3R.6R EXTENDED WATER HIERARCHY MODEL FOR SUSTAINABLE USE OF WATER DURING CONSTRUCTION

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ABSTRACT

There is a broad consensus in literature that effective utilisation of natural resources in any industry greatly influences sustainability of built environment. Hence, better management strategies of water began to emerge in all sectors; thus, different dimensions are in need to assess different industries. With this scenario, water sustainability on construction sites is one significant area, which demands the attention of construction stakeholders. Today many construction projects survive on potable water, and many strategies are available that can reduce the amount of water consumed by the construction industry. Water hierarchy is one strategy proposed for construction sites to reduce potable water consumption and encourage alternative water sources within the site. Literature and preliminary interviews further support identification of new 3R principles: Regulations, Responsibility, and Rewards that can influence on better water management on construction sites.

Therefore, purpose of this paper is to examine the applicability and implementation of 3R principles in conjunction with six stages (6R) of water hierarchy to improve efficient water use on construction projects in Sri Lanka. The study adopted triangulation convergence mixed method approach, and data collection involved case studies and a structured survey. Qualitative data is presented as narratives and quotations while quantitative data is presented as descriptive statistics. The results revealed that all factors were considered as 'applicable' and the possibility of implementing them on construction sites. Reuse and recycle were identified as the least applicable, and are rarely practised on sites, if it is not initially identified as a mandatory process. Experience and commitment of individual staff and costs are identified as important drivers on implication of each 9R principle. New 3R principles were recognised as supportive policies to implement all six existing stages of water hierarchy. Finally, the paper discusses the extended water hierarchy model developed for construction industry.

***Keywords**: Construction; Extended Water Hierarchy; Sustainability; Water Efficiency.*

1. INTRODUCTION

Previous studies have extensively addressed adverse environmental effects from construction activities such as energy consumption, waste generation, noise pollution, water discharge, misuse of water resources, water wastage, consumption of non-renewable natural resources, dust and gas emission, and land misuse (Chen *et al*., 2000; Shen *et al*., 2007). Kibert (1994) explained that all these issues are interconnected and embraced under the heading, 'sustainable construction'. Abidin and Powmya (2014) stressed that the approach to sustainable construction will enable construction practitioners to be more responsible towards the need of environmental protection. This emphasises the necessity of sustainability criteria for construction to achieve a more environmentally sound built environment. Simultaneously, rapid decreasing of freshwater resource availability directly threatens 1.1 billion people around the globe (UN, 2006). As stated by Ramachandran (2004), construction is a water intensive industry. Thus, water shortage severely affect construction sector. This implies the requirement of sustainable strategies for better management of water resource in construction industry. As Hart (1995) emphasised, how environmentally oriented resources and capabilities can yield sustainable resources of competitive advantage, is one challenge that demands attention in construction industry. This reveals the requirements

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and establishment of sustainable approaches to sustain water for a long-term benefit. However, Strategic Forum for Construction (SFfC) identifies that to date, relatively less work is performed on water sustainability in construction sites, and water use receives a relatively low priority in comparison to the focus made on reducing energy, waste, and improving the carbon footprint (Waylen *et al*., 2011). Further, it revealed that many construction sites located in urban areas enjoy potable water at subsidised rates for construction work due to issues in alternative water source availability (Waidyasekara *et al.,* 2012). Moreover, it was observed that construction stakeholders in Sri Lanka pay less attention to water use in construction sites. Singh *et al*. (2010) mention the need of new approaches for long-term water planning and management that incorporate principles of sustainability and equity. Waidyasekara *et al*. (2012); Waidyasekara *et al*. (2014) stated a vacuum exists with the body of knowledge in water management in the construction industry, compared to other industries in Sri Lanka. Frequently, construction activities have a potential to have a negative effect on the surrounding environment. Meanwhile, Dharmaratna and Parasnis (2012) and Deveraja (2013) predicted that if water resource management is not sustainable, a water crisis is possible within the next ten years in Sri Lanka. Therefore, with the help of real case scenarios, this paper presents perception of construction professionals on the applicability and implementation of 9R principles and sustainable use of water during construction. The study refers to 'sustainable use of water', meaning the optimum use of water resources in construction sites with minimum wastage and misuse, while causing minimum damage to the ecosystem and preserving that scarce resource to meet the needs of the future generations.

The paper is organised as follows: First, a literature review, which include water in the context of sustainability, sustainable water usage in construction industry, and water hierarchy and R principles, is presented. This is followed by a justification of data collection methods used and the results of the study.

2. WATER IN THE CONTEXT OF SUSTAINABILITY

Water is precious and many scholars define water as a finite resource. According to Leonardo da Vinci, water is the driver of nature; even if one can live without energy, nobody can live without water (Luan, 2010). The common explanation for available freshwater is either 2.5% or 3.0% of the total water, from which only 1% is easily accessible; the balance is stored as ice caps or deep ground water. According to United Nations (UN) estimates, more than 1 billion people living on the earth face water scarcity, and this number could increase up to 1.8 billion by 2025 (Economist, 2008). According to OECD (2008), 47% of the world's population will live in regions with severe water stress in 2030. Difference between the increasing demand for water and the limited water availability creates a gap that is transformed into water scarcity (Joyce, 2012).

Biswas and Seetharam (2008) recognise the importance of formulating policies and regulations. Accordingly, over pumping results in declining ground water levels, and alternatively, more energy is required to pump the same volume of water. Another problem faced by the water sector is that universally, the prices and tariff are almost below the full cost of supply (Rogers *et al*., 2002). Therefore, low-priced water encourages excessive consumption, and hence, services provided at a higher price would encourage water conservation and a better service. Currently, the demand for potable water is constantly increasing with population growth, industrial developments, and climate change (Johnston, 2003; Economist, 2008; Goodrum, 2008; Sala and Wolf, 2013) mentioned that at present, many services and industries depend on continuous availability of freshwater; however, freshwater is heavily subjected to spatial and temporal variability of its own quantity and quality. Many scholars identified limited freshwater is a major constraint on sustainable development (Khalfan, 2002; Horne, 2012). Smith *et al*. (2006) recognise that when actual amount of water extracted was below the sustainable level of extraction is not a problem, but over-extraction and subsequent overuse of river systems create undue pressure. Figure 1 depicts the investment on water infrastructure, wastewater treatment, desalination, and recycling expects to rise steadily over the next five years. It is apparent from Figure 1 that the demand for water grows further, which claim necessity for more sustainability applications.

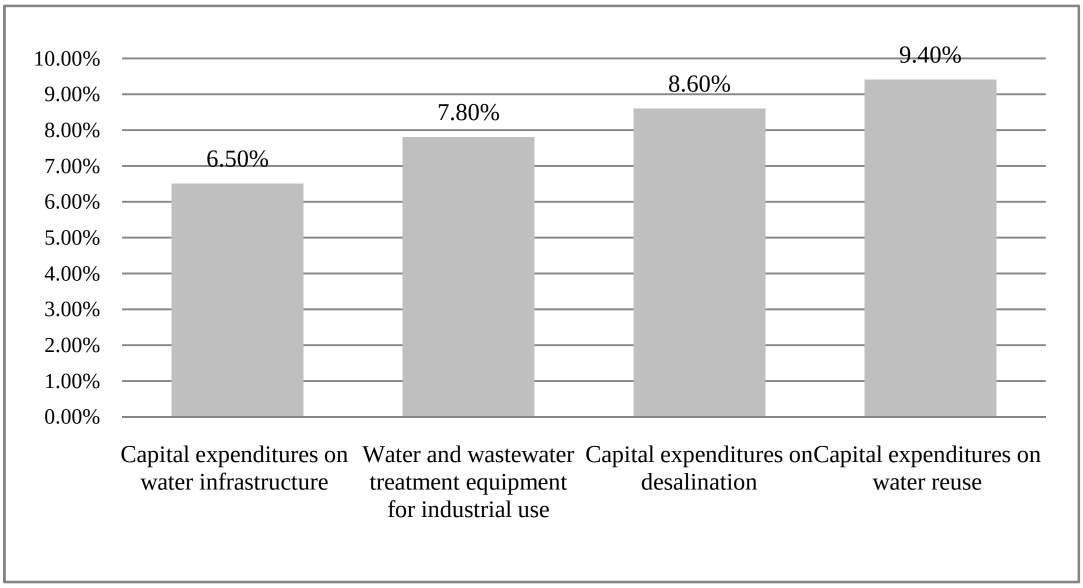


Figure 1: Growth in Global Water Industry Spending in Next Five Years
Source: Adapted from Rosegrant *et al.* (2012)

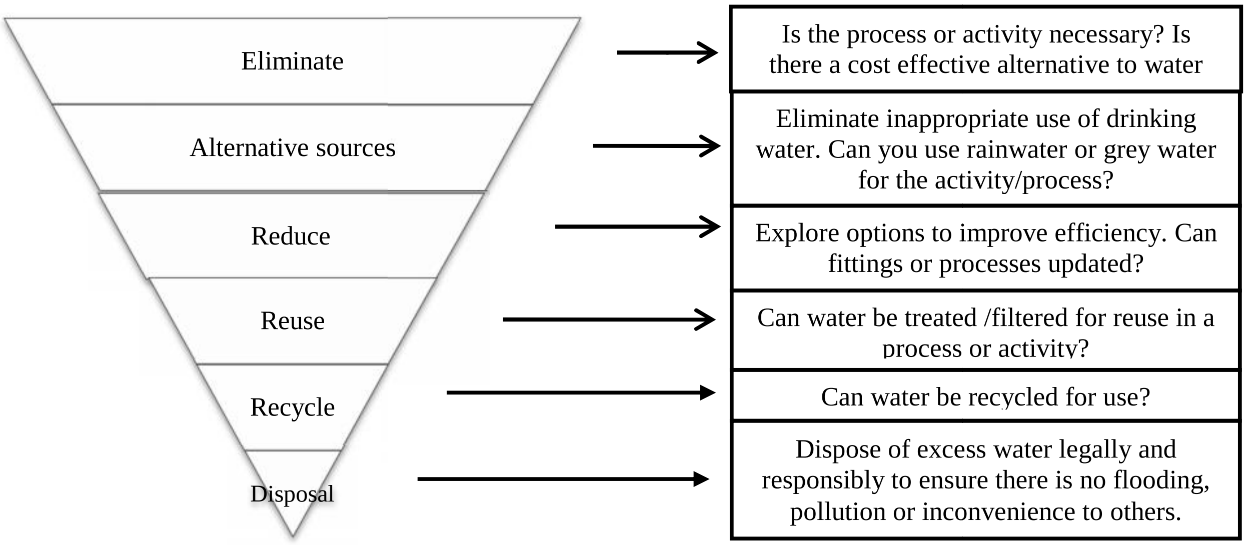
3. WATER USAGE IN CONSTRUCTION INDUSTRY

Construction industry is regarded as one of the largest users of water along with energy and material resources (Guggemos and Horvath, 2006). All construction work requires water from the inception to completion but the water quantity varies according to the site. In the past, the criteria for energy and water resources were not connected to one another, to materials selection, or to other issues of sustainable construction (Kibert, 1994). Water was merely considered as another input in construction projects (Kibert, 1994). At construction project level, water serves several purposes; it is not limited to mixing mortar and concrete, but also an essential component in curing work, dust controlling, soaking materials, vegetation establishments, geotechnical borings, pipe flushing, pressure testing, and washing and cleaning (The Workplace Health and Safety Queensland, 2007; Green roads TM manual, 2005; Utraja, 2010). According to Ramachandran (2004), use of contaminated water for mixing mortar and concrete, and curing will drastically reduce the structure life. However, many builders still do not realise the importance of such valuable processes and has not given the necessary priority during the practice. Alternatively, amount of water consumed by the construction is unknown and the extent of water consumption by the construction industry has not been adequately measured (Goodrum, 2008). While an enormous amount of water is utilised to operate buildings, a considerable amount is also used for extraction, production, manufacturing, delivery of materials to site, and for the actual on-site construction process (McComack *et al.*, 2007). As stated by Biswas (2008), water resource management attempts to optimise water usage and minimise the environmental impacts associated with its use.

Biswas and Seetharam (2008) recognise the importance of formulating policies and regulations for water construction activities; for instance, over pumping results in declining of ground water levels. Gleick (1998) mentions that sustainability criteria layout specific social goals that could, or should be attained, and it offers some guidance for future water management. As Ramachandran (2004) and Utraja (2011) stated, change of water quantity and quality in high or low degree greatly impacts on the product strength, but careless builders do not realise this in practice. This indicates the importance of adhering to design specifications and standard norms. According to Gonzales-Gomez *et al.* (2011), lack of intensive activities is one cause for poor water management practices. Responsibility, monitoring and supervision are other factors that influence sustainable use of water, as identified by many scholars. Based on the available literature, the Strategic Forum for Construction (SFfC) water sub-group, Waste and Resource Action Programme (WRAP), and Construction Industry Research and Information Association (CIRIA) are the main research bodies conducting research on water use on construction sites. SFfC mentioned that water use between construction sites and how water is consumed on a construction site varies over time. Aim of the above organisations is to work towards identifying and promoting water efficiency practices to reduce water consumption on construction sites in a sustainable manner. SFfC and WRAP emphasis the use of water technology, techniques and strategies actively influence a behavioural change, the work environment, and value for money (Waylen *et al.* 2011; McNab *et al.*, 2011).

4. WATER HIERARCHY AND R PRINCIPLES

Water hierarchy is another area that supports efficient water use. The joint government and industry strategy for sustainable construction published in 2008 identified water usage on construction sites as a priority area and included many targets pertaining to the more efficient use of water (McNab *et al.*, 2011). Waste hierarchy (prevention, re-use, recycle, recovery, disposal) (DEFRA, 2007), 3R (Reduce, Re-use, Recycle), and avoid, reduce, reuse, recycle, and treat (Mirata and Emtairah, 2011) are some common and popular hierarchies available in literature to reduce wastage and enhance efficient use of resources. Similarly, Silva and Pimentel (2011) mention that water efficiency can be achieved through 5R principle, which incorporates Reduce consumption, Reduce loss and waste, Re-use water, Recycle water, and Resort to alternative sources. Meantime, Strategic Forum for Construction (SFfC) water sub-group introduced a water management hierarchy for construction industry as depicted in Figure 2.



Is the process or activity necessary? Is there a cost effective alternative to water

Eliminate inappropriate use of drinking water. Can you use rainwater or grey water for the activity/process?

Explore options to improve efficiency. Can fittings or processes updated?

Can water be treated /filtered for reuse in a process or activity?

Can water be recycled for use?

Dispose of excess water legally and responsibly to ensure there is no flooding, pollution or inconvenience to others.

Figure 2: Water Hierarchy
Source: Adapted from Strategic Forum for Construction (SFfC): McNab *et al.* (2011)

Potable water standard is not always needed for all construction activities (McNab *et al.*, 2011; Waylen *et al.*, 2011). It is apparent in Figure 2 that water hierarchy encourages alternative water sources for potable water. This is proved further with the findings of Waidyasekara *et al.* (2014) that potable water must be specified only where necessary and other options must be allowed in the contract. Tam and Lee (2007) suggested that it is necessary to encourage and educate the staff on monitoring water usage, water reusing and recycling systems, and the use of wastewater treatment during construction. As McNab *et al.* (2011) stated, creating a culture within the construction sector that changes staff attitudes and behaviour to accept ownership of water efficiency is fundamental to improve the use of water efficiently.

As discussed, literature bears evidence that 3R, 5R and 7R principles are introduced for water stages of existing water hierarchy for the construction industry by SFfC. Therefore, in relation to this study, the definitions adapted for each step of hierarchy are presented in Table 1 with the proposed R principle.

Table 1: Stages of Water Hierarchy with the Proposed 'R' Principles

No.	Existing Term	Proposed Term with the R	Definition Adapted for the Purpose of Study
01	Eliminate use	Review	Check whether the process or activity is essential for potable water
02	Alternative non-potable water source	Replace	Find cost effective alternatives to potable water
03	Reduce	Reduce	Explore options to improve water efficiency. Basically, applying water efficient technologies, techniques, and strategies
04	Reuse	Reuse	Water reuse elsewhere without treat (as it is)
05	Recycle	Recycle	Water be recycled for reuse elsewhere during construction
06	Disposal	Removal	Dispose of used or excess water legally and responsibly to ensure no flooding, pollution, or inconvenience to others

Holmes and Hudson (2000), Cole (2005), and Pahwa (2007) identified the necessity of conditions or regulations to protect natural resources and environmental impacts due to construction. As Byrne (2011) explains, in water consumption, 'fit for purpose' approach should be adopted using potable water for all purposes. As discussed in the background study and literature findings, many researchers identified it is necessary to formulate new policies and review the existing ones (Rosegrant *et al.*, 2012; McComack *et al.*,2007; Houser and Pruess, 2009). The study conducted by Houser and Pruess (2009) justifies utilising appropriate best management practices in construction projects yield a minimal impact on overall water quality of surrounding water bodies. Tam and Lee (2007) suggested that it is necessary to encourage and educate the staff on monitoring of water usage, water reusing and recycling systems, and the use of wastewater treatment during construction. This is the responsibility of top management staff, since inappropriate incentives and institutions often hinder the effective use of water during construction (Houser and Pruess, 2009; Sala *et al.*, 2013). This simply explains promoting rewards and incentives for water use efficiency practices and the importance of rewards discussed by the preliminary interviewee personnel. Similarly, Boberg (2005) identified incentives as a mechanism to promote water conservation and efficiency.

Therefore, in addition to the stages of 6R (refer Table 1) of the water hierarchy, literature and the preliminary interviews support to identify three (03) new R principles, which will impact on the sustainable use of water during the construction phase. These are Regulations, Responsibility and Reward. Table 2 presents the new 3Rs and definitions adapted in this study.

Table 2: New 3R Sustainability Principles for Water Efficiency

New 3R	Definition Adapted
Regulations	Adhere to project and environmental specific rules and norms during water consumption
Rewards	Remuneration towards positive attempts to reduce water consumption and innovative ideas
Responsibility	Actions towards environmental and social conservation and preservation of natural resources

As stated by Waylen *et al.* (2011), all such sustainability concepts depend on user behaviour and attitudes. Further, Sala *et al.* (2013) mentioned that human consumption and their behaviour greatly affect sustainable consumption styles and environmental consequences.

5. RESEARCH METHODOLOGY

This research is exploratory in nature. Creswell (2007) explained that exploratory research is more suitable when previous work on the subject area is limited. In Sri Lanka, water sustainability in construction industry is one of the less acknowledged areas by the industry practitioners. It is vital to understand the acceptance and effective implementation of 9R principles during the construction phase for efficient water management. The study adopted triangulation convergence mixed method approach, and case studies and structured survey were employed during data collection. A robust questionnaire was developed based on the factors identified in the literature review and using a purposive sample, 160 questionnaires were administered among project managers, civil engineers, quantity surveyors, and architects having over ten years working experience in the industry. The respondents were given a 5-point Likert scale (refer to Table 3) to indicate the level of applicability of 9R principles on construction sites based on their professional judgement. In addition, four (04) ongoing construction projects located in Colombo were selected to explore and examine the implementation of each R on construction sites. Multiple sources of evidence were employed during the case study data collection. Qualitative data is presented as narratives and quotations while quantitative data is presented as descriptive statistics, i.e. mean, standard deviation, frequencies, and percentages were used appropriately to analyse data originated from the survey.

One-way ANOVA is used to determine the presence of a significant difference between the mean values among different groups: project managers, civil engineers, quantity surveyors, and architects at the 95% confidence interval. As the next step, based on the central tendency, a benchmark-mean score of 3.40 helped to identify the 'applicable' factors, while a benchmark of 4.2 was used for 'highly applicable' factors (Kazaz and Ulubeyi, 2007).

Table 3: Likert Scale for Level of Applicability

Scale	**1**	**2**	**3**	**4**	**5**
Level of Applicability	Not applicable	Less applicable	Neutral	Applicable	Highly Applicable

6. FINDINGS AND DISCUSSION

One hundred and five (105) usable responses were received, which made the response rate a formidable 65.6%. Out of the 105 respondents, over 27% had over 25 years, 23% between 20-24 years, 23.8% between 15-19 years, and 25.7% between 10-14 years of experience respectively. The total sample consisted of 21% project managers, 30.5% engineers, 28.6% quantity surveyors, and 20% architects. Results of one-way ANOVA indicated no significant difference between mean values on each variable, since significance level for each factor was greater than 0.05. This laid a solid basis to analyse data, considering all participants as one sample.

As stated in Table 3, participants were requested to rate the applicability on a scale of 1 (Not applicable) to 5 (Highly applicable). Detailed distribution of responses in terms of 'applicability' is summarised in Table 4. According to Table 4, all factors were considered as 'applicable' for construction industry by the respondents since the mean value of each concept received more than 3.4. Among them, Reduce, Review, Responsibility, Replace, and Regulations scored as the top five factors. The results further indicated that less applicability of 'Re-use' and 'Recycle' for construction sites received the 8th and 9th ranks respectively. Alternatively, the combined results of 'Applicable' and Highly applicable' were reported more than 70% for Reduce, Review, Responsibility, Replace, and Regulations as applicable for enhancing water sustainability practices on construction sites. When compared with all other stages of water hierarchy 'reuse' and 'recycle' received less percentage, which was 50.4% for each case. This reveals builders are certainly not willing to pay for wasted water in addition to 'treated' water.

Table 4: Applicability of R Principles to Enhance Efficient Use of Water during Construction Phase

9R	#1 %	#2 %	#3 %	#4 %	#5 %	Mean Score	Std. Dev.	Effect Level	Rank
Reduce	0.0	1.9	19.0	40.0	39.0	4.162	0.798	Applicable	1
Review	0.0	5.7	10.5	47.6	36.2	4.143	0.825	Applicable	2
Responsibility	3.8	4.8	13.3	32.4	45.7	4.114	1.059	Applicable	3
Replace	1.0	3.8	18.1	41.0	36.2	4.076	0.885	Applicable	4
Regulations	1.0	4.8	22.9	41.0	30.5	3.952	0.903	Applicable	5
Removal	1.9	4.8	27.6	36.2	29.5	3.867	0.961	Applicable	6
Reuse	3.8	13.3	31.4	29.5	21.9	3.524	1.093	Applicable	8
Reward	3.8	7.6	23.8	40.0	24.8	3.743	1.038	Applicable	7
Recycle	7.6	12.4	28.6	29.5	21.9	3.457	1.185	Applicable	9

1.00 ≤ ‘Not Applicable≤ 1.80; 1.80 < ‘ Less Applicable ≤ 2.60 ; 2.60 < ‘Moderately Applicable≤ 3.40; 3.40 < ‘ Applicable (A/R) ≤ 4.20; 4.20<‘ Highly Applicable ≤ 5.00

Review: This is the first stage of the water hierarchy, which checks whether potable water is compulsory for construction activities or processes. It revealed that none of the site documents clearly mentioned the water source required according to the construction activity. However, it was noted that the contractor holds the responsibility of making arrangements to obtain water for construction.

Replace: The case study findings revealed that ‘Replace’ is practiced by the four construction sites. Project manager of Case 2 stated that, “*if potable water is used on construction sites, water hierarchy will provide more benefits. At present, we have looked for alternative water sources before using potable water*”. Similarly, initially Case studies 1, 3 and 4 implemented this stage (Replace). However, it revealed that ground water contamination was a main barrier faced by construction sites during the attempts to obtain water from tube wells as an alternative source of potable water. Limited space availability on sites was identified as the main barrier for implementing rainwater harvesting by Cases 3 and 4.

Reduce: Monitoring, supervision, assigning responsibility, worker awareness through meetings and posters were implemented in Cases 1, 2, 3 and 4 to minimise water wastage due to construction activities. In addition, pressure gun hoses were employed during vehicle washing and cleaning the site, to reduce water and minimise unnecessary water wastages. Project manager of Case 3 stated, “*If curing components are applied on concrete walls, columns, and slabs, it reduces water usage. This is more expensive than the usual pond system but if water is a scarcity this is a very good solution*”. As stated by project managers of Case 1 and Case 4, all these applications totally depends on the cost, which is the responsibility of the contractor and the client, and prioritised within that context. Curing agents were already in practise in Case 4.

Re-use: It was observed that the implementation of ‘Reuse concept’ was successful in Case 1, which had a proper system to collect rainwater and use for dust controlling, vehicle washing, and for fire emergency. As stated by the project manager, Environmental Management System (EMS) was the main reason to implement above strategies on the site (Case 1). Case 3 used dewatering water during the construction of pile foundation. The engineers stated that the project did not have a predetermined plan for water use efficiency during the construction stage; however, such practices were implemented through staff experience. Further, the project manager of Case 3 stated that during construction, “*it is possible to re-use water that is used for water proof testing. It can be used for mixing mortar for the tile bed in the same floor if it is planned in advance*”. However, interviewees believed that the re-use of water is rarely accomplished on construction sites unless it is identified as a mandatory requirement during project initiation.

Recycle: EMS of Case Study 1 was greatly conducive for the implementation of ‘recycle’ during the construction stage. As stated by the project manager, it saved usage of potable water significantly. This is the only site, which adopted ‘Recycle’ concept for water resource. The interviewees revealed that none of the sites practised ‘Recycling’ if the requirements were not identified initially. It was noted, to get more benefits from them in a cost effective way, the intention should be communicated during the tender stage.

Removal: Removal means disposing the excess water legally with the responsibility of ensuring no flooding, pollution, or inconvenience to others due to disposal of excess or wastewater. The findings revealed another step of water hierarchy, which is in practice by the four construction sites. All sites adhere to current regulations with wastewater disposal. It is noted that this is one of the successfully implemented regulation on construction sites, since relevant authorities conduct inspections on regular basis.

Regulation: ‘Regulation’ is one of the policies acknowledged in literature. Most interviewees agreed that firm establishment of certain regulations for water use in construction is required to enhance water use efficiency practices in construction sites. It was observed that regulations on wastewater disposal were well practiced on construction sites, mainly due to regular inspection and monitoring as claimed by the interviewees. Project manager of Case 4 stated that rainwater harvesting should be implemented on sites and it is important to find ways to enrich ground water than just disposing wastewater to the municipal waste drain. If these aspects (re-use, recycling) are strictly implemented as shown in regulations initially, the contractor will be more responsible. Another important point highlighted by the project manager of Case 1 was, city water usage per day is unlimited, and no rules and regulations established for extracting ground water. The engineer of Case 3 stated, “*Regular check on quality of water is rarely practiced on construction sites. On many construction sites, city water is used for all direct and indirect activities. Therefore, the use of potable water must be monitored constantly; excess use of potable water needs investigation and strict control to make consumers realise the need for conserving potable water. Thus, regulations are vital to use potable water intelligently.”*

Reward: Interviewees of Case study 1 claimed, “*Rewarding is a good policy, which encourage both organizations (can be considered for contractor grading and awarding) and workers (incentives for innovative work) who strictly adhere to practice sustainability approaches*.” Similarly, engineer of Case 3 mentioned, “*If the contractor is rewarded for practicing innovative and sustainability practices during the annual award ceremony and during contractor performance grading, there is a high tendency to popularise water use efficiency measures including maintaining water hierarchy among contractors. These aspects will be well established in the construction industry*.” However, project manager of Case 2 stated, to implement water hierarchy, first it is important to educate management level, and these practices should begin at the director level or chairman level. Otherwise, planning and achieving his requirement becomes a massive task for the project manager. The project manager of Case 4 stated, “*Not only rewards but also penalties should be introduced with the system; then only people feel the value of taking steps on water saving measures*”.

Responsibility: Responsibility of industry stakeholders and actions towards environmental and social conservation and preservation of natural resources on construction site are primarily important to achieve sustainable use of water. It could be observed that in all cases, Responsibility of tasks is already determined and well-practiced. The project manager of Case 2 stated, “*We have already assigned persons and given responsibility on different tasks on water management on the site (e.g. recording daily water meter readings, site inspection on water collection areas, and report on leakages)”*. Many interviewees reported it is important that top management do monitoring, although others have assigned responsibilities.

Case study results showed that it is possible to implement ‘re-use’ and ‘recycle’ on construction sites; however, it should be communicated before starting the construction work.

Below is a previous experience on implementing water management strategies (stages of water hierarchy) on construction sites, shared during the empirical survey.

> *"This is an interesting exercise and a highly rewarding practice on the economics of the monthly cost overhead cycle of a contractor. I have personally practised this when working for ICC at the Pallekele Cricket Stadium site in 2003/2004. The labour accommodations had long tanks filled with potable water for bathing and washing. I did away with them and introduced showers and taps. The water bill reduced by over 70%. The ordinary toilet cistern used in female toilets and the male Water Closet flush down 6 litres each time. We introduced one litre plastic water bottle in the cistern and saved a litre of water on each flush. The runoff water from batching plant and the truck wash water was passed through sedimentation and a settling tank, and a filtering process. This water was subsequently used for curing work. It was so cost effective and interesting. Ultimately, it changed the attitudes and wrong practices of the workers as well".*
>
> "*According to my research, water curing is more effective than membrane curing. Water curing delays the initiation of corrosion more than membrane curing*".

In addition to the comments made on each R by interviewees, i.e. project managers and engineers, few made general comments on 3R as follows:

> *"None of the regulations work out properly without a proper monitoring system."; "Not only 'rewards' but also 'penalties' should come with the system. Then only people feel the value of taking steps on water saving measures"; "Even assigning responsibility among the parties, acknowledgement of attempts of each individual is crucial for better achievement".*

Furthermore, interviewees stated that, *"win-win sustainability situations are achievable and a close relationship exists among each other. For instance, monitoring is essential in 'responsibility' and 'rewarding' policies are in place. Consequently, if the job is performed in a more responsible manner, the rewards are offered automatically in return".*

7. EXTENDED WATER HIERARCHY MODEL

Information collated from findings of case study, questionnaire survey, and from literature findings, formed following conclusions in this study:

- The original six stages of sustainability strategies of water hierarchy (6R) of SFfC in the UK were statistically proved and accepted for the Sri Lankan construction industry.
- Case study results bear evidence that certain are followed in construction projects at present, but there is no proper way to establish such systems.
- New 3R principles (Responsibility, Regulations, and Rewards) were also accepted and identified as supportive to implement all six existing stages of water hierarchy; i.e. new 3R principles influence on receiving successful results from each strategy of existing water hierarchy.

Based on the above conclusions, the study presents 3R.6R extended water hierarchy model for efficient water use during construction phase, as illustrated in Figure 3, 3R principles represent the three vertical sides of the inverted pyramid that support each 6R principle This proposed extended water hierarchy model ensures excellent control of water resource and potential uses under the sustainability agenda and requirements may vary according to the unique characteristics in the construction projects and its goals. Thus, implementation of these concepts provides a positive indication of establishing water efficiency practices within construction sites.

Figure 3: 3R.6R Extended Water Hierarchy Model for Construction Industry

In addition, interviewees from case studies and questionnaire survey suggested that cost has a major impact on the implementation of water hierarchy other than challenges that may have to overcome initially, such as introducing at the design and tender stage, showing competitive advantages by implementing the system, and support from the authorised institutes. It revealed that the additional cost on attempting WEC measures and sustainable values in-use should incorporate into the contractual documents. Therefore, recognition of builders' capacity to deal with water use efficiency should integrate with pre-qualification and contractor selection criteria.

8. CONCLUSIONS AND RECOMMENDATIONS

The applicability of each R was explored with case studies and examined during the questionnaire survey. Thus, the study sought the views of construction professionals representing Project Managers, Civil Engineers, Quantity Surveyors, and Architects with over ten years of experience in building construction projects, on the acceptance of the applicability of 9R sustainability behaviour policies for water sustainability during the construction phase. In addition, four (04) ongoing construction projects were examined during the data collection process. Quantitative and qualitative approaches were employed during collection and analysis of data.

The study revealed that among the 9R principles, certain Rs in the hierarchy of SFfC, such as 'replace with alternative sources', 'reduce', 'reuse', 'recycle', and 'removal' are in practice in construction sites. Similarly, the Strategic Forum for Construction (SFfC) in United Kingdom identifies that 'reducing water use on construction sites' as an important aspect. However, idea of the majority of respondents was that "reuse" and "recycle" are rarely followed by construction sites, if not identified as a mandatory process. Conversely, the literature shows that 'Re-use' and 'Recycle' contribute positively to sustainability/ green concepts and to waste management processes. Interviewee personnel accepted the applicability of each R, and identified the importance of new 3R, i.e. Regulation, Responsibility, and Rewards. It denoted that all 9R are applicable, but actions taken by client/consultant during the design and tender stages and contractor (top management) during construction stage will inevitably propel the construction industry towards water sustainability. On the other hand, few respondents commented that application of certain 9R on construction sites totally depends on the experience and commitment of the individual staff. Cost was identified as an important driver on the implication of each R. New 3R attributes are identified as supportive principles to implement all six existing stages of water hierarchy. Based on empirical findings, the 3R.6R extended water hierarchy model was developed and that can be applied for sustainable use of water in construction industry**.**

Recommendations can improve the implementation of environmental policies on natural resources, and assigning responsibility and targets among the site staff. Concisely, sustainable use of water during construction phase is still in its infancy. Therefore, this research recommends that the relevant authorities in Sri Lanka, i.e. Construction Institute of Development Authority (CIDA), Central Environment Authority (CEA), Urban Development Authority (UDA), Road Development Authority (RDA), and National Water Supply and Drainage Board (NWS&DB) should formulate policy measures to promote and establish water sustainability policies during construction. The study will provide a platform for future builders, who shall be environmentally responsible and plan to implement water efficiency and conservation measures in practice. Finally, the study findings revealed that initiation of correct actions is necessary to bring sustainability or green concept in construction industry to the forefront of the development agenda of the country.

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