INVESTIGATING FACTORS FOR CONSIDERATION IN DECISION-MAKING FRAMEWORKS FOR HOUSEHOLD WATER TREATMENT IN SOUTHEAST ASIA & THE PACIFIC

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E4C Fellows:
Briana Jones, Australia

Partner collaborators:
Dr. Jeremy Smith, Australian National University
George Goddard, EWB-Australia

E4C Editorial team:
Carolina Rojas, Expert Fellow
Grace Burleson, Research Manager
Mariela Machado, Program Manager

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Introduction

Sustainable Development Goal Target 6.1 calls for universal and equitable access to safe and affordable drinking water[1]. However, with 2030 fast approaching, an estimated 785 million people still lack access to clean and safe water[2]. Rural areas within Southeast Asia and the Pacific are particularly vulnerable due to lack of support for implementations of point of consumption (PoC), water security measures.

Household water treatment (HWT) is an effective measure for improving the safety of water at PoC, if centralized water security measures fail. However, HWT is often not a priority for local governments or large NGOs, who may be more focused on community and municipality level interventions. Thus, HWT interventions are often taken up by smaller NGOs passionate about promotion safe water in communities[3]. HWT technology selection and implementation is a complex area to address, as a number of factors need to be considered within the process[4]. Selection of appropriate technology is often aided or justified by decision-making frameworks, of which have unique contextual categories for consideration[5]. The need for support for the decision-making process has resulted in the development of numerous tools within the Water, Sanitation, and Hygiene, (WaSH) sector. However, of these tools for selection of "most appropriate technology/approach/system", there does not exist a singular decision-making framework for selection of household water treatment technology. The reason for this may be that HWT is not a priority in most contexts, it is a stop-gap, most countries are more focused on wider spread solutions of which do not have the complexity of individual considerations[6].

Technologies may successfully address the water quality concerns and water needs of a user, however, it may not be appropriate to the context. Appropriateness of technology to context is a significant factor to address in determining the sustainability of a solution. The Centre for Appropriate Technology (CfAT), echoes this sentiment by stating, "a piece of technology or infrastructure has no value without utility to those in the community. It is what we can do with it, rather than the thing itself that is of value. Therefore, the engagement, education and training surrounding the installation or construction of something in a community will determine its success or otherwise."[7] Therefore, the ability of solutions to meet the unique needs of the users is subject to external factors beyond the technical capabilities of the technology[4]. Understanding of these factors and their implications allows for informed selection of technologies most appropriate to context. In collaboration with Engineers Without Borders (EWB)-Australia and the Australian National University, this research aims to investigate the parameters and conditions that should be considered for the selection of household technologies for treatment of water in Southeast Asia and the Pacific, in an ongoing effort to inform decision-making practitioners.

To gain understanding of the factors and considerations in HWT technology selection and implementation, we investigated practices in countries in Southeast Asia and the Pacific. Cambodia, Laos, Myanmar, Timor-Leste, and Papua New Guinea were selected as they align to where the research collaboration partner, Engineers Without Borders (EWB)-Australia works. Desktop research, and interviews with field experts within the sector and regions were conducted to gain experienced-based requirements of decision-making support tools and current state of HWT. Ten individuals from various organizations provided field insight into HWT within the select

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[1] United Nations, Goal 6: Sustainable Development Knowledge Platform, accessed June 2020
[2] World Health Organization, Drinking Water, June 2019
[3] Interview with a senior global WASH advisor, August 2020
[4] Ojomo, E., Elliot, M., Goodyear, L., Forson, M., & Bartram, J. (2015) Sustainability and scale-up of household water treatment and safe storage practices: enablers and barriers to effective implementation. *International journal of hygiene and environmental health*, 218(8), 704-713
[5] Palaniappan, M., Gleick, P. H., & Change, E. (2008). A review of decision-making support tools in the water, sanitation, and hygiene sector.
[6] Interview with WASH research advisor, August 2020
[7] Centre for Appropriate Technology, CfAT's Approach To Community Engagement, 2018

countries. Experts included five country-specific experts, three global WaSH advisors, two HWT field experts, two WaSH experts, and one HWT decision tree developer (for their privacy, all interviewees are anonymized in this report). Interviews with experts provided insight into technology procurement, provision, and sustainability of solutions. These data assist in identifying key factors for consideration in selection of HWT options.

Selection of HWT: Decision Making Frameworks

Trends towards certain interests in different technology implementations may stem from the interest in effectiveness in microbial removal. The World Health Organization's (WHO) International Scheme to Evaluate Household Water Treatment Technologies (Table 1) is a benchmarking tool to evaluate microbiological performance of technologies and processes for HWT in a tiered ranking system[8].

Table 1: WHO HWT Ranking System, adapted[8]

Performance Classification	Bacteria (log reduction required)	Viruses (log reduction required)	Protozoa (log reduction required)	Interpretation (log reduction required)
⋆ ⋆ ⋆	≥4	≥5	≥4	Comprehensive protection
⋆ ⋆	≥2	≥3	≥2	
⋆	Meets at least 2-star (⋆ ⋆) criteria for two classes of pathogens			Targeted protection
--	fails to meet who performance criteria			Little or no protection

In general, HWT technology performance falls between the first and third tier in WHO evaluation of HWT. Ceramic filtration, chemical disinfection, and biosand filtration each generally achieve one star. Solar disinfection, however, ranges between one and three stars, depending on the specific technology. Despite the implication that higher performing technologies are "better", health gains from 2-3 stars are similar (useful when pathogens are unknown); furthermore, one star can be effective if designed and selected based on the known microbial contamination of the source water[8]. Notably, some experts, such as those from the Centre for Affordable Water and Sanitation Technology (CAWST)

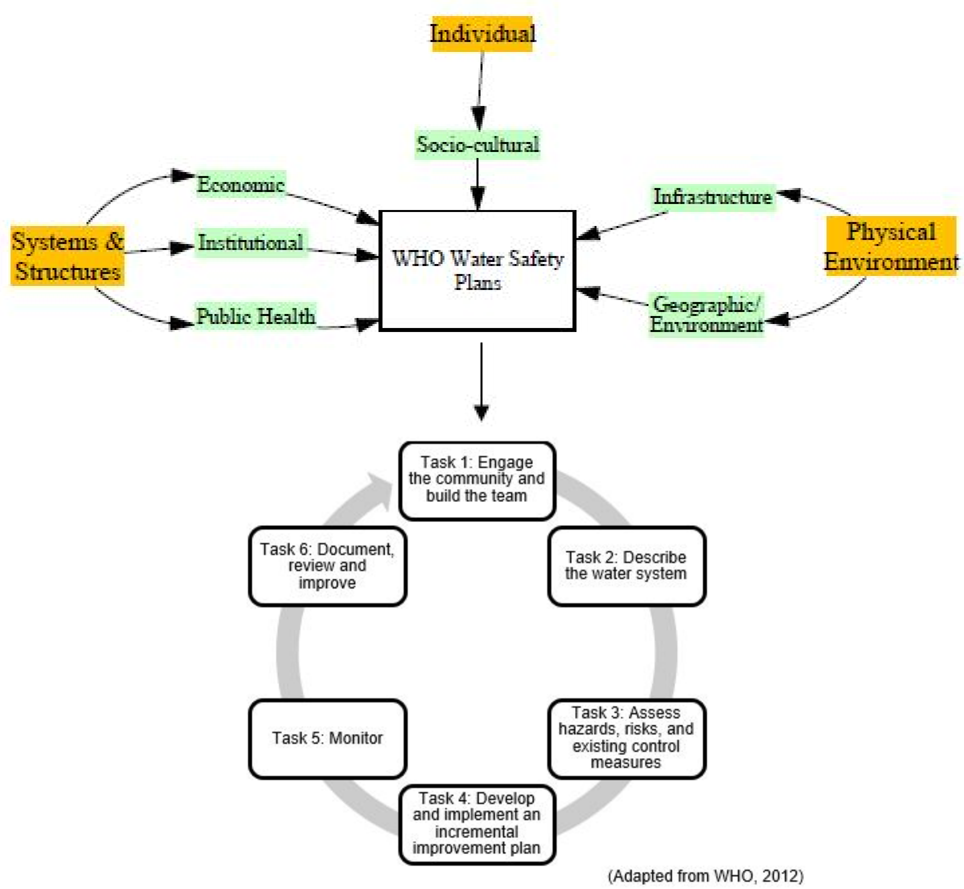

Figure 1: Contextual factors to consider within the WHO WSP.

[8] World Health Organization. (2016). Results of round I of the WHO International Scheme to evaluate household water treatment technologies.

argue that correct, consistent, and continuous use (also known as the 3C's) is of greater importance than tiered ranking of the technology[9]. Quantitatively, for HWT to be translatable into health gains, adherence to the 3C's has shown lower probabilities of infections and disease burden[10]. Furthermore, the adoption of middle tier performing technology is endorsed if the likelihood of achieving the 3C's is sufficient; this decision is based on key contextual factors for appropriateness of technology. It is recommended that social factors and other context-specific considerations are examined in addition to the technical requirements of water quality treatment need to be addressed for successful implementation[11].

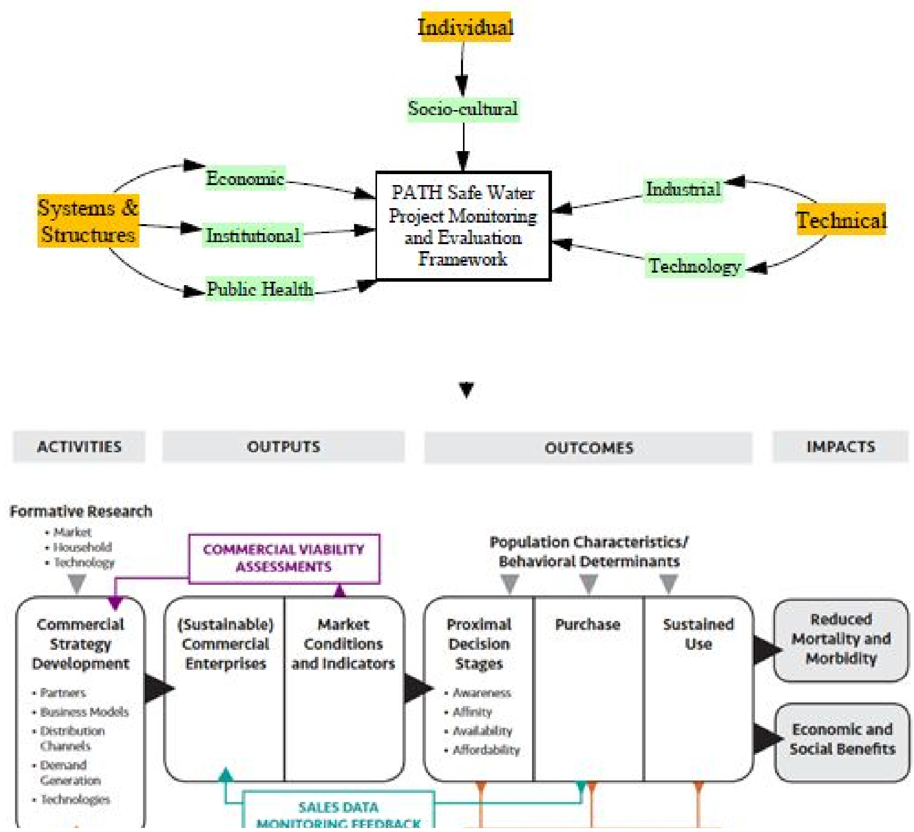

Figure 2: Contextual factors to consider within the PATH Conceptual Framework for the Safe Water Project M&E.

In addition to the tier designation, the WHO developed a scheme for HWT selection, presented in detail in the Appendix. The framework addresses technological capabilities required based on the practitioner's understanding of water conditions with informed performance. First, practitioners are asked to consider the types of microbial risks, then "reveal local conditions that support correct, consistent, and sustained use," ensuring water security allows for determination of water quality and assurance. Water quality forms the basis for technological requirements of a solution in isolation from other factors. Technical requirements can be addressed by application of various technologies on the market and are easier to measure and seek out in potential technologies. However, further contextual factors need to be explored and considered.

The PATH Conceptual Framework for the Safe Water Project M&E (adapted in Figure 2) is a system by which to analyze effective market viability of commercially sold HWT technology and user uptake. The framework highlights the need for community involvement, business models, and distribution channels for economic benefit. The framework also details the behavioral determinants for user benefits as: awareness, affinity, availability, and affordability.

[9] CAWST Blog, Should I chose the highest performance HWTS product?, 2020
[10] Bivins, A., Beetsch, N., Majuru, B., Montgomery, M., Sumner, T., & Brown, J. (2019). Selecting Household Water Treatment Options on the Basis of World Health Organization Performance Testing Protocols. *Environmental science & technology*, *53*(9), 5043-5051.
[11] Interview with senior global WAST advisor, August 2020

The Engineering for Change Solutions Library (E4C SL)[12] is a database of technologies that offers a "comparison feature" for examining potential solutions side-by-side. Each product in the E4C SL is organized into a corresponding Technology Category (e.g., ceramic filtration, chemical disinfection, etc.) which includes specific parameters for comparison across the category[13]. For example, for the ceramic filtration category, parameters include: type of filter, material, additives, flow rate, bacteria/virus/protozoa reduction, heavy metals reduction, recommended influent turbidity level, effluent turbidity level, recommended maintenance, lifetime volume, and safe water storage recommendations. This framework can be used for side-by-side comparisons to improve decision-making processes for practitioners.

Although designed for the context of designing medical devices, Aranda-Jan et al. (2016) provides key categorisation for holistic design in low-resource settings (adapted in Figure 3). Relevant categories included in this framework are: socio-cultural, institutional, economic, technology, and industrial factors. These are factors of which were highlighted by The Pacific Institute (2008)[14] as necessary for further development. It is recommended that practitioners consider these factors during their assessment stage to inquire if any will influence the technology decision and/or performance of the selection.

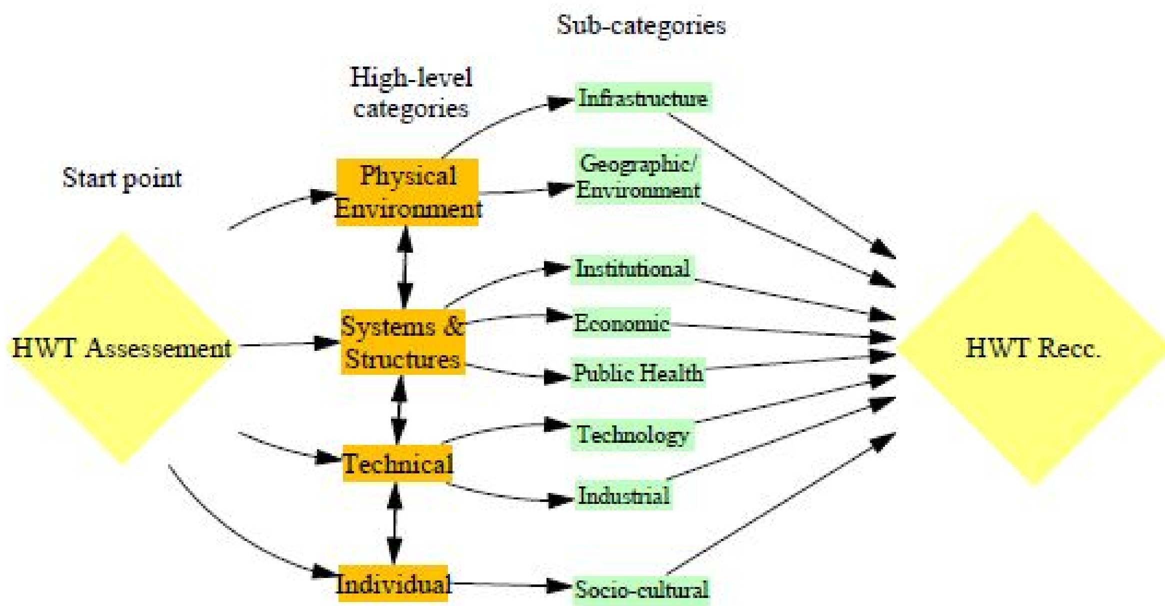

Figure 3: Adapted version of key-categories to adopt[15]

[12] Engineering for Change, Solutions Library
[13] Engineering for Change, Solutions Library About Page
[14] Palaniappan, M., Gleick, P. H., & Change, E. (2008). A review of decision-making support tools in the water, sanitation, and hygiene sector.
[15] Aranda-Jan, C. B., Jagtap, S., & Moultrie, J. (2016). Towards a framework for holistic contextual design for low-resource settings. *International Journal of Design*, *10*(3), 43-63.

Technology Trends in Southeast Asia and the Pacific

Water quality and security is often assured through the development and implementation of Water Safety Plans (WSPs). WHO Guidelines for Drinking Water Quality recommends water suppliers develop and implement WSPs in order to systematically assess and manage risks[16]. Of the identified factors there is the clear connection between the identified factors and the WSP approach. Of the countries to be researched all have WSPs in place, piloted in rural and urban areas. A summary of these water monitoring measures by select countries are listed below:

- Cambodia: National Rural Water Supply and Sanitation Strategy (2011-2025)
- **Laos:** Minister's Decision on Water Quality Standard Management for Drinking and Domestic Use, Ministry of Health (Standard enforcing WSPs)
- **Myanmar:** Water Safety Plan
- **Papua New Guinea:** No WSPs implemented in country, further research required to determine the development of this
- **Timor Leste:** Direcção Nacional de Serviços de Água (National Directorate for Water)

The securing of source ensures the provision of improved water services, security of source, and point of consumption (PoC) water quality. A comparison of the country's progression towards basic drinking water services provision to the population is visualized in Figure 4. Note that Figure 4 is a percentage out of the total population[17]. As can be observed, the countries perform in the following ascending order: Papua New Guinea, Timor-Leste, Cambodia, Myanmar, and Lao. PNG is significantly behind the four other selected countries. This may be attributed to the lack of WSPs, as highlighted previously, however further investigation into other factors is required.

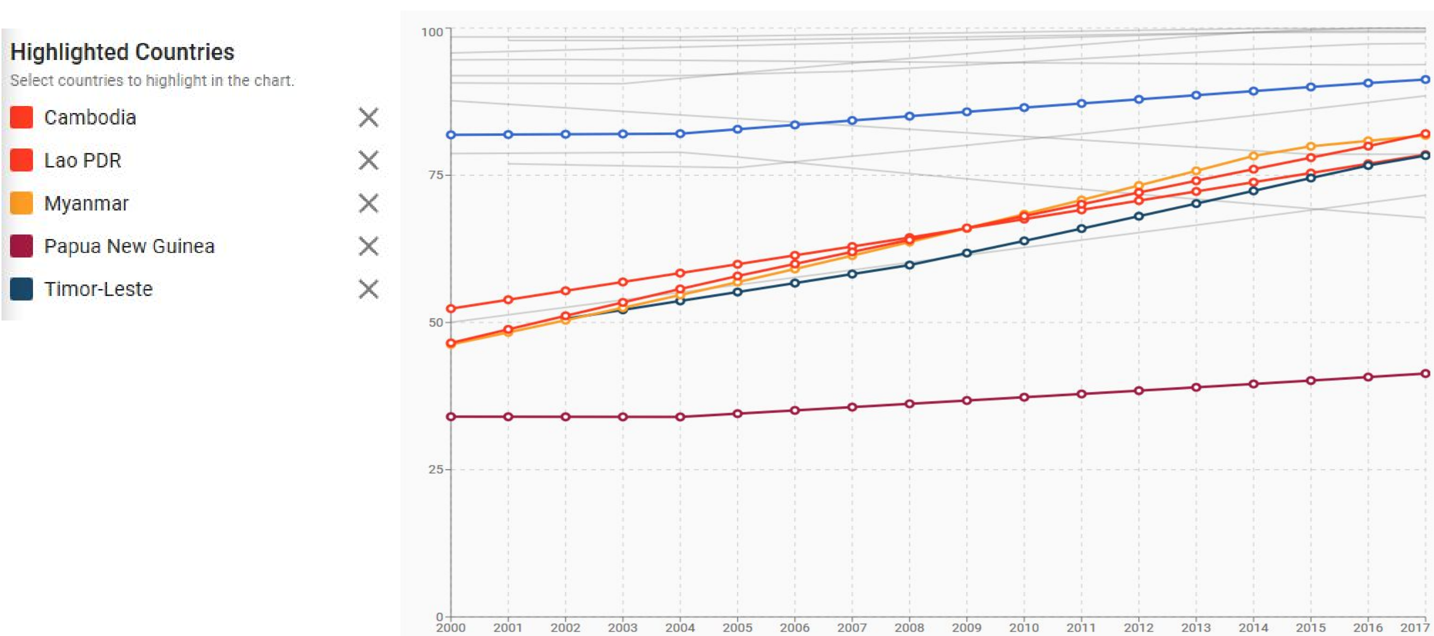

Figure 4: Population using at least basic drinking water services by select countries.

[16] Pandit, A. B., & Kumar, J. K. (2015). Clean water for developing countries. *Annual review of chemical and biomolecular engineering*, 6, 217-246

[17] SDG Index, Population using at least basic drinking water services, accessed October 2020

As a prominent implementer of HWT, CAWST's online database provides summaries of their HWT projects by country[18]. This is supplemented by additional background research for projects and implementations for PNG & TL, as there are currently no projects listed for these countries.

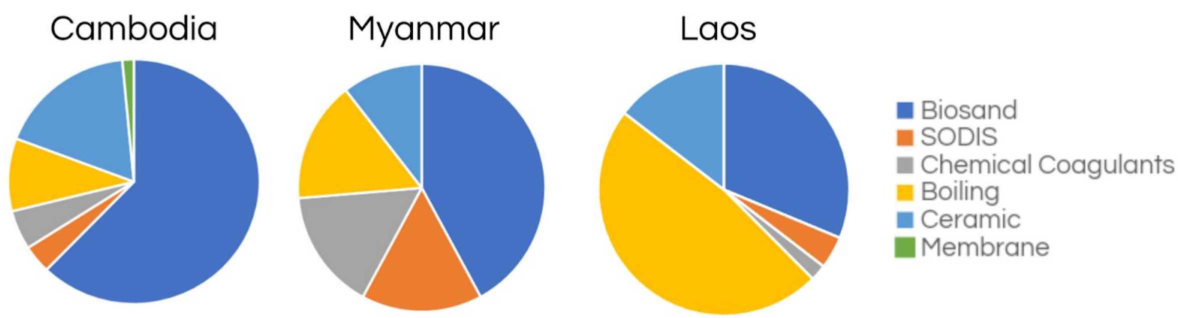

Figure 5: Distribution of Technology in HWT CAWST Projects in Cambodia, Myanmar, and Laos

Globally, boiling has proven to be able to achieve the greatest implementation scale compared to other HWT methods[19]. Boiling water is a dominant technology used within the CAWST project database, which suggests that boiling water is a favored method of HWT in these select countries, particularly in Laos[20]. It is arguable that increasing complexity of technology, reduces scalability of HWT methods[21].

Technology Provision & Context

Experts from Abundant Water, an Australian non-governmental organization that works in Timor-Leste and Laos, claim that receptibility to technology use and manufacturing is dependent on numerous contextual factors and implemented solutions can vary drastically between contexts [22]. Abundant Water Laos supports the in-country manufacturing of candle-stick clay water filter filters by local potters. In Timor-Leste, Abundant Water supports the promotion of, and provision of dome shaped clay filters, however these are imported from China. These showcase two different approaches to technology provision.

Both cases highlight the benefits of localization in different contexts and approaches. Localization is attributed to the long-term sustainability of solutions through capacity building and ownership of solutions. Abundant Water, like many other NGOs active in these regions, utilize the market-based approach (MBA) for technology provision in Timor-Leste. This approach trains community members to be technology specialists to become product vendors within their community. Locally driven technology proliferation within a community assists in building trust and supporting behavior change; this is as, "if your neighbor is using it and not getting sick. Noticing someone they trust using it. Trust with the vendor. Ensuring the vendor is equipped with knowledge."[22] This is beneficial in many ways, but also for the potential for growth as improvements in community uptake allow for reduction in costs, leading to ease of scalability[23]. MBA localization benefits the ease of integration into the community by building trust, and supports behavior change.

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[18] CAWST, Project Map, accessed October 2020
[19] Ojomo, E., Elliot, M., Goodyear, L., Forson, M., & Bartram, J. (2015). Sustainability and scale-up of household water treatment and safe storage practices: enablers and barriers to effective implementation. International journal of hygiene and environmental health, 218(8), 704-713
[20] Pandit, A. B., & Kumar, J. K. (2015). Clean water for developing countries. *Annual review of chemical and biomolecular engineering*, 6, 217-246
[21] Pandit, A. B., & Kumar, J. K. (2015). Clean water for developing countries. *Annual review of chemical and biomolecular engineering*, 6, 217-246
[22] Interview with experts from Abundant Water, August 2020
[23] Interview with WASH program director in Cambodia, August 2020

In addition to the benefits in community driven sales, is the associated monetary buy-in for technology. Wider spread technology implementation is achievable through this method in some cases through village buy-ins, particularly in Timor-Leste[24]. Larger volume sales allow for reduction in costs and further scalability. Community buy-in has proven to have greater acceptability and ownership of products[25]. However, this result is dependent on the implementor's approach. All interviewees stressed the importance of education, engagement, training and support for successful implementation.

Key benefits of the MBA are the supposed ease of integration to the community. However, all interviewees highlighted the issues associated with reliance on supply chains. Treatment options that do not require this reliance allow for greater sustainability and self-sufficiency[25]. As a consequence of this, physical treatment methods are generally preferred over chemical treatments. Additionally, manufacturing ability close to the implementation site means lower cost, making it physically and financially more accessible to the community[26]. MBA proves an effective method of technology provision with further considerations to context and accessibility.

Importing technology from other countries poses another unique socio-cultural factor to address. For example, in Timor-Leste, there is particular animosity to products made in China. However, when stressed that the organization procuring the technology is Australian, has proven successful in building trust in community Laos, with manufacturing in-country surpasses this issue. In contrast, Laos' approach of manufacturing in-country and providing training to the community, means that individuals can create filters themselves, or purchase one from the NGO[24].

Manufacturing in-country is one way to negate issues with supply chains, however implementation of local manufacturing requires time and monetary investment. Material procurement, manufacturing, and distribution all rely on a number of contextual factors to consider, such as the industrial and technological capability, local geography, economy, and social factors; among others. In Timor-Leste specifically, many communities may be geographically close but not interact due to cultural, social, and economic differences, thus increasing the complexity of local manufacturing and distribution[27].

Solution Sustainability

Key challenges in technology procurement and distribution are highlighted above, another aspect to address is the operation and monitoring (O&M) of solutions. This is particularly challenging in contexts, particularly with NGOs still taking a leading role in this process. Ensuring education, support, and ownership of solutions is important for co-operative leadership to build community capacity.

The Australian Centre for International Development (ACFID), details principles of practice to contribute to quality development and humanitarian outcomes through their Code of Conduct[28]. Participation, empowerment, & local empowerment, is a quality principle for inclusive sustainable change through the empowerment of local actors and systems. However, this model is not always adopted by NGOs. An expert in the Pacific region reflected on this issue with personal experience, "O&M reports were solely produced by NGOs. Field engineers would come in and observe the site, create a report, with minimal interaction with community or communication". Donors and NGOs' often require extensive testing to comply with regulations and meet obligations, this often limits community engagement potential. However, with some technologies, lower-tech monitoring operations can be conducted with ease in community, for example, flow-rate testing is often used as a proxy for determining functioning of ceramic filters[22]. Exploration of alternative O&M activities should be conducted for further community engagement and self-sufficiency.

[24] Interview with WASH practitioner in Laos, August 2020
[25] Interview with WASH program director, August 2020
[26] Interview with senior global WASH advisor, August 2020
[27] Interview with WASH practitioner in Timor-Leste, August 2020
[28] Australian Centre for International Development

Government involvement is necessary in projects that aim to make significant progress towards the UN Sustainable Development Goals[29]. Partnerships between organizations and government entities vary across projects and contexts, and it is very common for misunderstandings to occur. Interviewees highlighted that issues in operation and maintenance can arise if the government has not been involved and is not informed of the needs for the technology. Reflections from an interview with a field expert in Laos highlighted concerns regarding the local health department's testing capacity, resulting in falsely-reported results that the technologies were unsafe. Due to this misunderstanding, unsatisfactory test results lost public trust. Lack of effective government coordination means less ability to focus on sector coverage monitoring and donor programs[30].

Ensuring locally driven systems & structures are in place can contribute to sustainability of solutions. This has taken different forms, with NGOs often supporting the process by provision of technical support to government programs. Below is a list of the programs responsible for water security and provision for the select regions:

- Cambodia: Ministry for Rural Development (MRD)
- Timor-Leste: Programa Nasional Dezenvolvimentu (PNDS), National Program for Village Development
- Laos: Nam Saat; National Centre for Environmental Health and Water Supply
- Papua New Guinea: Environment Health Program, WaSH Policy Task Force
- Myanmar: Department of Rural Development

Having local community points of contact, in addition to these initiatives, such as local district health offices, allows for independent distribution and support of technology. Partnerships and relationships have been identified as particularly useful amongst interviewees, who's NGOs utilize the MBA.

The importance of community engagement and ownership of projects is widely acknowledged. However, the formation of water advocate committees within the above programs have had mixed results. Committee members vary in reliability in representing and meeting the needs of the community[31] and selection of vendors is based on eagerness and ability to learn[30]. Misrepresentation may stem social inequalities from classism within communities. Considerations of the social dimension, and socio-cultural factors through this lens is essential for sustainable development[32]. Another consideration for these groups, and distribution of authority is that often when a project is not one person's responsibility it may feel like 'no-one's responsibility'[31].

From these findings, the importance of relationships and trust within community and collaboration has been demonstrated. Engaged networks of community, NGOs, and practitioners, supporting collaboration and capacity building is important for community uptake and solution sustainability.

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[29] Interview with senior global WASH advisor, August 2020
[30] Interview with WASH program director, August 2020
[31] Interview with WASH practitioner in Laos, August 2020
[32] Bivins, A., Beetsch, N., Majuru, B., Montgomery, M., Sumner, T., & Brown, J. (2019). Selecting Household Water Treatment Options on the Basis of World Health Organization Performance Testing Protocols. *Environmental science & technology*, *53*(9), 5043-5051.

A Decision framework for HWT Selection

Based on published decision frameworks from organisations (e.g., WHO, PATH, CAWST, etc.), the technology comparison framework by E4C, the contextual framework by Aranda-Jan et al. (2016)[33], and insights from expert interviews, a number of factors have been identified as important considerations for selection of HWT in the specified regions (Table 2). It is recommended that practitioners incorporate these factors into their HWT assessment prior to technology selection and implementation.

Table 2: Decision Framework for HWT Selection

Sub-category	Key Questions/Considerations	Resources
Pre-assessment	- WSPs in place? How secure is the water source? - Pre-treatment water quality	- WSP for drinking water supplies - Proxy testing: further testing required (Y/N)
Infra-structure	- Methods of physical delivery - WSPs assessment	- Importing products: (1) is exporting country compatible with importers? (2) dependence on supply chain: financially and physical accessibility - Locally integrable manufacturing markets
Geographic/ Environment	- Geographic/environmental factors affecting delivery of technology - WSP: factors that affect water security	- Physical accessibility to product distribution: availability of local distributors - Environmental factors: do seasons affect the water quality?
Institutional	- Systems and structures: local water groups, government initiatives - Local safe drinking water guidelines	- Compliance with local safe drinking water guidelines→ technology that isn't 'over-engineered' for the needs of community - Engagement and involvement of local systems for advocacy, support, and distribution
Economic	- Subsidies from government/NGOs - Personal finances - Finances of communities: will beneficiaries buy in individually	- Considerations of personal incomes (TL: $115 USD/mo; Cambodia: $140 USD/mo; Myanmar: ~$33.42USD/mo; PNG: $159.17USD/mo; Laos: $103.74USD/month). Income estimates should be cross-referenced with census data as well as government funding/donor funding available.
Public Health	- Health concerns linked to water quality	- WSP to determine water quality - CAWST disease cards
Technology	- Technical ability to meet needs of water quality concerns - Ease of use, maintenance, monitoring - Manufacturing methods in-country (traditional skills/materials use)	- CAWST product and technologies : E4C SL for regional specificity of products used - Stakeholder involvement in selection, O&M, reviewing case studies of HWT projects
Industrial	- Capacity for manufacturing and maintenance in-country	- Potential for development of in-country industry or building on current country industry
Socio-cultural	- Participation - Aesthetics - Behavior change - O&M - Trust	- Stakeholder identification and involvement throughout the process - Balancing expectations with technology: aesthetically pleasing and financially accessible and appropriate - Identifying field O&M potential for community - Development of trust in product, ensuring trust in NGOs, field practitioners, and local teams

[33] Aranda-Jan, C. B., Jagtap, S., & Moultrie, J. (2016). Towards a framework for holistic contextual design for low-resource settings. *International Journal of Design*, *10*(3), 43-63.

Furthermore, practitioners are recommended to consider the taxonomy provided in the E4C solutions library (SL), which is a decision-making support tool in itself. The SL encompasses some of the aforementioned identified factors. The SL takes into account other product details such as the Manufacturing & Delivery, Research & Standards, as well as general Product Basics. These details feed into the Comparisons function allowing users to compare products based on product intellectual property, distribution, user provision model, target users and regions, pricing structure, technical support, lifecycle, and compliance with regulations. These parameters allow users to compare product reports of solutions.

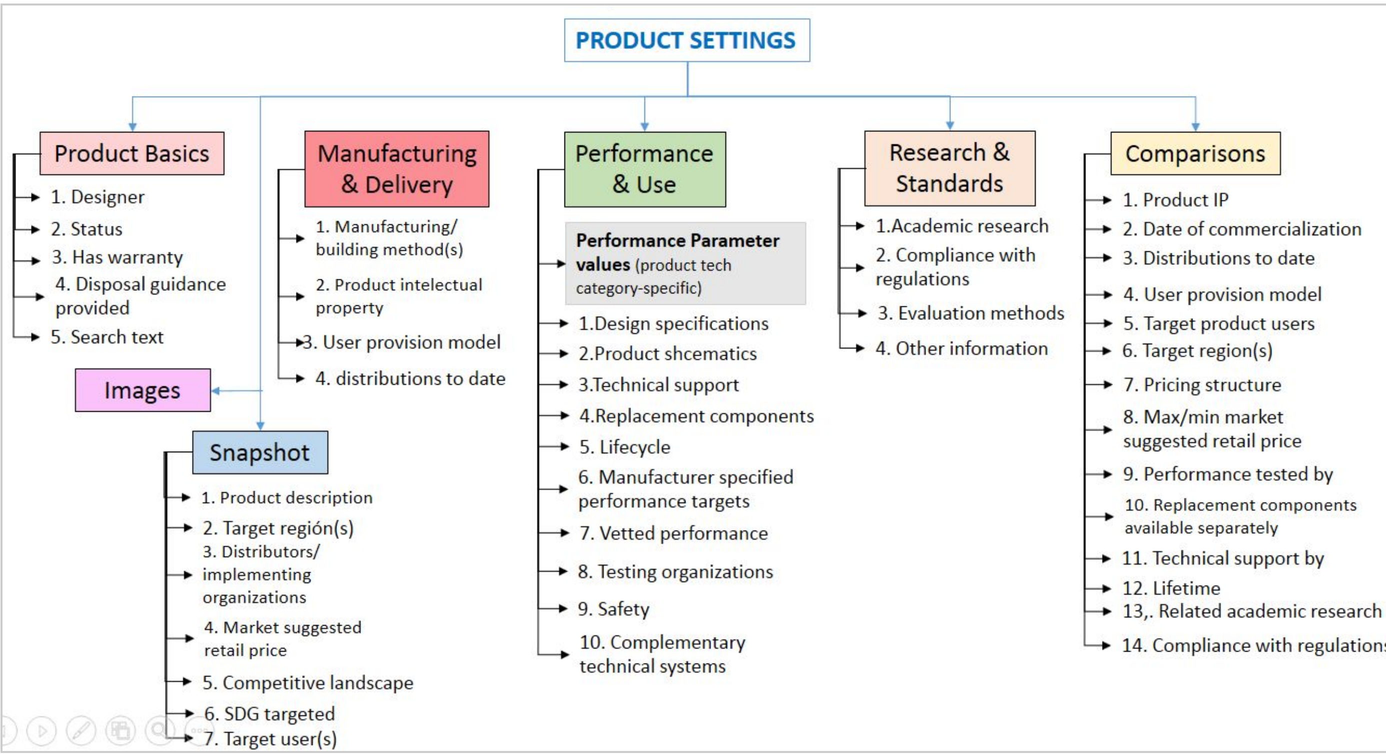


Figure 6: Engineering for Change Solutions Library Taxonomy

Using the E4C SL alongside the identified considerations and recommendations, a form of decision-making flow can be followed. Contextual factors are often difficult to quantify, however, the integration of other tools into this can prove useful in gaining a more holistic selection process.

Recommendations & Next steps

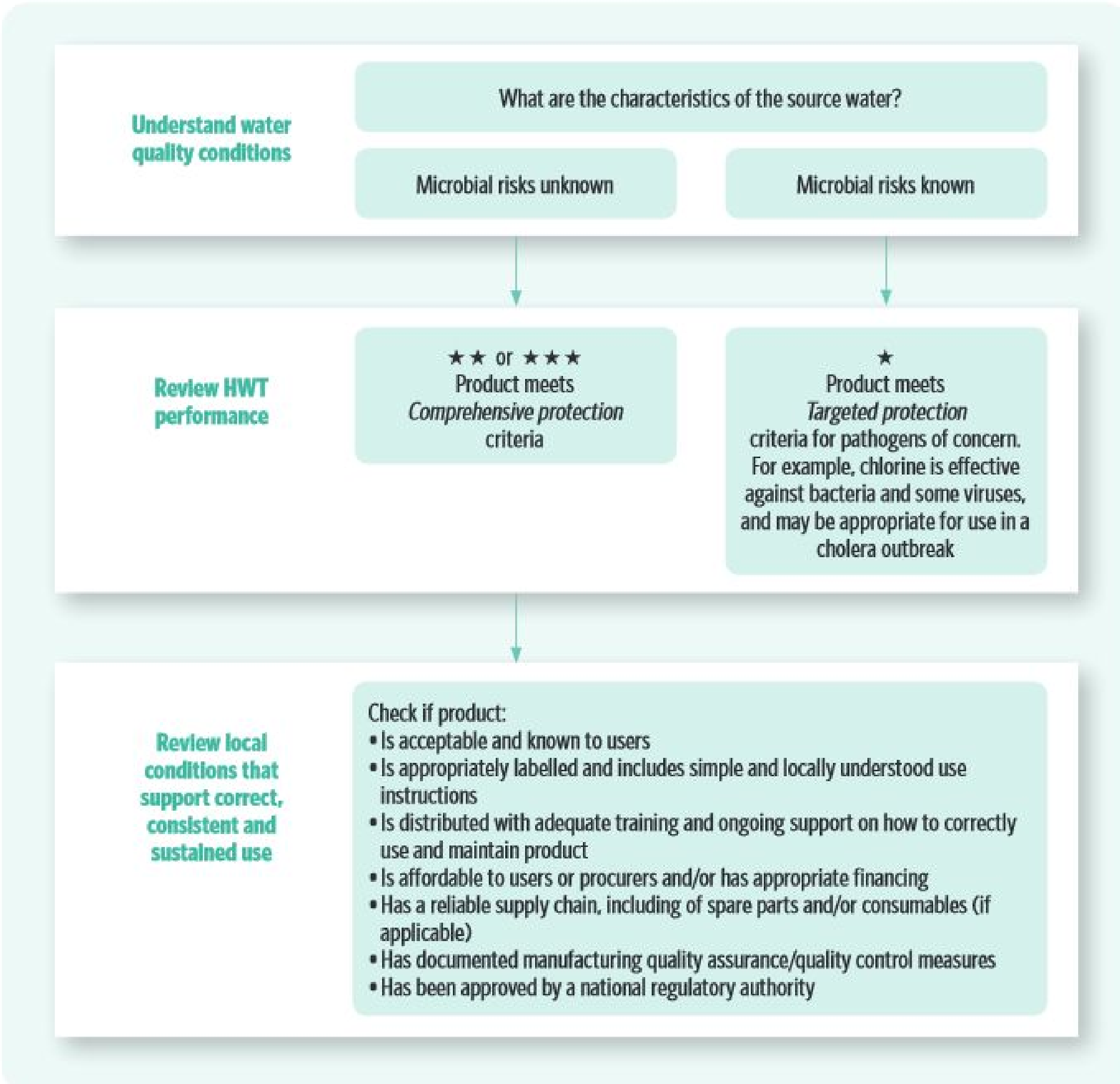
There are trends of which can be integrated into current systems to assist in the informed decision-making process of HWT selection. The E4C SL framework could be useful as a decision-making tool with the integration of select factors into current fields. Implicitly, considerations of socio-cultural factors are inferred by the identification of "Target Region(s)" (Snapshot: 2). Additionally, inclusions of MBA if available for the product could be useful in making informed choices, and would be included in the "User provision model" section.

In terms of research and next steps, it is evident that there are gaps in knowledge still needed to be further explored. Interviews were not conducted with Papua New Guinea experts in-particular, further primary information should be collected to gain insight into this country and potentially identify further factors. The common themes identified seemed to be quite transferable throughout the regions, with specific considerations within the factors for each country. Additionally, further information should be collected surrounding the current state of HWT within these regions, regarding implementation and stakeholder feedback to further validate success factors and considerations.

To make this information of further use as a support tool a decision-making flow and resources repository should be developed. This could take the form of a flowchart with linked resources to demonstrate decision flow. Further consultation with potential users of this tool should be conducted to determine what would be a suitable method of presentation.

Identification of factors for consideration in HWT for the regions have been highlighted through this research. The select countries provided insight into trends for HWT selection and implementation. Due to time constraints and availability research surrounding PNG was largely desktop. Further primary data should be assessed to determine if the factors trending in the other countries are synonymous to PNG. The interview group highlighted the importance of collaboration and participation of community, as well as the overarching influencing factors regarding supply and maintenance for solutions sustainability. Integration of current tools and building on current frameworks will assist in further steps towards developing a comprehensive framework.

Appendix: WHO HWT Selection Scheme



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