The Institution of Engineers, Malaysia

IEM Position Paper on
Elevating The Safe Ultilisation of Harvested Rainwater for Potable and Non-Potable Uses at Household Level

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Remarks by Chairman of IEM Position Paper on Elevating the Safe Utilisation of Harvested Rainwater for Potable and Non-Potable Uses at Household Level

Water is considered a vital resource for global sustainability and economic growth. Nevertheless, global climate change, rapid urbanization, and environmental degradation are causing clean water resources to deplete at the fastest rate in the twenty-first century. Rainwater Harvesting Systems (SPAH) are a promising alternative source of water.

In Malaysia, the application of SPAH has gained traction due to its potential in mitigating water scarcity issues and reducing reliance on traditional water sources. Numerous guidelines have been established, focusing primarily on the design and requirements for non-potable uses, such as irrigation, toilet flushing, and industrial processes. However, these guidelines often overlook crucial aspects of water quality and safety. While the design and installation of SPAH are well-covered, the monitoring and maintenance practices necessary to ensure that the harvested rainwater remains safe for its intended use are frequently underemphasized. Issues such as contamination from roofing materials, improper storage, and inadequate filtration can compromise the safety of the harvested rainwater, posing health risks to users.

The Water Resources Technical Division (WRTD) Committee agreed to appoint me as Chair of the Position Paper Committee during its 111th WRTD Monthly Meeting held on 13th February 2024. This position paper was drafted by IEM WRTD in collaboration with Universiti Sains Malaysia (USM) and Universiti Kebangsaan Malaysia (UKM). The paper was completed with contributions from invited experts from government agencies and industry representatives.

With the above effort and hard work in producing this paper, I would like to express my utmost appreciation to all members of the Position Paper Committee involved. I would like to thank the Engineering X - Engineering Skills Where They are Most Needed programme for funding the project "Elevating the Safety of Rainwater Harvesting Systems for Non-Potable Uses Through Interdisciplinary Training" (Ref. no. ESMN 2123\2\140). My sincere gratitude is also extended to the PPCC for their invaluable opinions and suggestions in improving and enhancing the paper. My deepest thanks also go to the IEM Secretariats for their patience and dedication in supporting this work.

By.
Chairman of IEM Position Paper on Elevating the Safe Utilisation of Harvested Rainwater for Potable and Non-Potable Uses at Household Level
Ir. Dr. Chang Chun Kiat
Date: 3 October 2024

ELEVATING THE SAFE UTILISATION OF HARVESTED RAINWATER FOR POTABLE AND NON-POTABLE USES AT HOUSEHOLD LEVEL

EXECUTIVE SUMMARY

The sustainable management of water resources has become a pressing issue amidst escalating urbanisation, population growth, climate change, and the depletion of freshwater reserves. Rainwater harvesting, a method of collecting and storing rainwater in surface or sub-surface storage tanks before it becomes surface runoff, has gained substantial attention as a promising strategy to address water scarcity and enhance water security. Rainwater harvesting system (SPAH) offers environmental, economic, social, and operational benefits. In Malaysia, it is particularly practical and can significantly reduce reliance on treated water. However, many nations, including Malaysia, face increasing water shortages due to rapid development, population expansion, and prolonged drought exacerbated by climate change. Additionally, severe pollution of water sources from industrial discharge, agricultural runoff, and untreated waste significantly degrades water quality, complicating the water treatment process and straining water supply systems, which in turn reduces the availability of potable water. Particularly for rural populations struggling to access clean water for domestic and non-domestic usage, the adoption of SPAH is crucial for improving water availability and quality. This position paper proposes a comprehensive framework to elevate the safe utilisation of harvested rainwater for both potable and non-potable household applications, in alignment with Sustainable Development Goal 6 (SDG 6) for clean water and sanitation. The framework includes rigorous water quality standards, systematic risk assessment and management, advanced treatment technologies, and effective monitoring and control measures. The rainwater harvesting and use system matrix categorises uses from basic irrigation to advanced potable uses, while emphasising the importance of public awareness and education on safe practices. It is crucial that control measures consider both the implementation and ongoing maintenance of the system to ensure long-term efficacy and safety. By addressing existing gaps and leveraging Malaysia's climate, the frameworks aim to ensure sustainable and safe water resources, thereby enhancing water security and supporting environmental sustainability. Emphasising safe collection, treatment, and application strategies will enable households to improve water sustainability and resilience. Continuous education, technical support, and community engagement are essential to overcoming challenges and maximising the potential of rainwater harvesting in addressing water crises in regions like Malaysia. By integrating the WHO 2024 Guidelines for Drinking-Water Quality: Small Water Supplies, the position paper reinforces its commitment to addressing water scarcity and pollution challenges in Malaysia, leveraging the practical benefits of rainwater harvesting. Together, these efforts leverage the benefits of rainwater harvesting to meet both potable and non-potable water needs safely and sustainably.

INTRODUCTION

The sustainable management of water resources has emerged as a critical concern in the face of growing urbanisation, population expansion, and the depletion of freshwater reserves. Within this context, rainwater harvesting has garnered substantial attention as viable strategies to address water scarcity and enhance water security.

Rainwater harvesting is a technique of collection and storage of rainwater in surface, surface storage tanks or sub-surface storage tanks before it becomes surface runoff and with primary use for residential and commercial applications. The rainwater harvesting system (SPAH) is a supplementary source of water supply for household, commercial, landscape, livestock, and agriculture. SPAH mean a rainwater harvesting and ultilisation system where rainwater is collected from a roof, conveyed to a rainwater tank and stored for use (Uniform Building by-Laws (UBBL)1984 (Amendment) 2011).

The SPAH adoption contributes to value creation in terms of:

- Environmental – reduce environmental impact, promote sustainable landscaping, reduce strain on stormwater drainage (water quality), reduce residuals from Water Treatment Plant (WTP) (decreased demand for treated water)
- Economic and operational – improve supply resilience, provide additional water resources, and reduce consumption of potable water across domestic and non-domestic sectors. Achieve cost-effectiveness through reduced expenditure on water bills for non-domestic usage.
- Social – construct a circular economy, improve sustainability, and reduce demand for treated water.
- Standby supply - Improves security of supply in times of emergency
- Helps mediate soil erosion and flooding caused by excessive runoff.

BACKGROUND

Rainwater Harvesting in Malaysia

The Malaysian government has implemented various proactive measures, including public awareness campaigns and the promotion of Rainwater Harvesting Systems (SPAH). First introduced in 1999 after a severe drought in 1998, the Ministry of Housing and Local Government (KPKT) was tasked with developing mechanisms to incorporate SPAH into buildings across Malaysia. The "Guidelines for Installing a Rainwater Collection and Utilization System" introduced in 1999 aimed to reduce dependence on treated water and provide convenience during water shortage emergencies.

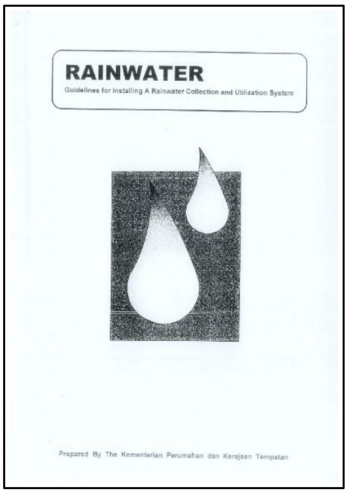

Figure 1: Guidelines for Installing a Rainwater Collection and Utilization System (KPKT, 1999)

In 2005, The Federal Constitution transferred all matters related to water supply service from State List to Concurrent List, enabling the Federal Government to get involved in the water service sector. Subsequently, the Ministry of Energy, Water and Communication (KTAK), introduced two new water related laws, namely Water Services Industry Act 2006 and Water Services Commission Act 2006. Under these acts, KTAK actively promoted water-saving programs and SPAH implementation. On March 27, 2006, the Prime Minister announced that SPAH would be made mandatory in large buildings, such as bungalows, factories, and schools (Mohd.-Shawahid et al., 2007), and in 2007, SPAH provision were included in the Uniform Building By Law (UBBL) 1984 during the National Water Council.

The Department of Irrigation and Drainage (DID) Malaysia and The Ministry of Energy, Green Technology and Water (KeTTHA) are key government agencies leading the initial implementation of SPAH. This initiative aligns with the National Water Resources Council's efforts to promote SPAH among government buildings. In 2009, DID published the "Guideline on Rainwater Harvesting: Guidebook on Planning and Design," supporting the goal of achieving three percent of the national water supply through stormwater utilisation and uses techniques for all major towns by 2020 (DID, 2009). In addition to these efforts, the Urban Stormwater Management Manual for Malaysia (MSMA) includes a comprehensive chapter on rainwater harvesting, addressing its role in managing stormwater runoff. This chapter's guidance on the planning, design, implementation, and maintenance of rainwater harvesting systems within urban environments, was then formalised in MS-2526: Part 6 in 2014 by the Department of Standards Malaysia.

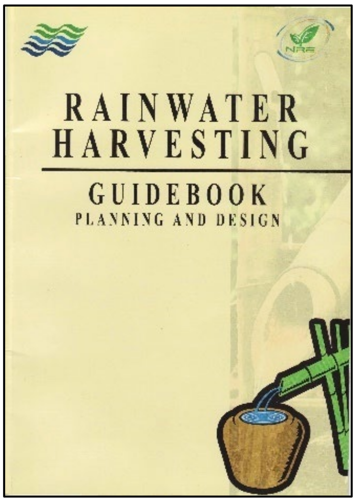

Figure 2: Guideline on Rainwater Harvesting: Guidebook on Planning and Design (DID, 2009)

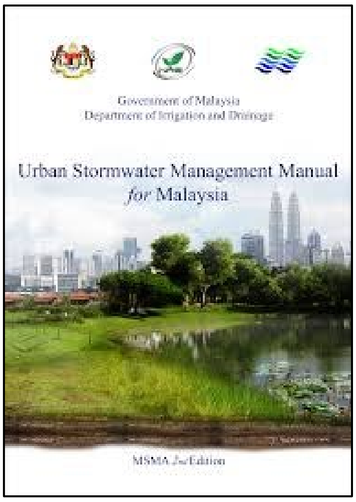

Figure 3: Urban Stormwater Management Manual for Malaysia (DID, 2011)

Figure 4: Malaysian Standard on Urban Stormwater Management (MS-2526): Part 6 (DSM, 2014)

In 2009, the National Water Research Institute of Malaysia (NAHRIM) introduced the "Guideline on Eco-Efficiency in Water Infrastructure for Public Buildings in Malaysia," promoting environmentally sustainable practices in the design and construction of water infrastructure for public buildings (NAHRIM, 2009). These guidelines emphasise water conservation and stormwater management. Developing eco-efficiency infrastructure is an appropriate step towards the sustainability of freshwater resources, energy conservation and habitat conservation. Consequently, the practice of SPAH is encouraged to reduce stormwater runoff discharge, facilitate its uses for non-potable purposes, and decrease the consumption of potable water.

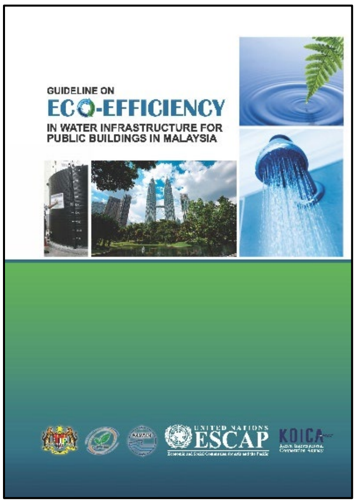

Figure 5: Guideline on Eco-Efficiency in Water Infrastructure for Public Buildings in Malaysia (NAHRIM 2009)

In 2012, with the government's commitment to green growth development and the introduction of the Green Building Index (GBI) and the "Green Neighbourhood Planning Guidelines", PLANMalaysia published the "Guidelines for Implementing Green Neighborhood Development Initiatives -

Rainwater Harvesting System" in 2013 to assist local authorities in implementing SPAH in support of the National Green Technology Policy 2009. The adoption of harvested rainwater is then recognised as a green initiative to promote water efficiency and sustainable development.

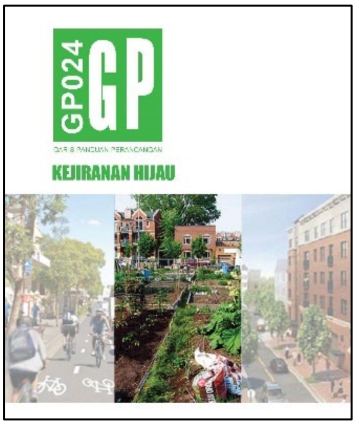

Figure 6: Green Neighbourhood Planning Guidelines
(PLANMalaysia, 2012)

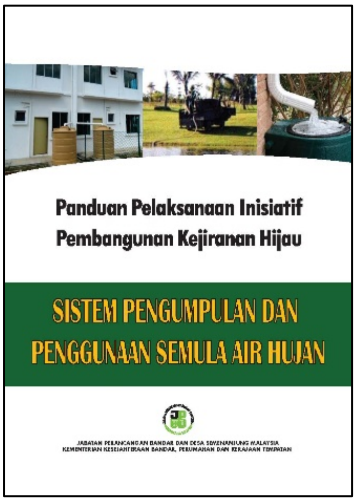

Figure 7: Guidelines for Implementing Green Neighborhood Development Initiatives - Rainwater Harvesting System
(PLANMalaysia, 2013)

Additionally, in 2013, the KPKT published the "Guidelines for Implementing Rainwater Harvesting Systems" (KPKT, 2013), enhancing the 1999 guidelines to encourage the use of harvested rainwater as an alternative to decrease treated water consumption.

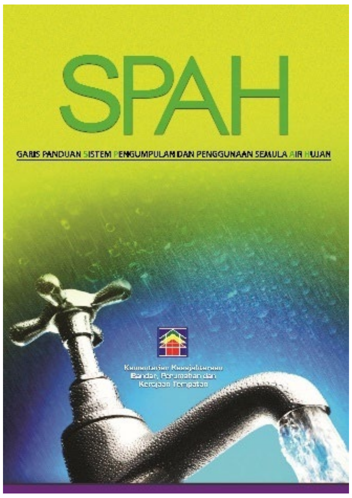

Figure 8: Guidelines for Installing a Rainwater Collection and Utilization System (KPKT, 2013)

These revised guidelines (KPKT, 2013) stipulate that installation of SPAH must be carried out by licensed plumbers, who registered with the National Water Services Commission (SPAN). The materials used in SPAH must comply with and be approved by the Standards and Industrial Research Institute of Malaysia (SIRIM) and SPAN. however, the Research, Development, and Innovation Division of SPAN does not endorse any specific materials or equipment for

SPAH, as untreated rainwater falls outside SPAN's jurisdiction (Lee et al., 2016). For the integrated system of SPAH and public water supply, SPAN has regulated the SPAH installation and connection in any building category. The Water Services Industry Act 2006 [Act 655], Section 180 (k) and (l) stipulates that SPAN may make such rules for all matters relating to the safety and security of water supply systems as follows:

- Backflow preventers or similar equipment shall be installed at the RWH system to prevent untreated rainwater from flowing reversely or being back-siphoned to the public water supply system.
- The distribution pipes for supplying non-potable water shall be painted green along its entire barrel. In addition, taps and outlets for non-potable water shall be clearly identified as "Not for Drinking Purposes" (SPAN, 2018).

This measure to separate and ensure no cross-connection between non-potable and potable water distribution systems within buildings aims to prevent potential contamination of the public water supply plumbing system by untreated rainwater, which could eventually be consumed by households/end users (Lee, 2014).

In 2014, NAHRIM published "NAHRIM Technical Guide No. 2 - the design guide for rainwater harvesting systems," which provides design examples for SPAH distribution system, including gravity-fed system, indirect pumping system and direct pumping system (NAHRIM, 2014). NAHRIM has also pioneered the development of SPAH software in Malaysia. Tangki NAHRIM 1.0, a desktop application developed in 2008, calculates the optimal tank size for rainwater harvesting in Malaysia. Tangki NAHRIM 2.0, an R-based water balance model for rainwater harvesting tank sizing application, evaluates proposed tank sizes based on water saving and storage efficiencies (Goh and Ideris, 2021). A significant milestone for NAHRIM is the development of rainwater drinking water product called "Cloudrain" and "Raindrops," harvested from NAHRIM's compound and the pristine surroundings of Kuala Tahan National Park. These products meet stringent water quality standards and received Ministry of Health (MOH) approval in 2018, showcasing NAHRIM's commitment to safe rainwater consumption and environmental protection.

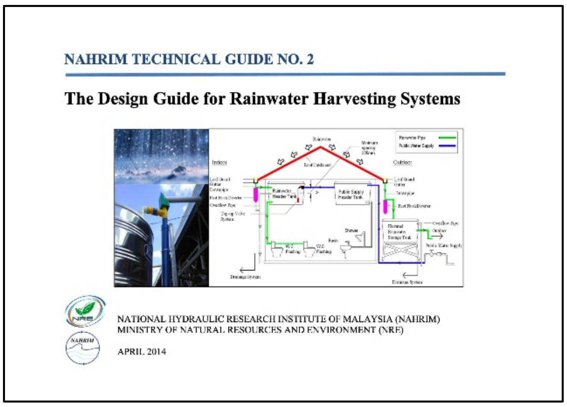

Figure 9: NAHRIM Technical Guide No. 2 - the Design Guide for Rainwater Harvesting Systems

In 2014, the Kuala Lumpur City Hall (DBKL) established requirements for processing SPAH plans for approval, as outlined in the Stormwater Management System Guidelines. In 2022, DBKL issued the "Guidelines on Responsibilities for the Maintenance of the Stormwater Management System" to emphasise efficient SPAH system maintenance.

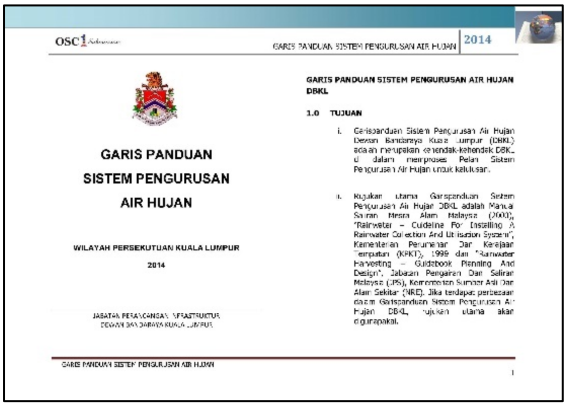

Figure 10: Stormwater Management System Guidelines (DBKL, 2014)

Figure 11: Guidelines on Responsibilities for the Maintenance of the Stormwater Management System (DBKL, 2022)

The Public Works Department Malaysia (JKR) published the "Standard Specifications for Building Works 2020," which includes updates aligning with advancements in construction technologies (JKR, 2020). The improvements have been made based on the Standard Specifications for Building Works 2014 (JKR, 2014). The latest JKR guideline 2020 outlines key components of rainwater harvesting systems, detailed work scopes for contractors, specifications for rainwater goods (e.g. flashing, gutters, and rainwater downpipes), as well as testing and commissioning requirements for SPAH.

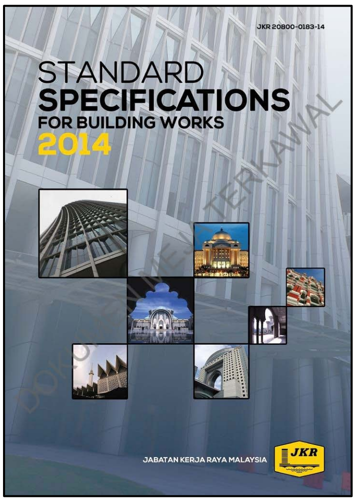

Figure 12: Standard Specifications for Building Works 2014 (JKR, 2014)

Figure 13: Standard Specifications for Building Works 2020 (JKR, 2020)

In summary, while Malaysia has numerous guidelines focusing on SPAH design and requirements for non-potable uses, but often overlooking crucial aspects of water quality and safety. This highlights the need for more comprehensive guidelines that address these critical issues to ensure the effective and safe utilisation of harvested rainwater.

In certain rural or remote areas lacking government water supply, rainwater serves as the primary water source. Since the early 2000s, the World Health Organization (WHO) has advocated for water quality assurance through water safety plans, formally recommending them in the Third Edition of Guidelines for Drinking Quality published in 2004 (WHO, 2004). The Ministry of Health (MOH) Malaysia, aligning with WHO recommendations, has taken the initiative to develop "Water Safety Plan Handbook for Rural Water Supply" to ensure safe water supply for rural communities (MOH, 2011). There are various water supply systems implemented in rural areas across Malaysia, including the Gravity-Feed System (GFS), sanitary wells, sanitary wells with house connections, and rainwater collection systems, aiming to provide an adequate supply of water that meets basic health and hygiene standards at minimal expense. However, rural residents are advised to boil drinking water as a precaution since these systems deliver untreated but generally safe water.

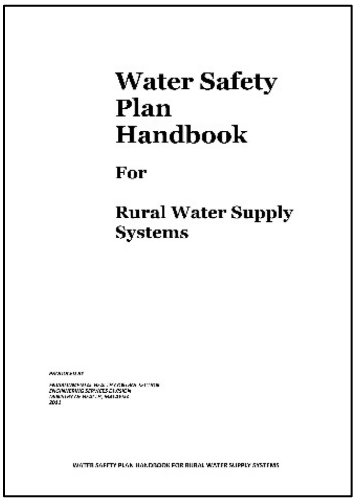

Figure 14: Water Safety Plan Handbook for Rural Water Supply (MOH, 2011)

Figure 15: Water Safety Plan (WSP) Guidelines (SPAN, 2021)

The WHO's "Guidelines for drinking-water quality: small water supplies" (WHO 2024a) offer decision-makers recommendations on health-based regulations, water safety planning, sanitary inspections, and independent surveillance for small water supplies. Supported by WHO's 2024 "Sanitary Inspection Packages" (WHO 2024b), these guidelines emphasise proactive risk management and update the 1997 guidelines with a broader focus on preventive risk management and a wider range of supply types, including households, communities, and professional-managed systems. Examples include rainwater collection and storage, dug wells, tube wells, springs, kiosks, and household practices. Sanitary inspections are crucial for supporting proactive risk management. These guidelines present proven good practices, proactive risk management and support water quality surveillance across various scenarios and are designed for use by health authorities, surveillance agencies, water suppliers, and other stakeholders to ensure ongoing safe water management.

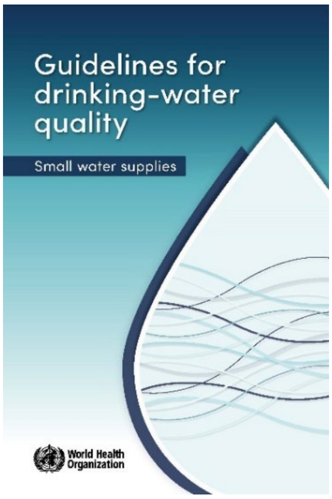

Figure 15: Guidelines for Drinking-Water Quality: Small Water Supplies (WHO, 2024a)

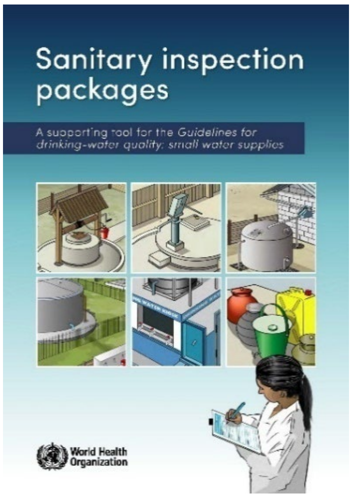

Figure 16: Sanitary Inspection Packages – A Supporting Tool for the Guidelines for Drinking-Water Quality: Small Water Supplies (WHO, 2024b)

The Issues

Streams and rivers with and without impounding reservoirs contribute 98 percent of total water used in Malaysia. Over the past few decades, the country has faced increasingly significant water crises. Urban areas such as Kuala Lumpur, Selangor, and Putrajaya are currently experiencing water shortages despite the country's tropical climate and abundant water resources.

Malaysia has faced challenges due to the El Nino phenomenon, resulting in severe droughts in 1997/1998, February/March 2014, and January 2020, significantly impacting the country, especially the public water supply sector and residents. These droughts have led to water shortages and intermittent disruptions in water supply. Consequently, climate change poses a threat to our water security by altering rainfall frequency and intensity, leading to imbalances between dry and wet periods. For example, Tan et al. (2014) reported that every region in Malaysia is expecting increase in mean precipitation and temperature compared to historical data. This change in the balance between wet and dry periods exacerbates water shortage issues during prolonged dry spells. Additionally, with the recent increasing water shortage and rationing events, the practical application of SPAH has become more apparent.

The scarcity of water resources is becoming increasingly prominent during urbanisation. However, statistics show that the worldwide utilisation rate of rainwater resources is remarkably low, especially in underdeveloped countries (United Nations, 2023). Increasing the utilisation of rainwater, improving on-site storage and utilisation efficiency have become crucial factors in building resilient cities and the implementation of rainwater strategies (Gao et al., 2024).

Malaysia aims to achieve 98 percent clean water coverage by 2025. As of 2022, water supply access coverage stood at 97.1 percent in urban areas and 97 percent in rural areas. Currently, SPAN is collaborating with the Ministry of Health (MoH) to ensure quality and safe water supply in the rural areas, especially in Sabah and Sarawak. Water distribution networks are centrally managed in major towns and cities in these states, while regional water networks are applied in smaller townships. The development of water supply service has been uneven, with some rural populations struggling to access clean water for domestic and non-domestic usage. A decentralised water system or small water supplies, such as SPAH and tube well are more beneficial for rural areas in Sabah and Sarawak, allowing for the collection and treatment of water at the point of use.

SPAH present a sustainable alternative to mitigate the water crisis with minimal environmental impact. These systems offer an auxiliary water supply that communities can leverage. Nonetheless, the quality of harvested rainwater can significantly fluctuate, leading to variable levels of required treatment to ensure safe usage. This variability extends to all aspects affecting treatment systems, highlighting the concern over pollutants present in water supplied through rainwater harvesting systems, especially for end-users.

Enhancing the adoption and efficacy of SPAH is essential for their recognition as a sustainable solution to the water scarcity challenge, prioritising public health and environmental conservation. The transition towards considering SPAH as a viable option for both potable and non-potable use at the household level hinges on the assurance of safety for the harvested rainwater intended for community or end-user consumption. These systems are engineered not only to provide water in sufficient quantities but also to uphold basic health and hygiene standards.

SPAH will often have some level of treatment to meet public health standards and other criteria established to protect the environment, system equipment, and structures. Nonetheless, using this water for drinking purposes raises significant public health concerns. Many infectious diseases can be transmitted through the consumption of water tainted with bacteria, parasites, viruses or hazardous chemicals. Consequently, to ensure the safety of harvested rainwater for both potable and non-potable purposes, it is essential to adhere to the latest WHO's "Guidelines for Drinking-Water Quality: Small Water Supplies" and "Sanitary Inspection Packages" (WHO, 2024a & 2024b).

THE OBJECTIVES

This paper aims to contribute on sustainable water resource management, promoting the adoption of SPAH as a key component in addressing global water challenges. It underscores the importance of adhering to regulations that safeguard public health while promoting social acceptance and economic viability through stakeholder collaboration and links them to the Sustainable Development Goals. The paper emphasises two primary aspects: (1) health & safety, and (2) performance & reliability, aiming to:

- Deliberate the utilisation of harvested rainwater as an alternative water source, strategically addressing the imperative need to effectively alleviate water stress and adapt to the impacts of climate change.
- Establish a framework that will act as a definitive guide for users in selecting appropriate rainwater uses systems and technologies, ensuring they meet the required health and safety benchmarks.
- Undertake extensive risk assessments, identify local risks, evaluating and managing the risks associated with the collection and uses of rainwater comprehensively.
- Access water treatment technology to ensure it effectively provides a safe, alternative water source, enhancing the reliability and quality of water supplied through SPAH.

This paper explores the potential of SPAH development in Malaysia under the dynamic climate by reviewing the government policies associated with SPAH initiatives. While there are guidelines, regulations, and policies on requirements for design, sizing, installation, and other technical aspects, there are no specific federal or state regulations or policies in Malaysia mandating the quality or safety standards for rainwater. This gap underscores the importance of addressing key areas such as:

1. Health & Safety**:** Ensuring the harvested water meets health and safety standards to protect community well-being.
2. Risk Assessment and Risk Management**:** Implementing comprehensive risk assessment strategies to identify potential hazards and developing robust risk management plans to mitigate them.
3. Performance & Reliability**:** Ensuring the consistent operation and reliability of SPAH, effectively providing a safe, alternative water source.

This paper aligns with Sustainable Development Goal (SDG) 6: Clean Water and Sanitation. By ensuring the quality and safety of rainwater, households contribute to achieving SDG 6's targets of universal access to safe and affordable drinking water and adequate sanitation by 2030. Additionally, promoting rainwater harvesting supports SDG 13: Climate Action, as it mitigates the impact of climate change by conserving freshwater resources and enhancing water resilience in communities. Implementing measures to improve the safe ultilisation of harvested rainwater not only safeguards public health but also advances progress towards sustainable water management and environmental stewardship, which is in line with the broader agenda of the Sustainable Development Goals.

FRAMEWORK

The rainwater captured at the source is considered one of the purest water sources available. The planning and design of SPAH should take into consideration for quality control to ensure the water meets the requirements for its intended uses. Modern RWH integrates several advanced elements to ensure high technological standards. These elements include roof and gutter protection screening, gutter, rain head, first flush diverter, tank screen, rainwater tank, insect-proof flap valve, auto-fill system, pump system, irrigation filter, and water level indicators (Van Seters et al., 2011).

Typical SPAH consists of three main components: a catchment/ collection area, a conveyance system, and a storage area. The catchment area is any area from which rainwater can be harvested. The best catchments have hard, smooth surfaces, such as concrete or metal roofing material. The volume of harvested water depends on factors such as the catchment area size, storage tank capacity, surface texture, and slope of the catchment area (DID, 2009). System design can range from simple to complex, depending on the specific needs and technological integration.

For rainwater uses (potable and non-potable), most research focuses on treatment options for SPAH (Figure 17). SPAH has been used mostly for water for non-potable purposes, mainly because harvested water is microbiologically contaminated by a variety of indicator and pathogenic organisms, unless special care is taken during the collection and storage of the rainwater (Meera and Ahammed, 2006). The harvested rainwater should be filtered to remove debris, large particulates, and contaminants before it can be stored. The systems should include the first flush device to improve the quality of the harvested rainwater. First flush systems divert the early stage of each rain event, typically the portion of runoff that has the highest concentration of contaminants. Hence, a first flush devices would remove any particulates or debris, and then a screen would keep finer particulates from clogging the system. Typically, the first flush volume should match 0.5mm of rainfall to the catchment area (DID, 2009).

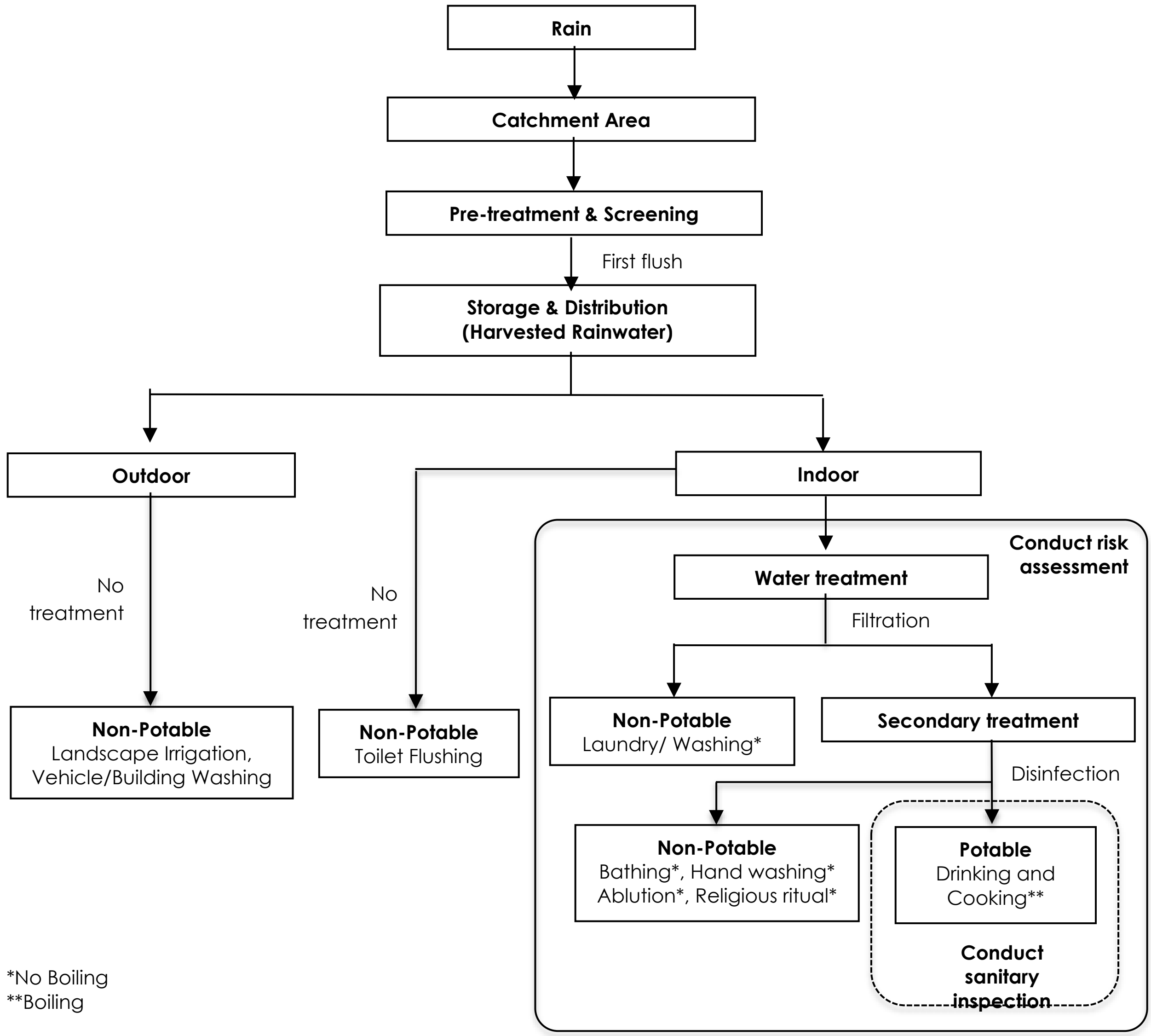

Figure 17: The Framework for Ultilisation of Harvested Rainwater for Potable and Non-Potable Uses at Household Level

The goal of pre-treatment is to remove leaves and debris from the rainwater runoff as thoroughly as possible before it enters the storage tank. This reduces the organic matter in the tank and minimises the need for post-storage treatment. To prevent leaves and debris from entering the system, mesh filters are commonly provided at the mouth of the drainpipe, and a first-flush device is used in the conduit before it connects to the storage tank.

Treatment of harvested rainwater becomes essential when contamination is anticipated. Importantly, treated rainwater must be protected from recontamination if it is to be stored over a longer period for subsequent use. Filtration, such as using a home water filtration pitcher, may effectively remove chemicals, dust, pollen, mold, and other contaminants. Filters may be made of paper, polypropylene, or non-corrosive metal, and typically involve fine particle filtration and activated charcoal filtration. Fine particle filtration removes microorganisms, sediment, metals, and organic matter. Hard water can interfere with the functioning of a filter, which makes rainwater-a soft water-easy on filters. Activated Carbon Filtration (ACF) employs filtration and adsorption techniques. Water passing through a fine sediment filter is then treated through an ACF rated at 3 microns or smaller, using carbon-based materials such as coal, fruit pits, or coconut husks.

Secondary treatment of stored rainwater only makes sense if it is done properly and if hygienic collection and use of the water will ensure it does not suffer from re-contamination. There are several types of treatment possible, the most common being chlorination, boiling, filtration and exposure to ultraviolet.

A sanitary inspection is a quick, on-site evaluation, typically conducted using a checklist, to identify and address priority risk factors that could lead to water supply contamination. After identifying these risk factors through the inspection, corrective actions and ongoing management and monitoring can be implemented to progressively manage and mitigate these risks (WHO, 2024a & 2024b).

While some countries permit the use of harvested rainwater as a source of drinking water, some prohibit it requiring separate plumbing systems (Campisano et al., 2017) for potable and harvested water to prevent contamination. Untreated rainwater can pose health risks, making treatment and disinfection essential to meet drinking water guidelines and safeguard public health. Therefore, treatment and disinfection of harvested rainwater are required to meet the drinking water guidelines and protect public health. Nonetheless, boiling is a very effective method of disinfection and very simple to carry out. Boiling water for 10 to 20 minutes is typically sufficient to inactivate most harmful pathogens. Hence, boiling can help make it safer for human consumption.

RAINWATER HARVESTING AND USE SYSTEM MATRIX

Table 1 summarises the water quality standards for various typical beneficial uses of rainwater and outlines the corresponding treatment levels required for different types of harvested rainwater to meet these standards.

TECHNOLOGY CONSIDERATIONS

Harvested rainwater offers a sustainable alternative water source to consumers/end users, helping offset the demand for freshwater. Rainwater harvesting captures, diverts, and stores rainwater from rooftops for later use. With additional treatment including filtration and disinfection, harvested rainwater can be used for various beneficial applications, including potable uses. Additional considerations and components specific to rainwater harvesting system systems are detailed in Table 2 (Leong et al., 2017).

Table 1: Typical Beneficial Uses of Harvested Rainwater and Level of Effort

Beneficial Uses		Health criteria Level	Level of effort
Outdoor	Irrigation / landscaping	Limited human contact and controlled access at point of use	Minimal
	Vehicle/ building washing	Limited human contact and controlled access at point of use	Minimal
Indoor	Toilet flushing	Limited human exposure at point of use	Minimal
	Laundry/ washing	Limited human contact and controlled access at point of use	Medium
	Bathing, hand washing, ablution, religious ritual	Human contact	High
	Drinking water	Drinking water standards	Drinking water standards and boiling

Note:
Minimal – pre-treatment;
Medium – pre-treatment + treatment;
High – pre-treatment + treatment + secondary treatment (disinfection**)**

Table 2: Specific Considerations to a Potable and Non-Potable Rainwater Harvesting System

Component	Description/Function	Technology/Technique
Pre-treatment	The systems that enabling dust, other debris, contaminants, and any fecal matter that collects on the roof and in gutters between rainfalls to be flushed out at the very beginning of the water collection process.	Debris screens First flush diverter Pot filter Basket filter Downspout filter Tank screens Insect-proof flap valves
Physical treatment	Water is pumped through the filters/membranes that must remove at least 99% of particles that are 3.0 microns or larger in diameter. This is sometimes achieved in stages with filters set up in series.	Slow sand filtration Rapid sand filtration Activated carbon Filter cartridges Membrane filtration (Polymer, metal, ceramic)
Secondary treatment - Disinfection systems	Disinfection systems are capable of inactivating (or killing) viruses that might be in the water.	Boiling Ultraviolet (UV) irradiation

Rainwater quality can be affected by geographic location and local economic activities. Rainwater collected in rural or non-industrialised areas generally has higher quality compared to areas with heavy industrial or agricultural activities (DID 2007). Furthermore, prolonged storage of rainwater can lead to changes in water quality, with potential growth of protozoa and other bacteria. This variability underscores the importance of assessing the effectiveness of rainwater harvesting and treatment systems and determining the appropriate treatment levels needed to meet water quality standards for intended uses.

Table A.1 in Appendix outlines the recommended standards set in the drinking water quality standard published by MOH (2004), which refer to the Second Edition, Volume 2 of WHO Drinking Water Quality Guidelines (1996) as the main reference. The drinking water quality standards apply to all water intended for human consumption, including drinking water from public water supply systems, tank supplies, and water used for bottled drinks and ice manufacturing. The source area from which rainwater is collected significantly influences its quality attributes. Table 3 outlines unique water quality considerations for harvested rainwater based on different roof types, including hard roofs, green roofs, and brown roofs.

Table 3: Typical Rainwater Pollutants, Summary of Sources and Potential Concerns for Harvested Rainwater Uses

Pollutant	Sources	Potential Concern
Nutrients ● Nitrogen ● Phosphorus	● Atmospheric deposition, sediment (adsorbed nutrients) ● Organic debris ● Animal feces	● Support growth of algae or unwanted microbial growth on the water surface in the storage unit, in the water column of harvested rainwater.
Organic Matter	● Organic debris (leaves, flowers, pollen, twigs, insect carcasses, etc.)	● Decomposition in tank can result in o low dissolved oxygen levels, nuisance odors, release of pollutants from sediments o growth of pathogenic microorganism o may proliferate humic substances and cause brownish appearance of water
Suspended sediment / Airborne particles (Dust)	● Paved surfaces ● Construction activity ● Atmospheric deposition	● May clog pump intake or distribution ● Increases maintenance of storage
Chlorides	● Water softening chemicals ● Catchment near to sea	● Corrosive to metal pipes/ plumbing
Pathogens	● Animal feces (including bird feces on rooftops) ● insects/vector organisms ● drainage area activities such as waste management	● Human health risk
Metals	● Vehicle exhaust emissions ● Roofing materials	● Plant toxicity ● Human health risk
Organic chemicals ● Pesticides/ herbicides ● Industrial chemicals and solvents ● Petroleum-derived chemicals	● Catchment area activities that are potential sources of organics (e.g. herbicide/ pesticide use or waste management)	● Plant toxicity ● Human health risk

The use of harvested rainwater must ensure safety for human consumption and comply regulatory water standards related to human health. Comprehensive, systematic risk assessment and management are crucial, involving detailed evaluation and prioritisation of hazards and associated risk. Identifying these hazards and risks, followed by implementing appropriate measures to minimise them, forms the foundation of effective risk management plans.

RISK ASSESSMENT AND MANAGEMENT

Risk assessment and management are critical for ensuring the safety of harvested rainwater, covering all stages from the catchment area to the storage tank.

The first stage of risk assessment is to identify and understand the type of SPAH used. The next step involves identifying and documenting any potential sources of hazard or hazardous events that could impact the safety of the harvested rainwater. Finally, these hazards must be assessed to determine their risk levels to end-users. This involves calculating the probability of each risk occurring and multiplying it by the severity of potential health impacts, ranging from low to very high. The Risk Determination Matrix in Table 4 and Table 5 illustrates these risk assessment factors.

Table 4: Risk Determination Matrix (modified from MOH, 2011 & SPAN, 2021)

Risk Determination Matrix		**Hazard level (b)**				
		Insignificant (1) (Not Detectable)	Minor (2) (Requirement Compliance)	Moderate (3) (Compliance Aesthetic)	Major (4) (Compliance with laws)	Catastrophic (5) (Public Health Compliance)
Probability of Occurrence (a)	Almost Certain (5) (Daily)	Low (5)	High (10)	High (15)	Very High (20)	Very High (25)
	Likely (4) (Weekly)	Low (4)	Medium (8)	High (12)	Very High (16)	Very High (20)
	Moderate (3) (Monthly)	Low (3)	Medium (6)	Medium (9)	High (12)	Very High (15)
	Unlikely (2) (Yearly)	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
	Rare (1) (Every Decade)	Low (1)	Low (2)	Low (3)	Low (4)	Low (5)
Risk Score			<6	6-9	10-15	>15
Risk Rating			Low	Medium	High	Very High

Table 5: Risk Determination Matrix (modified from MOH, 2011 & SPAN, 2021)

Hazardous event	**Danger (Hazard)**	**Priority Risk**			**Existing control measures**	**Proposed additional control measures**
		For category of probability occurrence	**For category of risk level (Severity)**	**Score (a)x(b) (Risk Level)**		
Among the hazardous activities/ events that may occur	Hazard due to the hazardous activities/ events	Possibility of hazardous activities/ events will occur	Risk Level of hazardous activities/ events will occur		Control measures that must be carried out	Other control measures that can be carried out
Climate change impact: Drought	Scarcity of water. Foreign matters, dusts and dusty water storage tanks.	Moderate (3)	Major (4)	High (3 x 4 = 12)	Periodic cleaning of tanks and roofing are necessary.	Using appropriate equipment for cleaning.
Climate change impact: increased temperature	Scarcity of water. Bacteria growth, decay in water quality	Moderate (3)	Major (4)	High (3 x 4 = 12)	Periodic cleaning of tanks and roofing are necessary.	Using appropriate equipment for cleaning.
Animal wastes, decaying plants or human activities	The presence of pathogens which affects the water quality.	Likely (4)	Moderate (3)	High (4 x 3 = 12)	Periodic cleaning as and when necessary.	Overhanging vegetation may attract birds and drop debris onto the roof. Pruning the tree branches when necessary.
Acid Rain	Acidic water will damage the system components like roofing, pipes and tanks.	Likely (4)	Major (4)	Very High (4 x 4 = 16)	Release water by flushing when it is raining.	To use corrosion resistant materials for roofing, pipes and water tanks.
Dirty and rusty roofing. Copper & asbestos roofing materials	structures on or above the roof that may rust or corrode. The drinking water will cause waterborne diseases.	Likely (4)	Major (4)	Very High (4 x 4 = 16)	Replacement of rusty parts. Use high quality enamelled roofing material	To use corrosion resistant materials for roofing, pipes and water tanks.
Rotting dead animals	The presence of bacteria which affects the water quality.	Likely (4)	Major (4)	Very High (4 x 4 = 16)	Periodic cleaning of tanks and roofing are necessary.	Using appropriate equipment for cleaning.
Water filtration system for potable water due to absence of maintenance.	Contamination of collected water	Moderate (3)	Catastrophic (5)	High (3 x 5 = 15)	Periodic inspection of filter and do replacement when necessary.	Inspection and monitoring, ensure filtration systems are maintained on a routine basis

Table 5: Risk Determination Matrix (modified from MOH, 2011 & SPAN, 2021)

Hazardous event	**Danger (Hazard)**	**Priority Risk**			**Existing control measures**	**Proposed additional control measures**
The filter media is clogged and damaged due to absence of maintenance.	High turbidity due to problem of water quality.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection of filter and do replacement when necessary.	Use durable filter that is easy to service.
Clogged gutter	Water turbidity and risk of pathogenic bacteria. Potential mosquitoes breeding site.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection of gutters and cleaning, repair as and when necessary.	Screening and cleaning the surroundings leaves and tree branches.
Moss-grown and dirty sedimentation tank.	High turbidity due to problem of water quality.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection and flushing of water tanks.	For moss/ algae control, the selection of a storage tank should be opaque
Mossy and dirty storage tank.	Water becomes turbid and smelly.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection and flushing of water tanks.	None
Sediments/ airborne particles (dust) in the tanks.	Turbidity and quality of water is affected.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection and flushing of water tanks.	None
Prolong storage of water.	Turbidity and quality of water is affected.	Moderate (3)	Minor (2)	Moderate (3 x 2 = 6)	Periodic inspection and flushing of water tanks.	None
Tank has no cover or damage.	Entry of dangerous foreign matters	Rare (1)	Major (4)	Low (1 x 4 = 4)	Periodic inspection and replace cover when necessary.	The cover is made of quality material.
Leakage of water distribution pipe	Reduced water supply, contamination of collected water	Rare (1)	Major (4)	Low (1 x 4 = 4)	Periodic inspection and repair when necessary.	Use durable and quality material.

DETERMINING AND IMPROVING CONTROL MEASURES

Harvested rainwater can be used for drinking or non-drinking purposes, but using SPAH for potable water requires a long-term commitment to ensure safe operation and maintenance. This ensures that SPAH remains functional and safe over time (DID, 2009).

Once risks are identified, implementing effective control measures is crucial to manage them. These measures typically involve regular monitoring and testing of rainwater quality and the structural integrity of the system. Monitoring may include checks for turbidity, microbial presence, chemical contaminants, and overall system condition.

Key questions to address when determining and implementing control measures include:

- What should be monitored? What will be monitored?
- How will monitoring be conducted? How will it be monitored?
- When monitoring is done? When will it be monitored?
- Where the monitoring should be conducted? Where will it be monitored?
- Who will conduct the monitoring? Who will do the monitoring?

Answering these questions ensures that control measures are appropriate and effectively mitigate identified risks (MOH, 2011).

Table 6: Periodic Investigations, Monitoring and Maintenance Schedule (modified from MOH, 2011)

Control Measures	Scope of Monitoring	Monitoring and Maintenance Process		Terms of Critical limit	Corrective Action	
Periodic cleaning of tanks and roofing are necessary.	Condition of tank structure, gutter, roofing and fittings.	What	Ensure the cleaning of all dirt and sediments.	Repairs needed to roofing, gutters and tanks.	What	Prevent foreign matters and wastes from entering the water tanks.
		How	Visual Inspection		How	Education of end users.
		When	Periodically and during heavy rain.		When	On-going
		Where	Roofing, gutters and tank		Who	House owner
		Who	House owner, End users.			
Release water by flushing when it is raining, at the storage tank and drainpipe.	Water quality	What	Water acidity should not be less than 6.0pH.	Ensure the water pH is not less than 6.5pH (for potable use).	What	Release water or add Soda Ash.
		How	Test with the pH meter		How	Education of end users, trained personnel.
		When	When the pH test on rainwater is less than 6.0.		When	On-going
		Where	Tank and drainpipe.		Who	House owner.
		Who	House owner, End users.			

Table 6: Periodic Investigations, Monitoring and Maintenance Schedule (modified from MOH, 2011) (Continued)

Control Measures	Scope of Monitoring	Monitoring and Maintenance Process		Terms of Critical limit	Corrective Action	
Replacement of rusty parts.	Quality of roofing construction materials	What How When Where Who	Ensure that the materials do not get rusty. Visual inspection All the time Roofing House owner, End users.	Roofing is rusty	What How When Who	Anti-rust materials. Knowledge on anti-rust construction materials. On-going House owner, End users.
Periodic cleaning of tank as and when necessary.	Condition of the structure of the tank.	What How When Where Who	Ensure the cleaning of all dirt and sediments. Inspection Periodically and during heavy rain. Storage tank House owner, End users.	Moss and sedimentation builds up in the tank.	What How When Who	Prevent foreign matters and waste from entering the water tanks. Education of end users. On-going House owner, End users.
Periodic inspection of gutters and carry out cleaning and repairs.	Structural condition of the gutter	What How When Where Who	Ensure the cleaning of all dirt and sediments. Inspection Periodically and during heavy rain. Gutter House owner, End users.	Dirt, foreign matters, waste in the gutters. Damages along the structure of the gutter.	What How When Who	Prevent the gutter from clogging. Education of consumer and maintenance. On-going House owner, End users.
Periodic inspection of filter and do replacement when necessary.	Condition of the filter media.	What How When Where Who	Ensure the cleaning of the filter of sediments and replace when necessary. Inspection and cleaning Periodically and during heavy rain. Filter House owner, End users.	Damaged filter	What How When Who	Prevent the filter materials from damage Education of consumer and maintenance. On-going House owner, End users.

Table 6: Periodic Investigations, Monitoring and Maintenance Schedule (modified from MOH, 2011) (Continued)

Control Measures	Scope of Monitoring	Monitoring and Maintenance Process		Terms of Critical limit	Corrective Action	
Periodic inspection and flushing of water tanks.	Condition of the storage tank structure	What How When Where Who	Ensure the cleaning of sediments in the storage tank. Inspection and cleaning During downpour Storage tank House owner, End users.	Mossy and dirty storage tank.	What How When Who	Prevent the presence of sediments and carry out the necessary cleaning. Education of end users, trained personnel and maintenance. On-going House owner, End users.
Ensure the water tank used is in good condition and durable	The condition and cleanliness of the tank End users receive safe water from the distribution system.	What How When Where Who	Whether there is leakage, which affect the condition and cleanliness of the tank Presence of leakage and unstable pressure in the distribution pipe. Visual inspection Carry out inspection of the pipe distribution through observation. Once a week and in the event of crisis or emergency. Monthly At the storage tank House owner, End users.	Mossy and dirty storage tank. Presence of E. coli in the water distribution line Water will be less/below the designated level	What How When Who	To check signs of damage or leakage to the tank. Maintenance of the tank Carry out any maintenance and renovation of damages immediately. Cleaning, maintaining or repairing (when necessary) the tank. Education of end users, trained personnel and maintenance. Immediately upon detection House owner, End users.

CONCLUSION AND RECOMMENDATIONS

The sustainable management of water resources has become an urgent issue in the face of escalating urbanisation, population growth, climate change, and the depletion of freshwater reserves. In Malaysia, rainwater harvesting systems (SPAH) offer significant environmental, economic, social, and operational benefits. However, water shortages are exacerbated by rapid development, population expansion, prolonged droughts, and severe pollution, which degrade water quality and strain treatment processes. Therefore, adopting a comprehensive SPAH approach is essential. This strategy should include detailed guidance on system design, water treatment methods and control measures to ensure the safety and reliability of harvested rainwater for both potable and non-potable uses. Developing robust maintenance practices is crucial to ensuring the long-term functionality and safety of these systems. Additionally, establishing a monitoring framework is vital for regularly evaluating the performance and water quality of SPAH systems across various regions, ensuring compliance to health standards.

To refine these recommendations (Table 7), focus group discussions and public stakeholder workshops have been conducted. The following summaries present the key recommendation along with relevant lead Implementing ministry responsible for implementations. IEM is fully committed to supporting the ministries in translating these recommendations into actionable steps. This could be through providing technical expertise, equipment, or advisory services to ensure effective and practical implementation. IEM stands ready to collaborate and offer its full range of professional services to assist in achieving the desired outcomes.

Table 7: Recommendations

Lead Implementing Ministry	Recommendations
Ministry of Health (MOH) Malaysia	• **Establish comprehensive rainwater quality data collection and interpretation**. Conduct assessments to understand and address the health impacts of development projects. For example, SPAH at Bekalan Air dan Kebersihan Alam Sekeliling (BAKAS) project at Sabah and Sarawak is subsidised by MOH. This includes developing a sanitary inspection checklist, conducting training for trainers (TOT), and performing pilot tests to ensure effective implementation and monitoring. • **Provide guidance on water treatment methods and system design** to ensure a safe and reliable water supply. • **Develop maintenance practices for SPAH** to ensure ongoing system functionality and safety. • **Establish a monitoring framework** to regularly assess the performance and water quality of SPAH across different regions. • **Develop guidelines and regulations specifically for SPAH intended for potable use**. These should ensure water quality meets health standards set by the ministry, including microbiological and chemical safety. • **Collaborate with universities and research institutions** to study the health impacts, cost-effectiveness, and environmental benefits of widespread adoption of harvested rainwater for potable use.

Ministry of Energy Transition and Water Transformation (Petra), Ministry of Rural and Regional Development (KKDW), Ministry of Housing and Local Government (KPKT)	• **Develop strategic plan for execution and implementation of the developed guideline by MOH**. This ensures that the guidelines are effectively integrated into practice and consistently followed. • **Launch national campaigns to educate the public on water conservation and reuse**. Aim to reduce their consumption of treated water by 10 percent, promoting water-saving habits and the benefits of using harvested rainwater.

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APPENDIX A

Table A.1: Drinking Water Quality Standard (MOH, 2004)

No	Parameters	Maximum Acceptable Value mg/l (unless otherwise stated)
	Group I	
	Microbiological:	
1	Total coliform	MPN method/Membrane filtration method: Must not be detected in any 100ml sample
2	E. coli or thermotolerant	Absent in 100ml sample
3	Coliform bacteria	
4	Faecal streptococci	Membrane filter method: Absent in 100ml sample MPN Method: < 1 in 100ml sample
5	Clostridium perfringens	Absent
6	Viruses	Absent In 100ml
7	Protozoa	Absent In 100ml
8	Helminths	Absent In 100ml
	Physical:	
9	Turbidity	5 NTU
10	Colour	15 TCU
11	pH	6.5 - 9.0
12	Free residual chlorine	0.2 – 5.0
13	Combined residual chlorine	Not less than 1.0
14	Monochloramine	3
	Group II	
	Inorganic:	
1	Total Dissolved Solids	1,000
2	Chloride	250
3	Ammonia (As N)	1.5
4	Nitrate (As N)	10
5	Iron	0.3
6	Fluoride	0.4 - 0.6
7	Hardness	500
8	Aluminium	0,2
9	Manganese	0.1
	Group III	
1	Mercury (total)	0.001
2	Cadmium	0.003
3	Arsenic	0.01
4	Cyanide	0.07
5	Lead	0.01
6	Chromium	0.05
7	Copper	1
8	Zinc	3
9	Sodium	200
10	Sulphate	250

Table A.1: Drinking Water Quality Standard (MOH, 2004)

No	Parameters	Maximum Acceptable Value mg/l (unless otherwise stated)
	Trihalomethane: The sum of the ratio of the concentration to each of the guideline value should not exceed 1.	
11	Chloroform	0.2
12	Bromoform	0.1
13	Dibromochloromethane	0.1
14	Bromodichloromethane	0.06
15	Selenium	0.01
16	Silver	0.05
17	Magnesium	150
18	Antimony	0.005
19	Barium	0.7
20	Boron	0.5
21	Molybdenum	0.07
22	Nickel	0.02
23	Uranium	0.002
24	Hydrogen sulfide	0.05
25	Mineral oil	0.3
26	Phenol	0.002
27	Bromate	0.025
28	Chlorite	0.2
29	2-Chlorophenol	0.0001
30	2,4-Dichlorophenol	0.0003
31	2,4,6-Trichlorophenol	0.2
32	Formaldehyde	0.9
33	Dichloroacetic acid	0.05
34	Trichloroacetic acid	0.1
35	Chloral hydrate (Trichloroacetaldehyde)	0.01
36	Dichloroaceto-nitrile	0.09
37	Dibromoaceto-nitrile	0.1
38	Trichloroaceto-nitrile	0.001
39	Cyanogen chloride (as Cn)	0.07
	Group IV	
1	Aldrin and dieldrin	0.00003
2	DDT	0.002
3	Heptachlor & heptachlor epoxide	0.00003
4	Methoxychlor	0.02
5	Lindane (BHC)	0.002
6	Endosulfan	0.03
7	Chlordane	0.0002
8	1,2-Dichloropropane	0.04
9	1,3-Dichloropropene	0.02
10	Hexachlorobenzene	0.001
11	Pentachlorophenol	0.009
12	Alachlor	0.02
13	Aldicarb	0.01
14	Ametryn	0.05
15	Atrazine	0.002
16	Bentazone	0.3
17	Carbofuran	0.007
18	Chlorotoluron	0.03

Table A.1: Drinking Water Quality Standard (MOH, 2004)

No	Parameters	Maximum Acceptable Value mg/l (unless otherwise stated)
19	Cyanazine	0.0006
20	2,4-Dichlorophenoxy–acetic acid (2,4D)	0.03
21	Diquat	0.01
22	1,2-Dibromo-3-chloropropane	0.001
23	1,2-Dibromoethane	0.0004
24	Isoproturon	0.009
25	MCPA	0.002
26	Metolachlor	0.01
27	Mounate	0.006
28	Pendimethaun	0.02
29	Permethrin	0.02
30	Propanil	0.02
31	Pyridate	0.1
32	Simazine	0.002
33	Trifuralin	0.02
34	2,4 DB	0.09
35	Dichlorprop	0.1
36	Fenoprop	0.009
37	Mecoprop	0.01
38	2,4,5-T	0.009
39	Terbuthylazine	0.007
	Organic Substances	
40	Carbon tetrachloride	0.002
41	Dichloromethane	0.02
42	1,2-Dichloroethane	0.03
43	1,1,1-Trichloroethane	2
44	Vinyl chloride	0.005
45	1,1-Dichloroethene	0.03
46	1,2-Dichloroethene	0.05
47	Trichloroethene	0.07
48	Tetrachloroethene	0.04
49	Benzene	0.01
50	Toluene	0.7
51	Xylene	0.5
52	Etylbenzene	0.3
53	Styrene	0.02
54	Benzo[a]pyrene	0.0007
55	Monochlorobenzene	0.3
56	1,2-Dichlorobenzene	1
57	1,4-Dichlorobenzene	0.3
58	Trichlorobenzene (total)	0.02
59	Di(2-ethylhexyl)adipate	0.08
60	Di(2-ethylhexyl)phthalate	0.008
61	Edetic acid (EDTA)	0.6
62	Acrylamide	0.0005
63	Epichlorohydrin	0.0004
64	Hexachlorobutadiene	0.0006
65	Microcystin-LR	0.001
66	Nitrilotriacetic acid (NTA)	0.2
67	Tributylin oxide	0.002

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