting of Bottlenecks" in the health sector. The model has been developed with respect to 3 fundamentals that should exist in a health system (Tanahashi, 1978).

1. Allocating resources and organising services to serve as many people as possible
2. Ensuring if the services reach the people they should serve
3. Ensuring if the service has been effective in meeting people's needs

Having identified the complex relationships of supply & demand with entities such as policy making, the Tanahashi model was later expanded to accommodate all of them (Rollins School of Public Health of EMORY University, 2012). Thus the model now consists of four broader categories; Enabling Environment, Supply, Demand and Quality followed up with 10 standard Determinants. Critical factors considered in selecting Tracer indicators to represent these Determinants related to Eheliyagoda WSP are shown in the *Table 4.14.*

Table 4.14 – Critical factors in selecting Tracer Indicators for Eheliyagoda WSP

Category	Determinants in Enhance Tanahashi Model	Critical Factors Considered in Defining Tracer Indicators
Enabling Environment	• Social Norms • Legislation / Policy • Budget / Expenditure • Governance / Partnership	- Community living in catchment - Available financial resources - Stakeholder accountability
Supply	• Availability of essential commodities / inputs • Access to adequately staffed services and information	- Water quality testing - Stakeholders' competency on WSP
Demand	• Financial access • Social cultural acceptability • Continue of use	- Community living in catchment - Consumer participation
Quality	• Quality	- WHO priority on risks - Treated water quality

Determinants, Tracer Indicators and intended means of verification are shown in the *Table 4.15.* Analysis and rating of the Trace Indicators are in the *Table 4.16*.

Table 4.15 – Expanded Tanahashi Model for Eheliyagoda WSP

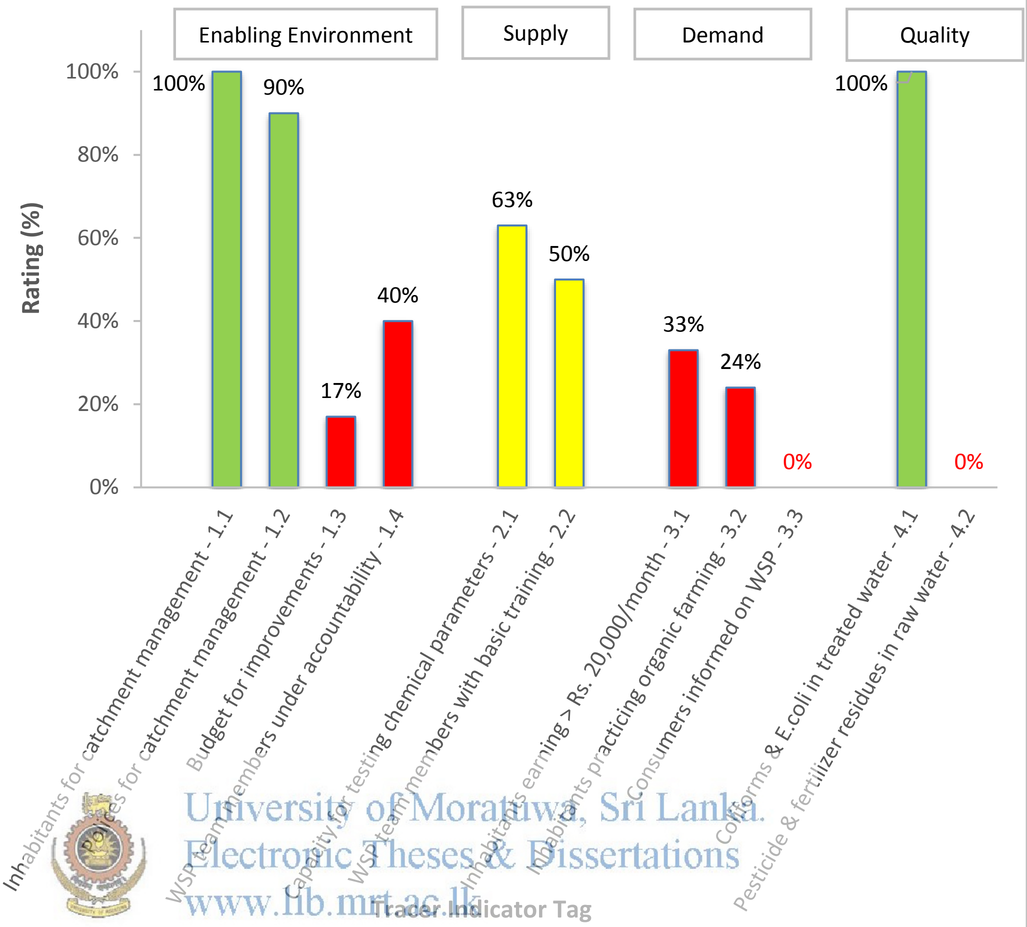
Category	Determinant	Tracer Indicator		Means of Verification
Enabling Environment	Social Norms	1.1	Proportion of community living in catchment willing to take part of the catchment management plan	Socio Economic survey in catchment (Table 3.9)
	Legislation / Policy	1.2	Proportion of Catchment Management Plan supported by existing policies	Chronology of policies and legislations (Table 3.3)
	Budget / Expenditure	1.3	Proportion of allocated budget for the improvement plan	WSP budgets (Table 4.12) and interviews
	Governance / Partnership	1.4	Proportion of WSP team under an accountability framework for water safety	WSP team information (Appendix 2)
Supply	Availability of essential commodities / inputs	2.1	Proportion of default chemical parameters as per SLS 614 with facilities to test within the region	Monthly treated water quality data from regional lab (Table 3.6)
	Access to adequately staffed services and information	2.2	Proportion of WSP team with training / knowledge on WHO WSP guidelines	Interviewing the WSP team leader and WSP team information (Appendix 2)
Demand	Financial access	3.1	Proportion of families in catchment with monthly income above Rs. 20,000	Socio Economic survey in catchment (Table 3.9)
	Social cultural acceptability	3.2	Proportion of households in the catchment practicing organic farming	
	Continue of use	3.3	Proportion of consumers informed and aware of the improved water safety after WSP improvements	WSP Document
Quality	Quality	4.1	Proportion of compliant samples tested for Total Coliforms and E.coli in treated water	WSP validation plan (not yet in place) Proxy validation with Table 4.7 data
		4.2	Proportion of compliant samples tested for pesticide and fertilizer residues in raw water	WSP validation plan (not yet in place)

Table 4.16 – Analysis of Tracer Indicators for Eheliyagoda WSP

Category	Tracer Indicator		Sample Analysis	Rating %
Enabling Environment	1.1	Proportion of community living in catchment willing to take part of the catchment management plan	ALL – out of 85	100%
	1.2	Proportion of Catchment Management Plan supported by existing policies	Almost all - out of Soil Conservation, Land use, Environment and Protection / Conservation of Water Sources, Catchments and River Basins,	90% (10% margin for interpretation issues)
	1.3	Proportion of allocated budget for the improvement plan	Rs. 4 million – out of two budget estimates for Rs. 24 million	17%
	1.4	Proportion of WSP team under an accountability framework for water safety	12 – out of 30	40%
Supply	2.1	Proportion of default chemical parameters as per SLS 614 with facilities to test within the region	10 – out of 16	63%
	2.2	Proportion of WSP team with training / knowledge on WHO WSP guidelines	15 – out of 30 total members	50%
Demand	3.1	Proportion of families in catchment with monthly income above Rs. 20,000	28 – out of 85	33%
	3.2	Proportion of households in the catchment practicing organic farming	20 – out of 85	24%
	3.3	Proportion of consumers informed and aware of the improved water safety after WSP improvements	No One – Since consumers have not been part of the WSP	0%
Quality	4.1	Proportion of compliant samples tested for Coliforms and E.coli in treated water	All – from January to October, 2014	100%
	4.2	Proportion of compliant samples tested for pesticide and fertilizer residues in raw water	NONE – Since improvements are not fully in place and proposed validation is not possible	0%

Figure 4.26 presents the bottleneck analysis with rated Tracer Indicators.

Fig. 4.26 - Bottleneck analysis of Eheliyagoda WSP



Bottleneck Type	Tracer Indicator Rating (%)	Colour Code
Severe	0 – 40 %	
Moderate	41 – 80 %	
No Bottleneck	81 – 100%	

Critical interpretations on the Figure 4.26 bottleneck analysis

a) Severe bottleneck in Quality category (with zero rating on chemical aspects) means that the intended service to the public (water safety) is yet to be achieved regardless of relatively less bottlenecks in Enabling Environment and Supply. However since there is no bottleneck on microbial aspects the existing bottleneck and related risk are concealed compromising its deserved attention on resources.

b) Severe bottlenecks in the Demand category seriously compromises the sustainability of implementing the WSP. This may discourage decision makers in utilizing resources on other categories. It is also possible that inhabitants' high willingness under indicator 1.1 may conceal the Demand bottlenecks.

c) Supply category remains relatively moderate in terms of bottlenecks. Also the associated bottlenecks can be immediately addressed with existing resources.

d) Interestingly there is a substantial diversity of bottlenecks in the Enabling Environment. While social norms and policy level remain much favourable for the WSP the budget allocation and accountability would seriously compromise its progress. However the budget needs a serious review to understand if it is targeting the right bottlenecks particularly in the Demand and Quality categories. The issue on mutual accountability between stakeholders is a serious constraint since as of now the WSP is almost driven by the water supplier (NWS&DB).

While *Figure 4.26* explicitly show the dynamics at the Tracer Indicator level, it is worth seen the same at the higher level of Determinants as shown in the *Table 4.17.*

Table 4.17 – Analysis of Categories interms of Determinants

Category	Determinant	Determinant Analysis – Tr. Ind. No.	Determinant Analysis – Ind. Rating (%)	Determinant Analysis – Severity	Category Analysis – Avg. Rating (%)	Category Analysis – Avg. Severity	Remarks
Enabling Environment	Social Norms	1.1	100%		**62%**		Enabling environment has moderate severity where Social norms and existing policies are much favorable. Resources are needed on Budget and Governance / Partnership related to WSP.
	Legislation / Policy	1.2	90%				
	Budget / Expenditure	1.3	17%				
	Governance / Partnership	1.4	40%				
Supply	Availability of essential commodities / inputs	2.1	63%		**57%**		Supply category is moderately severe where bottlenecks can be addressed with current resources
	Access to adequately staffed services and information	2.2	50%				
Demand	Financial access	3.1	33%		**19%**		Severe bottlenecks indicate that "Demand Creation" at both inhabitants and consumer levels is of utmost importance to sustain WSP
	Social and cultural acceptancy	3.2	24%				
	Continue of use	3.3	0%				
Quality	Quality	4.1	100%		**50%**		Though the bottleneck is moderate it needs immediate attention for the sake of public health
		4.2	0%				

4.10 Rationalized resource allocation for Eheliyagoda WSP

Analysis on semi quantitative risk matrix, quantification of hazards and Tanahashi model for bottleneck analysis clearly show that there needs to be “consistency” in allocating resources with respect to the basic objectives of the WSP. Separate outcomes from these analysis need to be aligned rationally so that the decision makers could be convinced with justifications on where to prioritize.

Building the rationale

a) High ratings on the bottlenecks pertaining to social norms and policies make the enabling environment “look fine” from the top of the spectrum. Yet it is clear that budget allocation and accountability are key issues that compromises this category.

b) The budget deficit captured in the analysis may not be the extract constrain but whether the budget was estimated on optimum interventions is the key concern. Analysis on other categories provide clues on where the optimum priorities could be with respect to ratings and quantifications of the extreme risks.

c) Lack of mutual accountability between different stakeholders within the WSP team itself reflects the challenge on sustaining resource allocation under their own systems. Stakeholders by default focus on their core business thus consistent resource allocation on water safety other than their business needs a lot of commitment and ownership. Much resources (time, knowledge an human) may have to be initially invested to create the demand to commit and own a slot. Also the current stakeholder roles can be easily upgraded to accountable interventions. As an example an agricultural officer incorporating water pollution on his/her regular duties on agrochemical/ fertilizer use will be much effective.

d) Supply category is moderately bottlenecked yet seems to be recoverable by sharing available resources rather than new fund allocations. As an example the water quality parameters, not possible to be tested in the region, may be verified from a closer facility through mere coordination. Similarly the whole WSP team can be oriented on the basics of water safety through participatory orientations.

e) Severe bottlenecks in the Demand category indicates inhabitant's economical limits and realistic engagement in catchment management with organic farming as of now. Less income may influence any environmental friendly alternative unless it gives them at least the same income. Not counting the consumers is the most severe bottleneck in the WSP. It has seriously compromised most critical end user demand for safe water. As a whole the WSP seriously needs a comprehensive community mobilization plan to create demand for both catchment management and safe water. The budget referred in the enabling environment did not have any demand creation activity.

f) Even with the identified extreme microbial risks on raw water, the treated water has so far been free of microbial contaminants. Yet in the absence of proposed improvements the extreme risk of pesticide and fertilizer residues in treated water is totally relevant. Regardless of the residues' concentration, the visual observation of them entering into the stream consistently is alarming from water safety point of view. Quantification of soil erosion and use of agrochemicals and fertiliser in the catchment gives enough evidence to justify immediate resource allocation on this extreme risk. Resource allocation in this case can be of two options.

I. Investing more resources on current budget proposals under enabling environment (catchment management) that eventually assures raw water quality improvement.

II. If above investment under option 1 not affordable or time consuming, consumers should be immediately advised to use household ceramic filters (for Turbidity) and household activated carbon filters (for chemical contaminants) until the water supply system itself is improved. This could be followed by boiling for added protection against possible infiltration of pathogens due to existing risks and limitations. This option needs more human and time resources to mobilise consumers with knowledge and creating their demand to invest.

The above rationalized resource allocation approach for Eheliyagoda Water Safety Plan can be illustrated as shown in *Figure 4.27*. Priority should be on raising the Tracer Indicators under Quality closer to 100% as the result of combined resources.

Figure 4.27 - Rationalized resource allocation for Eheliyagoda WSP

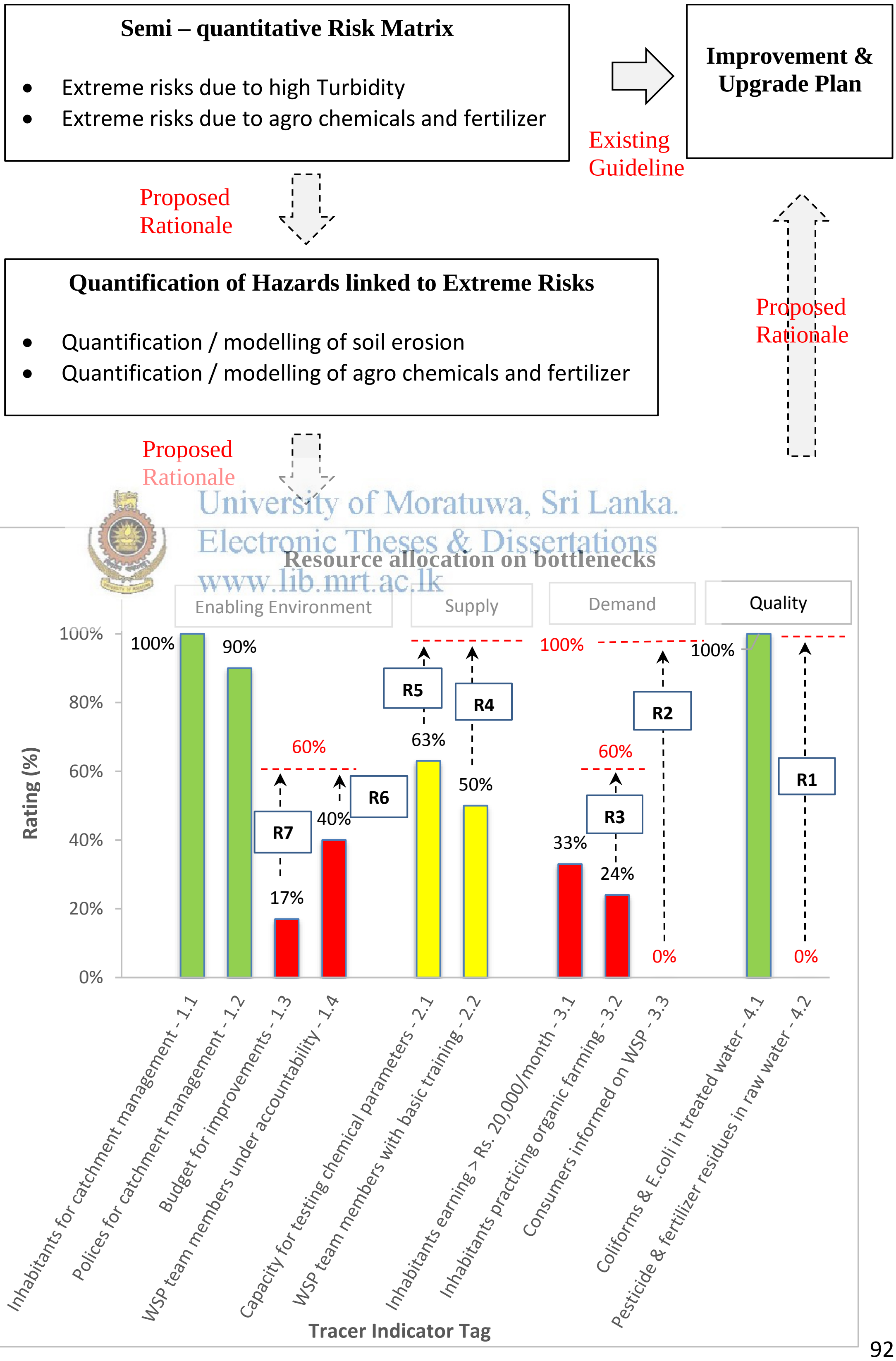


Table 4.18 – Rationalized resources matrix for Eheliyagoda WSP

Category	Tracer Indicator	Resource	Proposed Intervention	H	K	F	T
		Rationalized Resource Allocation (H -Human, K – Knowledge, F -Financial, T -Time)		**Dedicated Resource Types Involved**			
Quality	4.2	R1	**Option 1** – Comprehensive catchment management to mitigate pesticide / fertilizer residues in raw water (already in the current improvement plan yet long-term to get impact, complicated and expensive)	X	X	X	X
			Option 2 – Consumer awareness thus creating social demand for house hold water treatment to counter Turbidity, chemical residues and pathogens (Recommended – immediate impact, less time, less complicated and affordable)	X	X	No extra (but the staff cost)	X
Demand	3.3	R2	Consumer awareness on "water safety" thus creating social demand for "safe" drinking water	X	X	No extra cost	X
	3.2	R3	Dedicated promotion only focusing "organic farming" among catchment inhabitants and rubber plantation owners	X	X	No extra cost	X
Supply	2.2	R4	Hands on orientation and repeated refreshers on "water safety" to non-water sector stakeholders in the WSP team	X	X	No extra	X
	2.1	R5	Scheduling consistent periodic tests of raw water and treated water for agrochemical and fertilizer residues by liaising with other laboratories with capacity	No extra cost	No extra cost	No extra cost	No extra cost
Enabling Environment	1.4	R6	Establishing multi stakeholder mechanism on water safety going beyond coordination and collaboration thus defining clear accountabilities, commitments as well as resource allocation by concerned stakeholders other than the water supplier	X	X	No extra cost	X
	1.3	R7	**Option 1** – Raising and allocating funds for current WSP improvement plan on catchment management and treatment plant improvement	No extra cost	No extra cost	X	No extra cost
			Option 2 – Re budgeting and costing the proposed interventions in this matrix from bottleneck point of view (Recommended)	No extra cost	No extra cost	No extra cost	No extra cost

Note:- Trace Indicator 3.1 is associated with poverty reduction thus it is not logical to recommend interventions under the WSP. Yet its impacts on WSP is a concern.

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter wraps up the whole research output under the following sub categories

- **Conclusions**
  - Specific to Eheliyagoda Water Safety Plan
  - Common to WHO Water Safety Plan Manual for drinking water suppliers
- **Recommendations**
  - Specific to Eheliyagoda Water Safety Plan
  - Common to WHO Water Safety Plan Manual for drinking water suppliers

Furthermore *Table 5.1* maps the conclusions and recommendations derived in this chapter against Research Objectives.

Table 5.1 – Conclusions and recommendations against research objectives

Aim: Deriving an evidence based rationale for decision makers to further prioritize rated risks and optimize resource allocation during implementation of Water Safety Plans in the back drop of scattered multiple stakeholders across multiple domains with no mutual accountability and line of hierarchy			
Specific Objectives of the Research		**Relevant Conclusions**	**Relevant Recommen -dations**
1	To critically analyse a sample Water Safety Plan (WSP) of the NWS&DB with respect to the WHO fundamentals and the ground realities of Sri Lanka – (Eheliyagoda WSP)	From 5.1.1 to 5.1.9	5.3.1 5.3.4
2	To generate a rationale to prioritize resource allocation with the context based evidence other than standard risk priority criteria especially in the backdrop of limited resources and varying stakeholder demand & understanding	From Chapter 4 4.6, 4.7 4.8, 4.9	5.3.2 5.3.3
3	To interpret the developed rationale as an advocacy tool for the decision makers at policy, planning and operational levels	From Chapter 4 4.10	5.4.4
4	To interpret the developed rationale as a possible enhancement to WHO guidelines on WSPs	5.2.1, 5.2.2 5.2.3, 5.2.4	5.4.1, 5.4.2 5.4.3, 5.4.4

5.1 CONCLUSIONS – Specific to Eheliyagoda WSP

1. Catchment and treatment are most vulnerable to hazardous events respectively.

2. Most critical hazard types are chemical and microbial respectively.

3. Existing partial treatment system has been able to fully mitigate the extreme risk due to microbial contamination of raw water.

4. Non availability of tested evidences on fertilizer residues and agro chemicals critically compromises the validity of WSP risk ratings and proposed improvements.

5. The most critical water quality issue is the daily Turbidity fluctuation of treated water with elevated values much beyond the permissible levels.

6. Monthly tested Turbidity values do not reflect the critical fluctuation of daily Turbidity and associated limitations of the treatment process.

7. Apparent cause of critical Turbidity fluctuation in treated water is the catchment soil erosion during rain that suppresses the filter capacity.

8. Frequent high turbidity of treated water is a critical indicator of the risk of glyphosate and fertilizer residuals adsorbed to soil particles reaching consumers undetected due to limitations in testing.

9. Not incorporating "consumers" is a major and critical gap in Eheliyagoda WSP and it compromises the basic WSP principle of managing risks from catchment to consumer.

5.2 CONCLUSIONS – Specific to WHO WSP Manual

1. Semi quantitative risk matrix is good as a trigger yet is not strong enough to convince decision makers and stakeholders particularly on allocating resources when there is no mandated commitment on water safety.

2. Resources for WSP implementation are not limited to financial resources. Human, knowledge and time resources play a crucial and equal role. Achieving WSP improvements can be a combination of several such resources.

3. Current WSP guidelines are centred on water supplier as the convener and coordinator. There is less clarity on making other stakeholders accountable. This poses a risk on sustainability of the WSP.

4. When bottlenecks on resource allocation and accountability are not counted in WSP, it could lead to a "false impression of safety".

5.3 RECOMENDATONS – Specific to Eheliyagoda WSP

1. Consumer element must be incorporated in the WSP ensuring "end user water safety at the point of use". Thus in case risk management in other three elements is delayed, the improvement plan should immediately be revised with consumer awareness on associated risks and alterative household treatment options such as ceramic filters (for Turbidity) and charcoal filters (for agro chemicals).

2. Before allocating resources there needs to be further comparison between the proposals on Catchment management and Treatment plant improvement. It should be based on quantified evidence on soil erosion, agro chemical pollution, plant operational cost, polluters' willingness to commit and consumer health burden.

3. Universal Soil Loss Equation (USLE) can be comfortably used to model the extent of soil erosion in the catchment. It can be further improved to incorporate agro chemical adsorption to soil particles being eroded. Such model would be a much tangible and influential evidence to persuade stakeholders and decision makers beyond semi quantitative risk matrix.

4. Water quality testing capacity needs to be urgently improved to test fertilizer residues in both raw and treated water. Furthermore a mechanism needs to be in place to test agro chemical residues for the same. Such evidence would be essential on convincing major changes such as organic farming.

5.4 RECOMENDATONS – Specific to WHO WSP Manual

1. Risk sequence that ranks chemical aspects as the 2nd priority does not capture "exposure time" in the long run (even at permissible levels). Thus there needs to be a criteria to interpret cumulative or accumulated health risk over a time scale exposed to chemical pollutants.

2. In most contexts, the catchments are highly populated and with complicated human and pollution interactions that are far beyond the water suppliers' purview and capacity to deal with. Hence it is recommended that the catchment element to be separated from the water supply system and develop a comprehensive environmental pollution control Module for both catchments and river basins under the mandate of a suitable authority other than water suppliers. This would resolve some of the current grey areas related to mutual accountability as well as will open the door for detailed and customized planning for unique and exceptional dynamics.

3. It is recommended to add a Module on “demand creation and communication on safe water” consisting tools and guidance on the following;
    a. Creating social demand for safe water among consumers
    b. Creating social commitment for water safety among those who don’t benefit from a given water system (eg. dwellers in the catchment).
    c. Dissemination of key messages to difference audiences (eg. graphical presentations for decision makers, Illustrations for consumers)

4. “Improvement and upgrade plan” currently based on the “risk re-assessment” alone is recommended to have the following upgrades;
    a. Tools for quantification of risks associated with hazard types (eg. modelling or estimations)
    b. Separate Module on resource allocation based on analysis of bottlenecks (eg. Tanahashi model) across the WSP
    c. Guidance for mapping resource allocation and accountability

5.5 SWOT Analysis of the research

This research was a descriptive and interpretative case study on the Water Safety Plan of a given Water Supply System implemented at sub national level while engaging at national / policy level that facilitates the enabling environment to sustain such initiative. This nature of the research makes it ideal for a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis.

The Strengths, Weaknesses (Limitations), Opportunities and Threats associated with this research are presented in the SWOT analysis in *Figure 5.1*.

STRENGTHS	WEAKNESSES
- Aim and objectives were derived from actual work related scenarios - Both policy and implementation levels were associated - Both quantitative and qualitative information was incorporated - Diverse stakeholders and domains were associated - Eheliyagoda WSP has a range of components, dynamics and complexities in a manageable scale so that its findings can be up scaled to a larger scale	- WSP implementation was still at its early stages thus data was not sufficient for advanced analysis - Institutional memory and records of the WSP was scattered and less consistent - Other than the interviews and observations, the study was largely based on the routine operational data of the water supplier - The research findings are more of conceptual nature so it may not be immediately available for improving the current WSP approach of the NWS&DB
OPPORTUNITIES	**THREATS**
- This is the first conventional WSP of the NWS&DB that stepped into implementation phase. The findings can add value to future WSPs as well as help mitigate the unforeseen constraints - WHO is involved in capacity building of the NWS&DB hence research findings can be shared with them on real time basis - Knowledge, tools and perceptions outside NWS&DB were used in the research from which NWS&DB can be benefitted - NWS&DB has plans to expand WSPs to community based rural water schemes. The scope and magnitude of Eheliyagoda WSP would well match with this objective	- The broader scope of the research was somewhat vulnerable to lose its focus - The presentation of research findings cuts across several subject areas hence at once it may not be clear where it would be most useful and applicable

Figure 5.1 – SWOT Analysis on the research

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APPENDICES

Appendix 1 - Eheliyagoda WSP Module 4 on Risk Re-Assessment

Process Step	Hazardous event	Hazard Type	Likely Hood	severity	Score	Raw Risk Rating	Existing Control Measures	Likely hood with control	Severity with control	Score	Residual Risk Rating	Validation/ Basis
Source 1– Stream (Catchment)	Microbiological contamination of raw water due to leachate accumulation from toilet pits	Microbio logical	5	5	25	Extreme	No Control	5	5	25	Extreme	*E.coli* in Raw water at three locations
	Microbiological and chemical contamination of raw water due to washing and bathing at river	Microbio logical	5	2	10	High	No Control	5	2	10	High	*E.coli* in Raw water downstream to bathing place
	Microbiological and chemical contamination of raw water due to solid waste discharges to the river from houses	Microbio logical/ Chemical	5	2	10	High	No Control	2	5	10	High	pH, BOD & COD in Raw Water both up and down stream
	Microbiological and chemical contamination of raw water due to leachate from solid waste dumping at nursery site	Microbio logical / Chemical	5	2	10	High	No Control	5	2	10	High	*Ecoli*,pH, BOD & COD in Raw Water both up and down stream to dumping site
	Microbiological and chemical contamination of raw water due to direct discharges of waste water from latex processing factory	Microbio logical./ Chemical	5	5	25	Extreme	Waste Water Treatment Plant	1	5	5	Low	Visual observation
	Microbiological and chemical contamination of raw water due leaking	Microbio logical/ Chemical	5	4	20	Extreme	Inspection by w/w	2	4	8	Moderate	*Ecoli*,pH, BOD & COD in Raw Water

	and overflowing of latex factory waste water treatment plant						plant operator					downstream to discharge point
	Microbiological and chemical contamination of raw water due to accumulation of effluent from line blocking and chamber overflowing of treated effluent transmission line from latex processing factory waste water treatment plant	Microbio logical./ Chemical and Physical	5	5	25	Extreme	Corrective maintenan ce	3	5	15	Very High	Visual Inspection
	Chemical contamination of Raw water due to accumulation of latex from latex collection center in catchment	Chemical	5	4	20	Extreme	No Control	5	4	20	Extreme	Visual observation and testing BOD, COD, pH of pollutant at accumulation point
	Chemical contamination of Raw water due to accumulation of Agro chemical residues from Eheliyagoda Estate	Chemical	5	4	20	Extreme	No Control	5	4	20	Extreme	Pesticide residue analysis of raw water for tolerance limits
	Chemical contamination of Raw water due to accumulation of Agro chemical residues from Home gardens, Tea plantations and Paddy fields	Chemical	5	3	15	Very High	No Control	5	3	15	Very High	Pesticide residue analysis of raw water for tolerance limits
	Chemical contamination of Raw water due to accumulation of fertilizer residues from Eheliyagoda Estate	Chemical	5	4	20	Extreme	No Control	5	4	20	Extreme	Fertilizer residues analysis of raw water for tolerance limits
	Chemical contamination of Raw water due to accumulation of fertilizer residues from Home gardens, Tea plantation and paddy fields	Chemical	5	3	15	Very High	No Control	5	3	15	Very High	fertilizer residues analysis of raw water for tolerance limits
	High turbidity in river water after rain event due to soil erosion	Phy. / Chem.	5	5	25	Extreme	No Control	5	4	20	Extreme	Turbidity measurement of raw water at intake
	Microbiological and chemical contamination of raw water due to accumulation of effluent from damaging of open space waste water	Phy. / Chem.	2	5	10	High	No Control	2	5	10	High	Visual observation

	effluent transferring line from latex processing factory waste water treatment plant										
	Less water in dry seasons	Bac./ Chemical	2	5	10	High	No Control	2	5	10	High	River flow measurement
	Waster accumulation to the war water from recreational activities at just upstream to the intake	Microbio logical ./ Chemical	4	5	20	Very High	Fencing and police patrols	3	3	9	Medium	Visual inspection
	Microbiological and chemical contamination of raw water due to un locking of intake chamber cover	Microbio logical / Chemical	2	5	10	High	No Control	2	5	10	High	Visual inspection
	Microbiological and chemical contamination of raw water due to vehicles movements in catchment road close to the river	Microbio logical/ Chemical	5	2	10	High	No Control	2	5	10	High	Visual inspection
Source 2 Well	Bad odor and taste in well water due to high iron content	Phy. / Chem.	5	5	25	Extreme	Aeration to iron reduction	3	2	6	Moderate	Visual observation and chemical analysis for Iron
	Accumulation of Agro chemical residues to the well water from paddy field	Chem.	5	3	15	Very high	No Control	5	3	15	Very high	Pesticide residue analysis of raw water for tolerance limits
	Accumulation of fertilizes residues to the well water from paddy field	Chem.	5	3	15	Very high	No Control	5	3	15	Very high	fertilizer residues analysis of raw water for tolerance limits
Water Treatment Plant for Stream Water	Contamination of treated water through poor seal of man hole cover	Microbio logical	5	5	25	Extreme	Locking facility	1	5	5	low	Visual observation
	High turbidity in filtered water due to inefficient filtration	Bac./ Che./ physical	5	5	25	Extreme	No Control	5	5	25	Extreme	Visual observation and turbidity measurement

	Microbiological Contamination of filtered water due to back washing the filters with raw water	Microbio logical	5	5	25	Extreme	No Control	5	5	25	Extreme	Microbiological analysis of filtered water
	Microbiological Contamination of treated water due to no post chlorination in power failures	Microbio logical	4	4	16	Very high	No Control	4	4	16	Very high	Microbiological analysis of treated water
	High turbidity entering to the filter due to no sedimentation facility	Microbio logical/ physical/ Chemical	3	5	15	Very high	No Control	3	5	15	Very high	Turbidity measurement
	Chemical contamination of treated water due to accumulation of factory waste water at the leakage of waste water line	Chemical	3	5	15	Very high	No Control	3	5	15	Very high	Visual observation and testing BOD,COD downstream to the point
Water Treatment Plant for Well Water	High turbidity in treated water due to no filtration	Microbio logical / Chemical	5	5	25	Extreme	No Control	5	5	25	Extreme	Test turbidity in plant outlet
	High color in treated water due to high Iron concentration	Microbio logical / Chemical	5	3	15	Very high	No Control	5	3	15	Very high	Test turbidity ,iron and color in plant outlet
	Microbiological contamination in treated water due to in efficient bleaching powder chlorination	Microbio logical	5	4	20	Very High	No Control	5	4	20	Very High	Microbiological analysis of final water
	Microbiological contamination in treated water due to due to week covering system of man holes in treated water tank	Microbio logical	5	4	20	Very High	No Control	5	4	20	Very High	Microbiological analysis of final water

Distribution system	Microbiological contamination in distribution system due to pipe line burst	Microbio logical	4	5	20	Very High	No Control	4	5	20	Very High	Turbidity and microbiological testing in distribution system
	Microbiological contamination in distribution system due to lack of system drainage facility	Microbio logical	4	5	20	Very High	No Control	4	5	20	Very High	Turbidity and microbiological testing in distribution system
	High level of turbidity in distribution water due to accumulation of suspended solids	Microbio logical / Chemical	5	3	15	Very high	No Control	5	3	15	Very high	Turbidity and microbiological testing in distribution system
	Microbiological and chemical contamination in distribution water due to back flow of customers individual systems	Microbio logical / Chemical	2	3	6	Moderate	No Control	2	3	6	Moderate	Turbidity and microbiological testing in distribution system
	Microbiological and chemical contamination in distribution water due to intrusions of outside water through leakages in negative pressure zones	Microbio logical / Chemical	4	4	16	Very high	No Control	4	4	16	Very high	Turbidity and microbiological testing in distribution system

Appendix 2 - Composition of Eheliyagoda Water Safety Plan team

Members of Water Supplier – National Water Supply and Drainage Board			
No	**Designation**	**Role in WSP**	**Individual Responsibilities with in WSP Team**
1	Assistant General Manager (Ratnapura)	Team Coordinator	1. Co-ordination works with outsiders and within the team members regarding WSP activities 2. Funding activities
2	Projector Director (GRWSP)	Team Member	1. Designing of WTP Improvement 2. Monitoring Implementation works of WTP Improvement
3	Manager (Ratnapura)	Team Leader	1. Hazard Identification 2. Implementation of corrective action 3. Implementation of Improvement Plan
4	Chief Engineer (P&D)	Team Member	1. Designing guidance to WTP improvement plan
5	Chief Engineer (P&C)	Team Member	1. Hazard Identification 2. Engineering guidance for WSP 3. Preparation of improvement plan
6	Chief Engineer (M&E)	Team Member	1. Hazard Identification 2. Preparation of SOP
7	Senior Chemist (Kegalle)	Team Member	1. Preparation of water Safety plan 2. Water and environmental quality management and overall monitoring 3. Hazard identification 4. Risk analysis and prioritization of risk 5. Preparation of improvement plan 6. Monitoring and Implementation guidance for WSP
8	District Engineer (Ratnapura)	Team Member	1. Hazard Identification 2. Monitoring implementation of WSP
9	Regional Chemist (Ratnapura)	Team Member	1. Hazard Identification 2. Water quality monitoring 3. Water sampling and analysis 4. Water Quality Surveillance
10	Sociologist (Sabaragamuwa)	Team Member	1. Social activities 2. Meeting arrangements and preparation of meeting minutes
11	OIC (Eheliyagoda WSS)	Team Member	1. Supervision of Scheme operations 2. Implementation of WSP 3. Coordination of all WSP activities
12	Plant Operator (Eheliyagoda WSS)	Team Member	1. Treatment Plant Operation 2. Onsite WQ Analysis 3. Record Keeping and maintaining

Members form other Stakeholder Domains			
No	**Designation**	**Role of WSP**	**Individual Responsibilities in WSP Team**
1	Nayake Thero (Chief Priest) , EheliyagodaWatta Temple	Team Member	1. Hazard Identification of catchment 2. coordination of improvement plan implementation of catchment management 3. Monitoring implementation of improvement plan to the catchment
2	District Secretary - Ratnapura	Team Leader for Stakeholders	1. Coordination and cooperation among other organization 2. Guidance among stakeholders for Implementation of improvement plan
3	Divisional Secretory - Eheliyagoda	Team Member	1. Coordination and cooperation among other organization 2. Guidance among stakeholders for Implementation of improvement plan
4	Head of Water, Sanitation Y Hygiene Division, UNICEF Sri Lanka	Team Member	1. Monitoring of Implementation Works
5	Medical Office of Health (Eheliyagoda)	Team Member	1. Monitoring of health issues 2. Implementation of preventive measures to health issues
6	Head Quarters Inspector of Police - Eheliyagoda	Team Member	1. Control illegal interventions and violation of WSP activity from the people
7	Environmental Officer – DS Office, Eheliyagoda	Team Member	2. Implementation of improvement plan
8	Assistant Land Use Planning Officer - Eheliyagoda	Team Member	1. Mapping and Demarcating of Reservations 2. Implementation of Land use measures to the reservation
9	Grama Niladharini (Village Officer) (EhiliyagodaWatta)	Team Member	1. Monitoring and evaluation of pollution & env. Degradation in catchment. 2. Implement corrective measures
10	Economic Development Officer, EheliyagodaWatta	Team Member	1. Monitoring and evaluation of pollution & env. Degradation in catchment. 2. Implement corrective measures
11	Agriculture Research and Production Assistant – EeliyagodaWatta	Team Member	1. Monitoring and evaluation of pollution & env. Degradation in catchment. 2. Implement corrective measures

12	Assistant Superintended (Eheliyagoda Plantations)	Team Member	1. Coordination and cooperation with the Eheliyagoda estate. 2. Implementation corrective measures
13	Public Health Inspector - Eheliyagoda	Team Member	1. Monitoring of health issues 2. Promotion of hygiene
14	Member from Village Community	Team Member	1. Actively participation for implementation 2. Monitoring violation of CMP activities
15	Member from Village Community	Team Member	1. Actively participation for implementation 2. Monitoring violation of CMP activities
16	Member from Village Community	Team Member	1. Actively participation for implementation 2. Monitoring violation of CMP activities
17	Member from Village Community	Team Member	1. Actively participation for implementation 2. Monitoring violation of CMP activities
18	Member from Village Community	Team Member	1. Actively participation for implementation 2. Monitoring violation of CMP activities

Appendix 3 – Drinking Water Quality Standards of NWS&DB

(Derived from Sri Lanka Standards for Potable Water - SLS 614:2013)

Microbiological Substances		
No.	**Parameter**	**Maximum Limit** (colonies /100 ml)
1	E.coli	0
2	Total coliforms	0

Toxic Substances		
No.	**Parameter**	**Maximum Limit** (mg /l)
1	Arsenic	0.01
2	Cadmium	0.003
3	Chromium	0.05
4	Cyanide	0.05
5	Lead	0.01
6	Zinc	3
7	Manganese	0.1
8	Copper	1

Chemical Substances		
No.	**Parameter**	**Maximum Limit** (mg /l)
1	Aluminium as (Al)	0.2
2	Chloride (as Cl)	250
3	Total Alkalinity (as $CaCO_3$)	200
4	Ammonia: Free Ammonia (as NH_3)	0.06
	Ammonia: Albuminoid Ammonia	0.15
5	Chemical Oxygen Demand (COD)	10
6	Nitrate (as N)	50
7	Nitrite (as N)	3
8	Fluoride (as F)	1
9	Total Phosphates (as PO_4)	2
10	Total Dissolved Solids	500
11	Total Hardness (as $CaCO_3$)	250
12	Calcium Hardness (as Ca)	100
13	Magnesium Hardness (as Mg)	150
14	Total Iron (as Fe)	0.3
15	Sulphate (as SO_4)	250
16	Free Residual Chloride	1
17	Oil and Grease	0.2

Physical Substances		
No.	**Parameter**	**Maximum Limit**
1	Colour	15 (Hazen unit)
2	Odour	Un objectionable
3	Taste	Un objectionable
4	Turbidity	2 (N.T.U.)
5	pH at 25°C ± 2°C	6.5 – 8.5