Liquid Waste Management in the Construction Projects

Professor Srinath Perera

A/Professor Mary Hardie

Shiyamini Ratnasabapathy

WESTERN SYDNEY UNIVERSITY

Centre for Smart Modern Construction

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ABOUT THE AUTHORS

Professor Srinath Perera, Professor in Built Environment & Construction Management, Western Sydney University

Professor Srinath Perera is the founding Director for the Centre for Smart Modern Construction (c4SMC) and holds a personal chair in Built Environment and Construction Management in the School of Engineering, Design & Built Environment at Western Sydney University. He is a Chartered Quantity Surveyor and a Fellow of the Australian Institute of Builders. He was admitted as a Fellow of the Royal Society of New South Wales in 2017. He is also a member of the Australian Institute of Project Management and the Australian Institute of Quantity Surveying. He is a board member of the International Council for Research and Innovation in Building and Construction (CIB). He holds a PhD from the University of Salford, UK. Professor Perera is a pioneer in the field of construction informatics where his work contributed to the integration of AI technologies into construction management subsequently developing his research in the area of e-business and Blockchain in construction. He has over 200 peer-reviewed publications and textbooks. He has received over 20 million dollars in research grants in his research career.

Associate Professor Mary Hardie, Professor in Built Environment & Construction Management, Western Sydney University

Mary Hardie is the Associate Professor in Construction Management and a Director of Academic Programs at Western Sydney University. She is a registered architect who has been involved in the construction industry for more than 40 years and has worked in 'Design and Construct' building companies as well as in building design. She is a Fellow of the Australian Institute of Building and a member of the Australian Institute of Architects. Her research interests are construction innovation and sustainable construction. Mary was involved with several research projects with the Cooperative Research Centre for Construction Innovation. The projects involved various aspects of the diffusion of construction innovations as well as waste minimization in construction. In 2011 she completed her PhD thesis which focuses on "Technical innovation in small and medium construction enterprises". She also has a strong interest in education for sustainable practice.

Shiyamini Ratnasabapathy, Doctoral Researcher, Centre for Smart Modern Construction (c4SMC), Western Sydney University

Shiyamini is a Doctoral Researcher at c4SMC and a Casual Academic at the School of Engineering, Design and Built Environment. Her educational qualifications and professional experience have been focused on developing a career path as an academic. She graduated with a Bachelor Honours Degree in Quantity Surveying from the University of Moratuwa, Sri Lanka where she also has successfully undertaken her Master of Philosophy in the area of Construction Procurement. Her current research focuses on developing a digital incentive mechanism to enhance construction waste management through Blockchain technology. Before she joined WSU as a Casual Academic, she had been serving as a Causal Academic at the Faculty of Built Environment, University of New South Wales (UNSW) and as a Lecturer at the University of Moratuwa. She has published several research papers in peer-reviewed journals and conferences. She is also a winning team member of 'Constructathon 2019', the first construction hackathon in Australia. She also has been working as a Consultant Quantity Surveyor for several international projects on a part basis.

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ACT	Australian Capital Territory
BOD	Biological Oxygen Demand
BOQ	Bill of Quantities
CCO	Chemical Control Orders
COD	Chemical Oxygen Demand
DA	Development Application
DEC	Department of Environment and Conservation
DWE	Department of Water and Energy
EIA	Environmental Impact Assessment
EPA	Environment Protection Authority
LW	Liquid Waste
LWM	Liquid Waste Management
PC	Principal Contractor
PM	Project Manager
PS	Provisional Sum
POEO	Protection of the Environment Operations
QS	Quantity Surveyor
NSW	New South Wales
VIC	Victoria
WA	Western Australia
SA	South Australia
QLD	Queensland
NT	Northern Territory
TAS	Tasmania
US	United States
SEDMP	Soil Erosion Drainage Management Plan
SS	Suspended Solid
ML	Milli Litre
WMP	Waste Management Plan

1 INTRODUCTION

The construction industry is increasingly concerned with improving its environmental performance and reducing the environmental damage which often results from construction processes. The depletion of natural resources, increased global warming and pollution is stimulating the construction industry to put more importance on issues related to environmental sustainability (Park & Tucker 2017). The future reputation of the industry depends on the careful and responsible use of finite resources. It also depends on the industry addressing the potential unintended damage done to the natural environment. While environmental impacts were once regarded as 'externalities' and therefore not counted in project evaluations, this is no longer the case. Triple Bottom Line assessment of all kinds of development projects is increasingly common (Elkington & Zeizt 2014).

There are several ways of evaluating the environmental impact of creating new buildings. We now routinely measure quantities such as embodied energy and embodied carbon. Building rating systems such as Green Star also take account of many diverse factors in order to produce a more accurate measure of the wholistic impact of a project. These ratings can incorporate several of the following elements:

- Sustainable management practices
- Indoor air quality
- Energy usage
- Transport connections
- Water usage
- Materials selection
- Land use and ecology
- Emissions
- Innovation

In order to continually improve the value of such assessments, the items of environmental impact that are not fully captured at present should be studied to improve the validity of the rating system. This intent motivates this research. While the water efficiency of fixtures in a building and the recycling of water for secondary usages are already captured, there are knowledge gaps around the use of water on-site during the construction process. In particular, the impact of Liquid Waste Management (LWM) on construction sites is under-recognised and rarely studied.

A large amount of water is used for cleaning on-site and even in times of water restrictions, this is largely ignored. It tends to become a matter that is monitored only when a concerned client mandates a focus on the issue.

There are few current studies that include LWM on construction sites (Waidyasekara et al. 2017) and the issue is largely disregarded by approving authorities for construction projects. Wastewater is often disposed of on-site with little regard to its impact on the site or to the quantum of water that is wasted for processes such as site cleaning and tool washing. Despite the liquid waste management services that are available for the management of liquid waste/wastewater generated on-site during the construction stage, an inspection carried out on 400 construction sites for sediment and runoff controls by 19 councils across Sydney and Lake Macquarie it was found that only 62 % of sites were compliant with the runoff requirements (NSW EPA 2019). Cost constraints often mean that some polluted wastewater is disposed of into the sewer, escapes to waterways or infiltrates into the soil. Each of these outcomes is problematic. Some chemicals used on construction sites can be deleterious to the natural environment even in the diluted form that may result from washdown. Residual chemical pollution in the soil may eventually escape during heavy rain and cause difficulties further downstream.

It makes sense that removal of potential contaminants at the source is a much preferable action to the recovery of contaminants once they have caused damage elsewhere. Consequently, this research will observe the current state of practice with the treatment and management of liquid waste on construction sites in Australia. It will investigate the range of current practices that are used to treat water before its disposal from the site. It also reviews the relevant legislation in managing water on construction sites. Systems that improve current practice will be studied as comparators.

The cost of water supplied to consumers in cities in Australia bears little relationship to the total cost of creating and maintaining our water supply infrastructure. Governments subsidise the cost of mains water heavily because water is an essential resource for living things. An unintended consequence of this is that the use of water on construction sites is largely unrestricted because the immediate cost impact of water use is negligible. Indeed, water usage on construction sites is often wasteful and even profligate. At the same time, however, many areas of Australia are drought-prone and undergo regular periods of water shortage and not infrequent sessions of imposed water restrictions. In view of this, it makes sense to look at all possible areas where water usage can be reduced by better management. Improved water management on construction sites can certainly play a role in reducing potable water wastage.

In summary, this research will investigate ways to reduce the overall use of water on construction sites, as well as, specific improvements that can be made to the quality of wastewater that is disposed of from construction sites.

The following are the main objectives of the project:

1. To review the literature on the current status of liquid waste management in construction;
2. To review the relevant legislation established for liquid waste management in general;
3. To evaluate the sources of liquid waste generated from major construction projects and identify the current management methods;
4. To estimate the volume of liquid waste generated on-site from data provided by the client;
5. To estimate the volume of water-saving by using sustainable waste management methods for liquid waste management;
6. To estimate the cost savings due to using more sustainable waste management techniques for liquid waste management.
7. To analyse the experience reported in three expert interviews focusing on liquid waste management on construction sites.

This research has the potential to add new and under-measured factors to the current systems for the Green Rating of buildings. In doing so it will strengthen the reliability of such assessments and produce a more sustainable construction industry.

2 RESEARCH DESIGN

This study primarily adopted a mixed-method approach comprising quantitative and qualitative methods of data collection and analysis to achieve the objectives of the project. It combines a comprehensive literature review, expert interviews, review of related documents and quantitative analysis of raw data collected from an organisation that provides a site-based, totally closed-loop tool wash solution for all construction and maintenance sites that require washout facilities for wet trades.

Figure 2.1 depicts the overall research processes followed in this study.

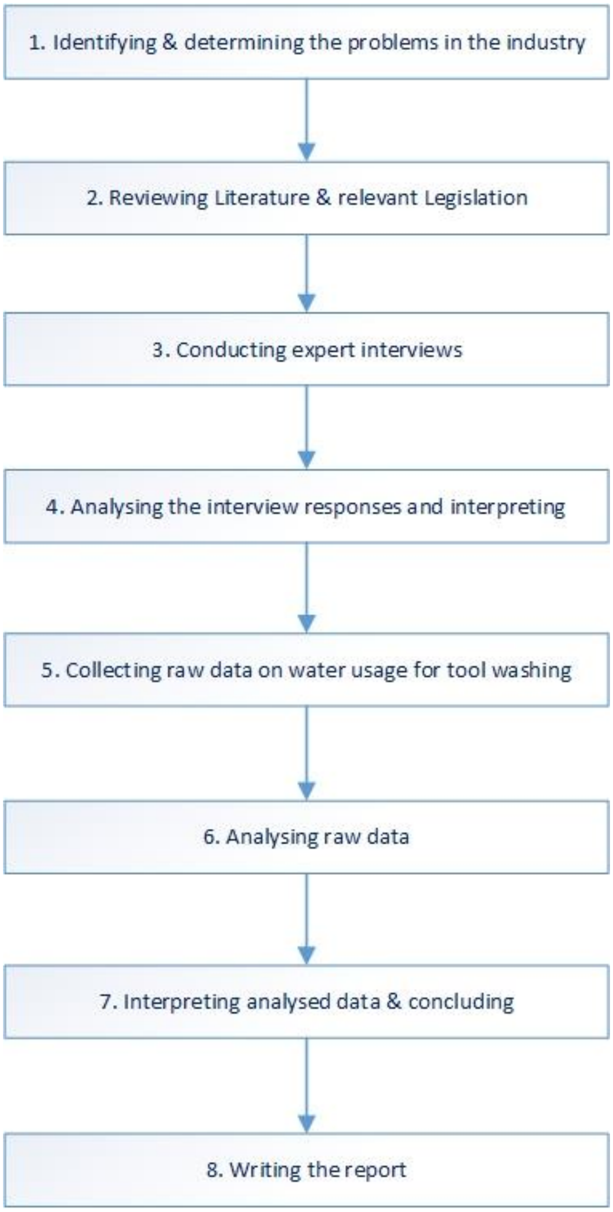

Figure 2.1:Overall research process

2.1 Literature Review

Initially, a comprehensive literature review was carried out to understand the definition of liquid waste/wastewater, the main sources of liquid waste, the classification and characteristics of liquid waste in general. An appropriate definition of liquid waste is important to provide a consistent means to determine whether or not liquid waste is suitable for disposal at the landfill or into the public sewerage network. In addition, the review identified the key LWM pathways, guidance for LWM and relevant regulations/legislation stipulated for LWM across the different states in Australia and currently practised in the construction industry.

2.2 Expert Interviews

Following the literature review, three semi-structured interviews were conducted with industry experts to evaluate the impact of liquid waste/wastewater generated from construction projects. Participants for the interviews were selected based on their level of involvement and experience in construction project management (a minimum of five years). The interviewees included top-level managers with more than 20 years of industry experience and represented different types of construction projects. The interview participants were asked to provide their opinion and comments on the current status of LWM practices followed in construction projects. The interviews mainly focused on identifying the main sources of LW, on-site LW management practices/procedures, pre-treatment requirements, any issues related to LW management and regulations established for managing LW on-site from the waste generation phase to the disposal phase.

2.3 Data Analysis

Qualitative data collected through the interviews were analysed using content analysis methods and the analysed data was used to evaluate the current status of wastewater management practices and issues with on-site LWM. Quantitative data collected from the subject organisation have been used to estimate several data points related to the research such as the volume of water used for the on-site tool washing and the possible volume of water-saving achieved in tool washing for different types of projects handled by different sizes of builders/developers.

3 REVIEW OF LIQUID WASTE MANAGEMENT IN CONSTRUCTION PROJECTS

This section provides a review of the status of the liquid (and/or wastewater) management, wastewater (Trade/Commercial) regulations and guidance for handling, storing and processing liquid waste in general in the Australian context. According to Liquid Trade Waste Regulation Guidelines 2009 (NSW Office of Water), liquid trade waste includes all liquid waste other than sewage of a domestic nature (waste typically produced in the course of daily residential living). The guidelines cover liquid waste/wastewater generated from any industry, business, trade, manufacturing process or similar that is approved for discharge to sewer but does not include wastewater from domestic nature (Trade Waste Code 2001 of Power and Water Authority of Northern Territory).

According to Sydney Water, trade waste includes the following;

- Wastewater produced at industrial or commercial premises
- Wastewater transported by vehicle, including septic effluent
- Wastewater from ships and boats
- Run-off from contaminated surface water and groundwater.

3.1 Guidance for the Liquid Waste Management: Storage, Handling and Processing

Proper management of liquid waste is critical to reducing the negative impact on the environment and human health. The NSW EPA provides guidance to effectively manage liquid waste. This guidance regulates the overall processes of liquid waste management including handling, segregation, storage and processing of liquid waste under the Protection of the Environment Operations Act (POEO Act) 1997 (State of NSW & NSW EPA 2016). According to Sydney Water, following the regulations and getting approvals for discharging trade wastewater has several benefits to health and the environment including;

- Protecting people working in and around the wastewater system
- Protecting the environments which receive wastewater such as rivers and oceans
- Protecting the wastewater system and treatment plants from damage
- Processing wastewater and producing recycled water and good quality bio solids
- Encouraging waste minimisation, cleaner production and water-efficient practices.

3.1.1 Handling liquid waste

An effective and safe method of handling liquid waste is critical to reducing the risk to the environment and social health. Once a safe method is determined, it is important to identify the areas on-site where the liquid waste is handled (DEC NSW 2005). This process requires a unique level of experience, precaution and responsiveness to detail. The key areas which need careful consideration include the following;

- Liquid waste storage areas
- Loading and unloading areas
- Production lines that generate liquid waste
- Wastewater treatment plants
- Wet areas where equipment or floors are routinely cleaned.

According to DEC NSW (2005), it is important to regularly inspect the areas where liquid waste is handled and make sure that:

- liquid waste handling areas are clean, tidy and free of trip hazards
- storage areas are routinely maintained and free of debris, rainwater and liquid waste
- stormwater drains are not located in areas where liquid waste is stored or handled
- all drums, containers and tanks that contain liquid waste are clearly labelled to ensure their contents and lids or caps are secure
- spill kits are located in areas where liquid waste is handled

At the same time, it is also important to make sure that the liquid waste does not enter the stormwater system by:

- locating all drains at the premises and knowing where they discharge to
- identifying the drains that are connected to the stormwater system and ensuring that only uncontaminated rainwater enters them
- ensuring that drains inside buildings or covered areas do not discharge to the stormwater system
- clearly labelling all drains at your premises and knowing which drains can only accept uncontaminated stormwater.

Department of Environment and Conservation (DEC, NSW) provides relevant guidance to improve the handling of liquid waste and minimise the harm to the environment.

3.1.2 Storing liquid waste

Liquid waste should be stored in an environmentally safe manner to make sure that it protects the environment and minimises the risks to a particular industry or domestic activity which generates liquid waste. Accordingly, liquid waste needs to be stored in a bunded and covered area and it is better to minimise the number of liquid waste containers stored at a particular premise. When selecting a suitable area for the storage of liquid waste, the following aspects are to be considered (DEC NSW 2005);

- Consider the type and volume of liquid waste to be stored.
- Identify the type and regularity of access to the waste storage area.
- Ensure that no stormwater drains are located in the proposed storage area.
- Where possible, minimise the distance needed to move waste containers on site (for instance between the storage area and where wastes are generated).
- Select a location where activities (such as forklift movements) are minimised.
- Consider the sensitivity of the surrounding environment when selecting a storage area.

Further, in setting up a storage area, all the designated liquid waste storage area and the contents of the liquid waste stored need to be clearly labelled to indicate that the liquid waste may be suitable for reuse or recovery or that are being stored for collection by a particular waste processing facility (DEC NSW 2007).

3.1.3 Processing liquid waste

Processing liquid waste varies with the type and contents of the liquid waste. The waste generator should classify the liquid waste prior to storing and collection by a processing facility. However, the receiving and processing facilities have the responsibility to ensure the waste has been properly classified to certify the waste can lawfully be stored and/or processed at their facilities. It is also the responsibility of the processing facilities to ensure the different types of liquid waste that they accept can be stored, processed and treated appropriately with standard operating procedures in place and without incompatible wastes being mixed. (State of NSW & NSW EPA 2016).

3.2 Trade Wastewater Management in the Construction Industry

Construction and demolition activities involve several trades and some of the trades require the use of different types of heavy equipment, trucks and tools which are generally identified as the parts of construction assets. These types of construction assets can accumulate dust, mud, concrete and other waste from trades such as painting, plastering, rendering and tiling. Therefore, each construction site requires on-site washing out facilities to enable regular cleaning of this equipment, trucks and tools used during the construction stage. Moreover, some types of machinery used for excavation and foundation require cooling by water after or while operating. Proper care and maintenance of these construction assets are important not only to avoid mechanical problems or corrosion but also to reduce failures and delays while construction activities are progressing (CleanaWater 2020).

At the same time, liquid waste generated from the tools washing and cleaning process involved with trades needs to be properly managed either on-site or off-site as it may contain toxic substances or gases and hazardous solid materials which are harmful to the environment and human health, polluting the groundwater and the ground soil. Chemicals, oils, and greases, as well as large amounts of silt, can cause blockages, resulting in overflows and strong odours released to the environment and problems in downstream wastewater treatment plants as well. These contaminants must be captured carefully and removed from wash bay wastewater (CleanaWater 2021; Icon Water (2020).

3.3 Classification of Liquid Waste Generated by Construction Industry

Waste classification systems grouped by jurisdiction classify waste into several categories which vary across the states. Waste definition and classification for C&D waste streams also differ across states and territories. The construction industry has not been included either under the category of discharging industrial trade wastewater or commercial trade wastewater in NSW. As such, there is no specific waste category available to include wastewater generated from construction activities on-site. However, wastewater generated by building and construction activities has been classified as ‘Liquid trade Waste’ in the ACT (Icon Water 2020).

At the same time, some basic materials such as cement, stone and abrasives have been included under the category of discharging industrial trade wastewater. Similarly, some of the processes associated with the construction sector (includes medium/high-density developments, mixed developments, commercial and industrial developments) have been included as the ‘deemed process’ for the requirements to meet pre-treatment, backflow prevention and other requirements under the category of commercial trade wastewater in NSW. Those deemed processes include slab formation (no discharge from this process to the sewer is allowed) and wash water generated by the washing of painting and plastering tools such as brushes, trays and spatulas (Sydney Water 2020). Pre-treatment is the process of treating trade wastewater appropriately using suitable items of equipment before discharging it to the sewer. Considering the need for approval to discharge the trade wastewater as a deemed process, wastewater generated during the construction stage can be included under the category of ‘Commercial Trade Waste’ treating the construction industry as a secondary manufacturing industry. However, the construction industry is one of the industries which largely fails to recognise that the industry is responsible for managing liquid waste to comply with the legislation.

3.4 Sources of Liquid Waste/Wastewater Generated from Construction Sites

The construction sector generates wastewater from various sources, which is related to several trades involved from the conception to the destination phase of a project. Concentrations of contaminates and flow rates of wastewater generated from construction trades greatly vary and depend primarily on the source (Aerofloat 2021).

Water is one of the key resource components for any construction project. It is not only used as an ingredient in some materials but it is also used as a means of cooling machines (e.g. tunnel boring machines, drilling rigs and cutting machines) which are involved in some trades such as excavation and as a means of cleaning construction assets (Nihon Kasetsu 2020). Simultaneously, water management is considered as an essential part of the Environmental Impact Assessment (EIA) of a construction project, particularly in major construction projects such as civil engineering projects where the volume of water usage and wastewater generation is comparatively high. Therefore, proper management of water in any type of construction project is essential to;

- optimise its consumption and
- ensure that the properties of such water when it is discharged to the public sewer has no adverse impact on human health and the environment.

The locations where wastewater from construction sites are likely to be discharged include natural ground, stormwater drains and public sewer networks. Many developed countries have established local and national regulations defining the quality of the water that is permitted to be discharged to the public sewer. Those regulations set some limitations for the values of some of the properties of water such as suspended solids (SS), acidity (pH), biological oxygen demand (BOD) and chemical oxygen demand (COD) (Nihon Kasetsu 2020). If those values exceed the limitation, the wastewater cannot be discharged to the sewer, resulting in a requirement for proper treatment on-site or off-site. Most of the jurisdictions in Australia require pre-treatment and approvals to discharge the wastewater/liquid waste generated at construction sites. Proper treatment is, therefore, essential to comply with the standards and regulations established by the local authorities. The level and type of wastewater treatment required for construction wastewater are determined by the type of construction and resultant effluent quality (Aerofloat 2021).

3.5 Stormwater Pollution Prevention at Construction Sites

According to the Environment Protection (Water Quality) Policy 2015 and hence by law, certain types of pollutants that are relevant to the building and construction industry should not be discharged into the stormwater system from any construction sites. Those types of pollutants that are most relevant to the construction industry are listed below (SA EPA 2021);

- Brick, bitumen or concrete cutting wastewater
- Building wash water
- Washdown water from cleaning vehicles or equipment
- High-pressure water blasting waste
- Building construction or demolition waste
- Concrete waste
- Roof cleaning waste
- Paint and paint scrapings, painting wash water, paint stripping waste, stain or varnish
- Plaster, plaster waste and plaster wastewater
- Sawdust
- Solvents, stain or varnish
- Soil, clay, gravel or sand
- Rubbish, hard waste

These pollutants must be properly managed to prevent impacts to the waterways and oceans. In order to ensure that the above-listed pollutants do not enter the stormwater system and also to fulfil the legal obligations of the Water Quality Policy, the Code of Practice for the Building and Construction Industry strongly recommends that all construction sites carry out erosion, sediment and drainage control management practices. It also requires all construction organisations to prepare a soil erosion drainage management plan (SEDMP) for certain cases;

- where there is a high risk of sediment pollution to adjoining lands or receiving waters; or
- if the total area to be disturbed or left disturbed, at any one time exceeds 0.5 ha.

The Code of Practice for the Building and Construction Industry when coupled with the Water Quality Policy is principally designed to assist construction organizations in compliance with their general environmental duty.

3.6 Relevant Regulations for Trade Wastewater Management

According to Hyder (2012), the Australian state and territory governments are mainly responsible for the regulation and management of environmental issues, including all waste streams, in accordance with their respective legislation, policies and programs. The review found that not all the EPAs across the nation have inclusions on the trade waste related aspects that are specifically associated with construction activities. As per the review, only EPAs of VIC, QLD and SA and the Department of Water & Energy of NSW Government have addressed some of the legal requirements, procedures and guidelines relevant to sediment control and discharge of contaminated water from construction sites. Local authorities such as water utilities are responsible for the administration and regulation of trade waste management and control in other jurisdictions. Table 3.1 presents some of the examples for legal requirements related to construction and demolition waste which are common to all waste types. Some of them are trade waste specific with respected regulations/policies/standards at the state government, local authority and council level in NSW.

A review of legal requirements, policies and guidelines from relevant documents published by several legal authorities across the different states and territories revealed that not all the jurisdictions have established regulations related to stormwater water pollution prevention and approval for the discharge of trade wastewater generated particularly from construction sites. While the liquid waste classification systems in Australia vary across jurisdictions, there are considerable inconsistencies in regulations related to liquid waste generated from the construction sector across the different states and territories. However, general requirements and guidelines have been established for all businesses and/or other industries that intend to install a wash down area which will be connected to the sewer. It is important to note that there have been lack of specific requirements and guidelines which are consistent across the jurisdictions established for the construction industry.

Table 3.1: Regulations and guidelines relevant to wastewater generated from construction sites in NSW

Level	Name of the Local Authority/Council	Description	Relevant Regulations/Guidelines	Reference
State Government	NSW Government-Department of Water and Energy	• **Liquid trade waste charging categories** Category 2 Discharger - Trade Waste dischargers with prescribed pre-treatment include Classification B activities: construction equipment maintenance (i.e. Earth moving equipment and /or cranes) and cleaning (External Truck washing) – waste includes Oil, Grease, Suspended Solids Detergent, Kerosene • **Pre**-treatment requirements for construction/plant equipment washing from the local council	Liquid Trade Waste Regulation Guidelines	Department of Water and Energy (2009); NSW Government (2021)
Local Authority	Sydney Water (Sydney)	**Approval is required to discharge commercial trade wastewater from certain construction trades as a 'deemed process:** • to use pre-treatment apparatus such as brushes, trays and spatulas • to discharge water from slab formation to the wastewater system (sewer)	• Protection of the Environment Operations Act 1997 • Responsibilities of connected customers policy	Sydney Water (2021)

Local Authority	Hunter Water Corporation (Newcastle)	• **Approval is required to install a trade waste pre-treatment facility** that complies with the local authority's requirements for on-site operations • **Pre-treatment facility requirements** • **Trade Waste Deed:** An approval required to discharge the trade waste to the sewerage system	• Trade wastewater Policy • Trade wastewater standards	Hunter Water (2021)
Local Council	City of Parramatta	**Submission of the waste management plan (not liquid waste specific)** required for all • Demolition work • Construction works including alterations or additions to existing buildings. • New and amendments to existing commercial developments that will affect waste generation and/or management **Submission of site plans/drawings** is required for management of ongoing waste generation, showing the location of areas for sorting, stockpiling and access path for vehicles removing waste from the site. **Controls:** Requirement for documentation of waste transport and disposal of waste and recycling materials from site **(not liquid waste specific)**	• Protection of the Environment Operations Act 1997 • Better practice guide for waste management	City of Parramatta (2021)

3.6.1 Issues especially related to construction sites

Construction sites are an environment that is constantly changing and have large quantities of materials and workers moving through limited spaces. This specific nature creates a challenge for most projects in implementing wash bays at project sites. Traditional washing systems are mostly centralised and not flexible enough to change the location, resulting in disturbing the movement of material and workers in and around the project site. Therefore, a wash bay should be designed to be modular and portable to facilitate the movement of the wash bay whenever it is required. A customized and portable wash bay that is specifically designed to suit the project's characteristics and its site environment would be more efficient than a traditional wash bay system. Figure 3.1 and Figure 3.2 portray an automated wash bay that has been installed in a landfill site and a modular tool wash box used in a construction project site respectively.

Moreover, certain legal requirements for pre-treatment of wastewater need to be considered in setting up the wash bays at sites. For example, according to Sydney Water, a minimum of 1,000 litres general-purpose pit or solid settlement pit is required to manage the wash water generated by washing equipment and tools. Key elements that are to be considered in designing a construction wash bay at sites are discussed below (CleanaWater 2020).

Figure 3.1: Automated wash bay located in a landfill site

Image Source: Catchments & Creeks Pty Ltd.

Figure 3.2: Sustainable Tool Washbox for construction sites

Image Source: Geosentinel Australia Pty Ltd.

3.6.2 Wash bays and tool washing

The reason for installing a wash bay is to contain and process wastewater for discharge to a sewer. If no trade waste sewer is accessible, it may be necessary to store the wastewater for disposal by a licensed contractor. At the same time, it is important to ensure that the customised wash bay solution provided at the construction site is compliant with the wash bay requirements in accordance with the Australian regulations (CleanaWater 2020).

It is important to prevent rainwater from transmitting to the trade waste sewer network via a wash bay rather than the stormwater network. Wastewater treatment plants are not designed for the peak flow rate of rain events. For this reason, either roofed construction or first flush diversion systems are required for wash bays more than 20 m^2 in area (CleanaWater 2020).

The availability of space at construction sites varies throughout a project. Portable wash bays provide high flexibility to move the bay from one area of the site to another, depending on the conditions dictate. In addition, they do not require excavations during installation which minimises their impact on the site (CleanaWater 2020).

4 ANALYSIS OF EXPERT OPINION

4.1 Purpose of Review

Construction activities involve work from several trades typically known as "finishing trades". These trades include painters, plasterers, tilers, renderers, block layers and landscapers. They use products such as paint, plaster, tile grout and adhesive, cement and various patching, filling and sealing compounds as part of their works. These products are applied using tools that are reusable and require cleaning at various stages of the works in order to maintain a productive and quality finish.

The washing of these tools takes place in water, and the process ultimately contaminates the water when the waste products are washed from the tools. This wastewater needs to be properly managed either on-site or off-site as it may contain toxic or hazardous compounds, or be required to be managed because of a regulation or waste classification pertaining to it. This type of liquid waste may be harmful to the environment and human health, polluting the groundwater, soil, creeks, rivers and oceans. Even if this waste is discharged into the sewer, there is still potential for it to enter the environment in either a raw or semi-processed state. Chemicals, oils, and greases, as well as large amounts of silt, can cause problems in downstream liquid waste treatment plants as well.

This review aims to evaluate the impact of liquid waste or wastewater generated from construction projects during the construction phase through the investigation of the current status of liquid waste management practices in construction projects. The following are the purposes of the review;

- To identify the sources of liquid waste generated from construction projects;
- To identify the current management methods practised on-site and possible pathways of managing liquid waste on-site;
- To estimate the volume of water used for the washing process on-site;
- To estimate the volume of water-saving by using sustainable waste management methods for liquid waste management;
- To identify the legal obligations and regulations related to on-site liquid waste management for the construction projects.

4.2 Profile of the Participants

Participants for the interview were selected based on their involvement and experience with a minimum of five years in construction project management. Altogether, three top-level managers who represented different types of the project were interviewed. The profile of the participants who were interviewed for this study is presented in Table 4.1.

Table 4.1: Profile of the interview participants

Interviewee No	Experience (years)	Position	Type of Project Engaged	Size of the Organization
Interviewee 1	20	Director	Residential	Medium
Interviewee 2	28	Project Manager	High school/ Multi storied car park	Large
Interviewee 3	30	Construction Manager	Research School for University	Large

4.3 Analysis of Expert Interviews: A General Summary

Table 4.2: A general summary of cross interview analysis

Main Aspects	Summary Statements
Sources of Liquid Waste (LW)	The trades which produce LW from construction projects are; • **Excavation**- sediment slurry runoff (which is sticky) from rock excavation/piling • **Concreting** - liquid from classic concrete washout • **Painting/Staining** - washing of brushes, rollers, trays tins, etc. • **Tiling** - washing tools • **Rendering/Plastering** - washing tools • **Plasterboard(Gyprock)** - washing tools used to join plasterboards • **Brickwork** - washing tools used for bonding and waster from acid washing • **Others** – - Water runoff from hydraulic and mechanical sprinklers during testing. - Water used for cooling concrete cutting and on machines.
Waste Management Plan (WPM)	• Plans for managing LW on-site is not specifically considered at the development stage of a project and planning is done during the construction stage only. Hence, there is no separate section included for LW in the general WMP.
On-site Liquid Waste Management(LWM)	• There is no planning for LWM done at the Development Application stage and it happens at the construction stage. • LWM is not specifically considered in planning waste management at the initial stage for all projects. For the projects to which the government is client, WM is part of the requirements for environmental management, planned through a construction environmental management plan. All the contracts requirements that are relevant to the WM need to be fulfilled and PM who is assigned for the project is responsible for developing the plan. No water is allowed to run off the street or storm waterlines. • Managing both solid and liquid waste is generally handled by the principal contractor(PC). if the PC installs something to manage the LW on-site, it is typically hiring Wheelie bins or 44 Gallon drums, placing them side by side, taking the overflow and letting the solid go down to the bottom of the bin/drum and remove them using a shovel. It is an intercept style of having 44 Gallon drums with an open hose cock for washing tools and Wheelie bins that collect all the solid waste which does not comply with the requirements of LWM. And the drained water is just discharged into the sewer. Plastic sheets are placed with signage to wash out the concrete. The solid part from the concrete is captured, dried out and crushed up. • In some projects, at the end of the day when closing the site, whatever the solids are tipped them out from the wheelie bin. No authority regularly has an inspection on it. • The LW removed from the site by a separate contractor is managed off-site and reported.

	• During the construction stage, for concrete, the box system with a sheltered filter was used. The concrete suppliers used to provide the sediment bins which is quite large, probably about 3 m x 3 m in size and include filters. A typical sediment tank arrangement with forced filtration is used for brickwork when there is no Washbox system installed on-site. • For other trades such as tiling, painting, plastering and so on, the trade people are required to use their own system for washing tools on-site till the Washbox was introduced to the project. As the subcontractors are typically on very low margins in the supply chain, they can't afford a solution like Washbox. • Some builders are learning from the past few years where they would actually have options and some are going forward into what their sustainability policies are and starting to use some form of washout.
Disposal of LW on-site	• In a project site where there are no proper washout services employed to manage the LW, the LW generated from tool washing and washout from concrete and brick/blockwork is discharged to the main sewer once the solid is drained out, but without treatment and no inspection is done by any authorities unless it is reported. • Water drained during the testing of hydraulic and mechanical sprinklers will go down to the sewer. • No water is allowed to run off the street or storm waterlines if the builder's policy is to fulfil the compliance.
Estimating and reporting of LW generated on-site	• There is no formal reporting involved with LW generated from the trades such as painting, tiling, plastering/rendering, plasterboard and acid washing. • LW which is managed by other companies who use vacuum trucks and take the LW away for recycling is reported by the wastewater recycler and the reporting is generally required to get the certificate. However, the inspection is done by an assigned site professional through observation. And the cost involved in disposing of the LW by another company is estimated and included in the budget. • The cost involved in disposing of the LW by another company is estimated by the Quantity Surveyor and included in the budget. • For a project where the head contractor does not take responsibility to manage LW, trade people are required to arrange the washout facilities on their own and inform the head contractor about the services. Trade people do not estimate the LW generated from their trade on-site. However, the trade people will allocate some costs for tool washing in the package. • Water used for tool washing is supplied from the main and it is generally not metered. However, the cost for the water usage is paid by the client. • The washout facility (like Washbox) employed to manage LW on-site used to maintain the data of water usage and saving.
Washout facility for on-site LWM and its' benefits	• Washbox is a closed-loop circuit working, that does not require plumbing connections and discharging wastewater into the main sewer/stormwater. • Washbox is generally employed on-site for tool washing involved with the trades of painting, plastering/rendering, tiling, gyprock as well as brickwork. • A medium-sized box is used to be employed and it will probably run at the middle and end of the days with breaks in between. • It is a stand-alone and mobile system. The contractor who employs the Washbox will be facilitating Washbox to provide the space to set up the Washbox system and monitoring the system. Treatment of wastewater is done by the Washbox system. • Solid from LW is extracted by Washbox itself and sent to the solid waste recycling facility. No shovel is required to remove the waste. • Being a closed-loop system, it recycles the wastewater once the box is filled. A such, water wastage is very minimal and 98% of the

	water is saved and the water is only going out by evaporation and spillages. • When a trade uses a washout facility closer to the workable area, productivity improves with a cleaner working area, safe working zone, improved safety and fewer defects. • As the Washbox system does not consume water from the main and therefore, the cost of water otherwise to be used from the main for washing on-site is a saving, little amount of cost can be saved. • It fulfils the legal compliance required for handling LW on-site.
The volume of LW	• The volume of LW generated on-site would vary with the trades involved during the construction stage. In general, LW would contribute around 5% of the total volume of waste generated on-site.
Compliance and its management (Project-specific)	• Application to discharge the trade waste is required and it is the responsibility of the builder/developer to get the approval or inform the local authority about their plan to manage the LW. However, it is not followed. Application to the approval for discharge of waste to the sewer should be done at the stage of a development application(DA). • It is the responsibility of the council to investigate, inspect and fine the builders who fail to comply with the requirements/conditions of a development application (non-compliance). • The PM (of PC) who is assigned to the project is responsible for managing the required compliance on-site. • Builders/developers will comply with the development conditions or requirements if the investigating bodies or authority requires the builder or developer to report the water usage or LW to the respected body or authority. • There will be no management required if the LW is not measured, reported and checked. • Comparatively, compliance to LW is still in its infancy. There is still room for catching up. • For public projects, to which government is the client (E.g. school project), the compliance is governed by guidelines stipulated in the contract by the client, not driven by the authorities. • No separate approval or license is required for discharging wastewater generated from tool washing or run off into the main sewer for projects developed in the ACT. • The Environment Protection Agreement aims to ensure that the land development sites achieve a consistently high level of environmental management and it ties to local requirements for sediment erosion control, as well as other required conditions. However, nothing was particularly mentioned about LW in the agreement. • This agreement is made between the Environment Protection Authority (EPA) of ACT and the organization that is responsible for the development of the project.
Standard procedures available for LWM	• There are no standard procedures available for LWM. • It is evident that the builder needs to manage the LW by running temporary structures for washing tools and is required to make sure that they fulfil the compliance and comply with the auditors and inspectors.
The cost involved in LWM	• The cost for managing LW is not estimated by QS and included in the BOQ, but estimation for solid waste management is done and included in the budget. The councils aren't enforcing or investigating the item to be included for LWM and the EPA is definitely not doing anything about it. • There is no specific cost allocated in the budget to employ any washout facilities, like Washbox on-site. The PC is not paid for such

	additional services by the Client. The PC has to complete the project within the budget and time without compromising the quality and make a profit for the company. The cost of employing a washout facility for managing LW on-site is a burden for PC and PC should not be dis-benefited for it. Hence, the builder should be paid by the developer as an allowance or by the client. • When the builder handles the cost of managing LW, there is a cost-saving for the builder and the supply chain because the supply chain is more productive • However, the cost involved in disposing of the LW by another company is estimated and included in the budget. • It is the general practice to allocate the cost in the form of a provisional sum (PS) for any expected fines. In projects where the government is the client, the builder rarely uses that PS to deal with the processes related to fines, because it is highly audited by the client and the auditing process would consume a lot of time. • The cost for LWM is included in the budget and the client pays for the services Washbox. Besides, the cost of Washbox can be shared among the trades when the trades get together and share the service –cost is saved by sharing. • For the projects to which Washbox service has not been employed, the sub-contractors will generally include the cost for tool washing involved with their trades such as painting, concreting, brickwork in the trade package.
Sustainable strategies used to reduce the water and save cost on-site	• Unfortunately, there are no sustainable practices are followed to manage LW in construction projects. • However, the developers should be held accountable to ensure their development meets the sustainability goals and the builder should then abide by that and have an allowance for the cost of managing LW in their tender. • The only solution is employing a washout system/facility like Washbox which manages and saves the water as it uses the closed-loop system and does not consume water from the main and require the LW to be discharged into the main sewer. • At the completion stage, projects consume a large volume of water for washing and cleaning buildings, footpaths and driveways. It is hard to save water. However, there are some water-saving strategies used in other facilities employed for site workers, such as auto-off taps or push up taps, that have timers to control the water flow in washrooms and toilets, low flow nozzles on horses and bubblers for drinking water in hot weather are effectively used. • In a school project, water is saved as the water is connected to the mainline of the school. The PC has to pay for the water usage to the school. Therefore, the PC always supervise the work and try to reduce water usage.
Barriers/Challenges in handling LW on-site	The following are the major barriers to not implementing proper LWM methods in construction projects; • The higher cost involved in LWM: The cost to employ a washout facility like Washbox is quite expensive though the process is good. There is no specific cost allocated in the budget to employ any washout facilities, like Washbox on-site. The principal contractor (PC) is not paid for such additional services by the Client. The PC has to complete the project within the budget and time without compromising the quality and make a profit for the company. Builders have really low margins and if the builders are not getting paid for the services by the developer or client, the builders cannot afford the services. It shouldn’t be an extra burden to the builder. • The developers are not being accountable to ensure their development is meeting sustainability goals and having no allowance in their tender. • There are no strong sustainability policies and environmental policies in builders’ business or organization that is enforced. • Lack of inspections and fines for not fulfilling compliance. • There has been no education or training at schools or training colleges to improve the awareness or knowledge on the impact of LW

	generated in particular for construction projects and LWM. • Lack of criteria or model to demand washout facilities like Washbox. • Lack of demand from the client to initiate the services and pay for the services.
Recommendations to improve the current practices of LWM	• LWM is a collaborative effort. The builder is required to inform the local council about the type of washout facilities that they are installing on-site and the local councils and the EPA should take the responsibility to check whether the builder has met the required conditions or certain criteria or not and based on checking they should issue the certificate. • The builder/developer who earns from development should be accountable for checking the compliance requirements. • There needs to be some form of metric or process that encourages the builder to be accountable. At present no one calling that the builders are accountable. Therefore, no one is holding the accountability for managing LW. • The client should demand washout services. 90% of the clients prefer to do the job at a cheap price and it is unusual for clients to demand any such services like Washbox. If clients prefer to have the services, there is mutual benefit. • The client who has the power to raise this issue with money needs to have awareness and be educated to demand the services. • At the same time, the Washbox system needs to be made a standard that can be probably achieved and the washout services have to make them more competitive economically. • Cost should be allocated for managing LW and the builder shouldn't be disadvantaged by putting that cost in. Skipping to include the cost in the tender will, in turn, skip the process to be followed on-site. • As the subcontractors are typically on very low margins in the supply chain, they can't afford a solution like Washbox. • The builder should get an advantage by doing this job and become very good in LWM and this position would make them bring more projects. • The Washbox system needs to be made as standard which can be probably achieved. • Washout facilities, like Washbox can issue a certificate and report the LW managed at the site. They've got a dashboard on all of their products and they measure water usage and savings for liquid wastes collected. • There is less opportunity on the price of it to just make money and it will take some time to get the continuous job, to do one job after another. The reputation earned on the previous project will bring more business to the company. • Saving of water is not reported to local authorities (e.g. council) and therefore not acknowledged (Though a high volume of water is saved in some projects (Melbourne CBD dam). It is good to receive some credits for projects which save water from construction. Unfortunately, no one even knows and care about it. Green star credit points can be added.
Unexpected fines related to LW	• When there is an unexpected fine found, the first procedure is to stop the work, coordinate up and inform the client about it. An adjoining team, the Geo tech people are assigned next to visit the site and inspect. The team will inspect and make a report and the Project Manager will act on that report legally and inform the client and the construction manager. • This procedure is governed by the contract in particular the government is the client. The client will issue a reorder once the action is taken and all related work is completed. • Everything will be reported to Work Safe NSW and a permit number will be issued. • For any expected fines, a cost is usually allocated in form of a provisional sum (PS) Bill of Quantities by the client. • The builder rarely uses that PS to deal with the process, because it is highly audited by the client and the auditing process would

	consume a lot of time.
Past and current status of LWM in general	• There is a significant improvement in managing waste, mostly with solid waste over the past 10 years. Managing liquid waste (LW) is also being improved over the last 2-3 years. However, managing LW is at the infancy level compared to solid WM in the construction sector. • Lots of bad practices have been followed over the past 30 years due to the lack of inspections and fines by the respected authorities. For instance, paints were fed into the local creeks 15 years ago. The incident has been reported immediately, action has been taken against the incident, and traced out, considering that as an environmental incident/issue. • No builder follows one standard method to manage the waste at the site. The management method that they adopt on-site depends on the on-site team. They mostly follow an array of methods and similar procedures. • The reason for that is the site team who works on how they wanted to attend each challenge at the site which mainly creates problems in the industry. • Most of the companies will have sustainability and environmental policies, impact policies and all other different types of policies. Though they say they have a certain policy, they do actually not follow those policies at the site and what happens on-site is something different. • However, it has recently been in attention around the LW and but also it is starting to be more attention around the management of water which is really be mined. it is a good time to trap those practices and bring the issues to the front. • Some builders are learning from the past few years where they would actually have options and some are going forward into what their sustainability policies are and starting to use some form of washout. • The builders primarily (3 years before) had an intercept style of managing liquid waste on-site, having 44 Gallon drums with an open hose cock for washing tools and Wheelie bins that collect all the solid waste which does not comply with the requirements of LWM. • At a construction site, everything is temporary. Water is just wasted, whether it from a bubbler, tap or a toilet, there is no rule or attention on wasting water, whether it is on a certain level and water will be run out as the water is not managed at all, then how we are going to manage liquid waste, not managing what we use to the least.
Washout system used on-site	**Wash box System** employed for Painting and plastering: A stand-alone and mobile system with no plumbing connections and shovel required for waste removal. It well keeps space with obvious benefits for housekeeping and safety. A typical Washbox system is shown in Figure 4.1. **Other washout systems used on-site**: Waste Interceptor Bin connected to the Sewer installed by plumbers. This is a fixed system that requires a shovel for waste removal, the mess in the areas, poor housekeeping and safety outcomes. An example of the Interceptor style system is shown in Figure 4.2.

Figure 4.2 : A typical Washbox system

Figure 4.1: An example Interceptor style system

Other examples of drum style washout systems used in state significant projects handled by large and medium-size builders around Australia are shown in Figure 4.3. However, these systems do not comply with requirements.

Figure 4.3 : Other examples of drum style washout systems used on-site handled by large and medium-size builders

5 REVIEW OF LIQUID WASTE MANAGEMENT IN CONSTRUCTION PROJECTS

This section analyses the on-site water usage in construction projects using data obtained from a series of construction projects where the Washbox system was utilised. Raw data collected indicates the amount of water used and the duration of use. These figures are then utilised to estimate the possible water usage if Washbox system was not used enabling the calculation of water savings achieved. Building data related to the gross floor area of the building was used to calculate the water usage per square meter of a building for cross-comparison purposes. It should be noted that due to limitations in data availability for different types of buildings it is difficult to make conclusive generalisations. The analysis provided is indicative and preliminary.

Note: It should be noted that in the following data analysis all project types except Defence projects have alternative liquid waste treatment methods other than Washbox has been employed. As such water usage per m^2 data may not be completely accurate. The single data point reflecting a Defence project exclusively used Washbox solution as the method of liquid waste management on site.

5.1 Analysis of water usage by building type

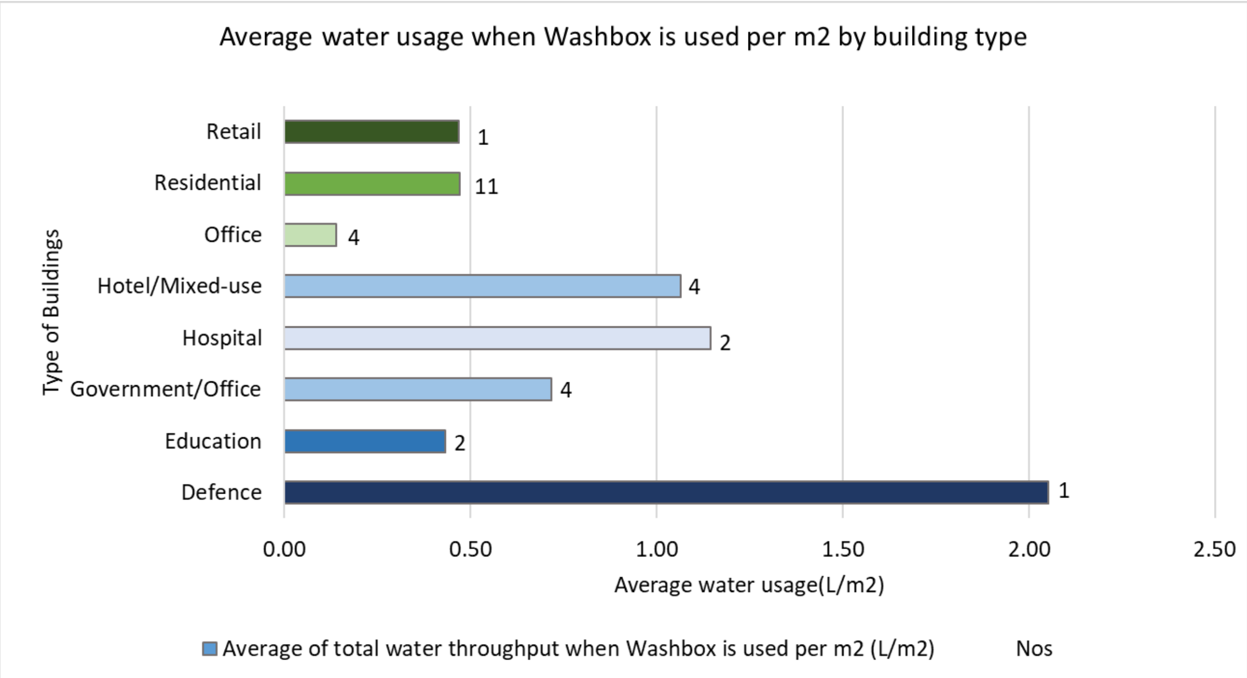

Figure 5.1:Average total water usage when Washbox was utilised (per m2 of gross floor area)

Figure 5.1 indicates the average of the total amount of water used for different building types when wash box systems were used. Residential projects indicate a very low usage of water when Washbox systems are used despite the greater involvement of wet finishing trades in residential buildings compared to other types of buildings. Defence indicates a very high (almost 4 times as residential) use but these are based on data from a single project.

5.2 Comparison of water usage and water saving by project type

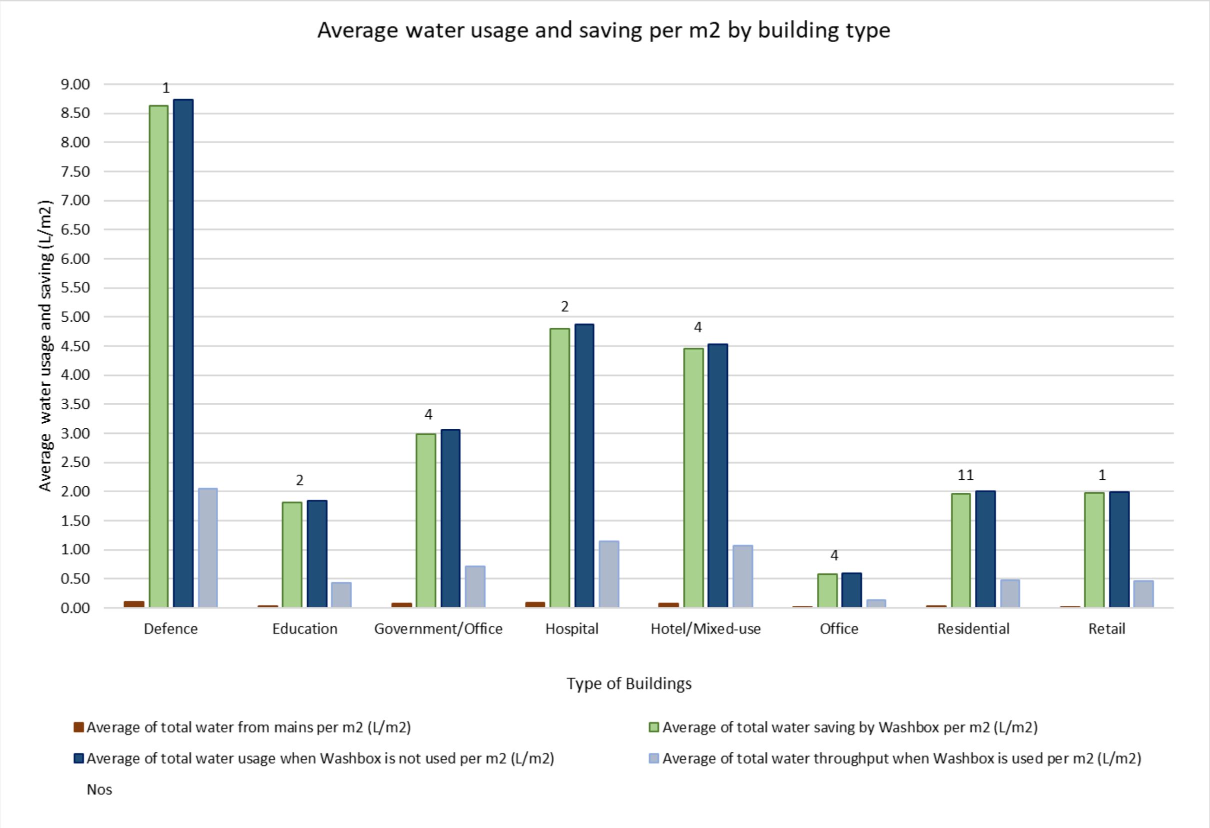

Figure 5.2: Comparison of average water usage and water saving per m2 of gross floor area by type of buildings

Here again, it is prudent to compare data for types of buildings where there are many data points. Figure 5.2 clearly indicates the amount of water saving that can be achieved across many building types. In all cases, it indicated over 95% water saving except for Education buildings (85%). The savings varied from 85% to 99% indicating a significant benefit due to water savings. Further, the use of such technologies means that waste water from tool washing, site washing and such activities are not reaching the main sewer system or waterways saving the environment from contamination.

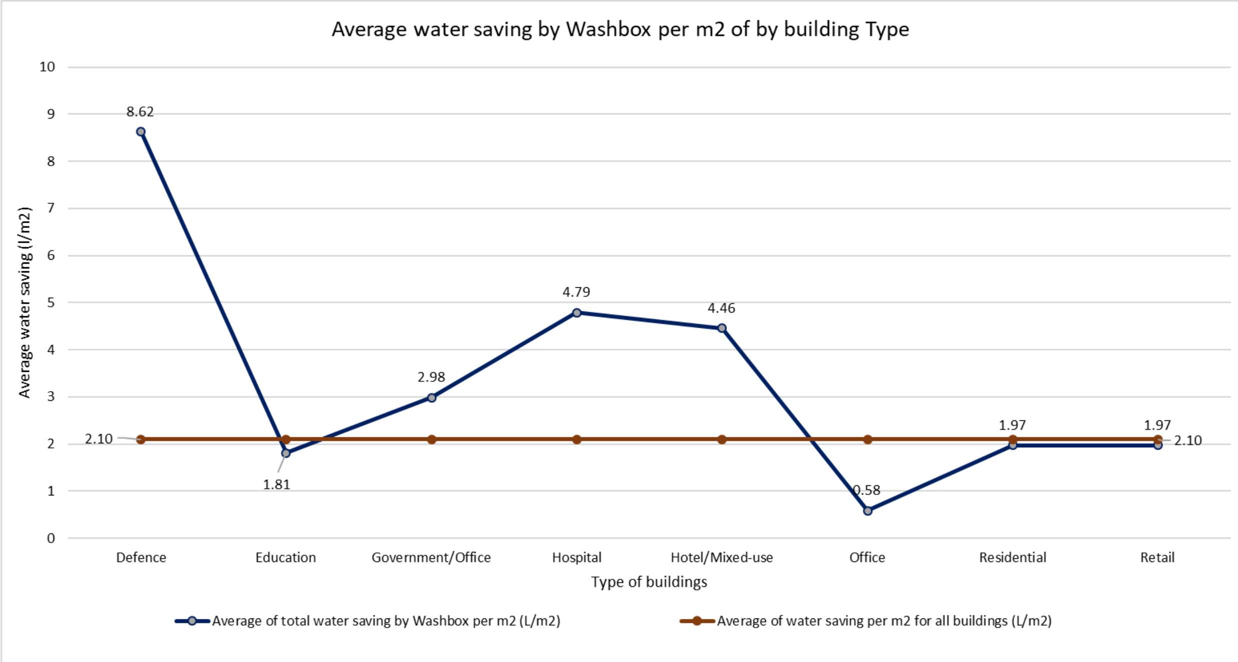

Figure 5.3: Comparison of average water saving by Washbox per m2 of gross floor area by building type

Figure 5.3 indicates the average water saving for different types of building projects analysed per m2 of building gross floor area. Data collected from Defence projects can be disregarded due to being based on one data point which may represent an outlier. However, its inclusion is justified due to the fact that evidently in this particular project the Washbox system was the sole water management system used. But the water savings per square meter of buildings for residential is representative with over 10 datasets is much more indicative of true savings. The average across all types indicates a saving of 2.1 litres per m^2 and this is significant and would potentially have a significant impact on water usage in construction projects across the sector.

The water saving that can be achieved for Class 2 type of buildings (multi-storey residential) is around 2 litres per m2. When this figure is extrapolated to the 53,000 apartments constructed in the 2017-18 period in Australia it is estimated that there will be around 10 million litres of water saved in a year. This is considerable and it is only just the saving from the Class 2 type of construction in NSW.

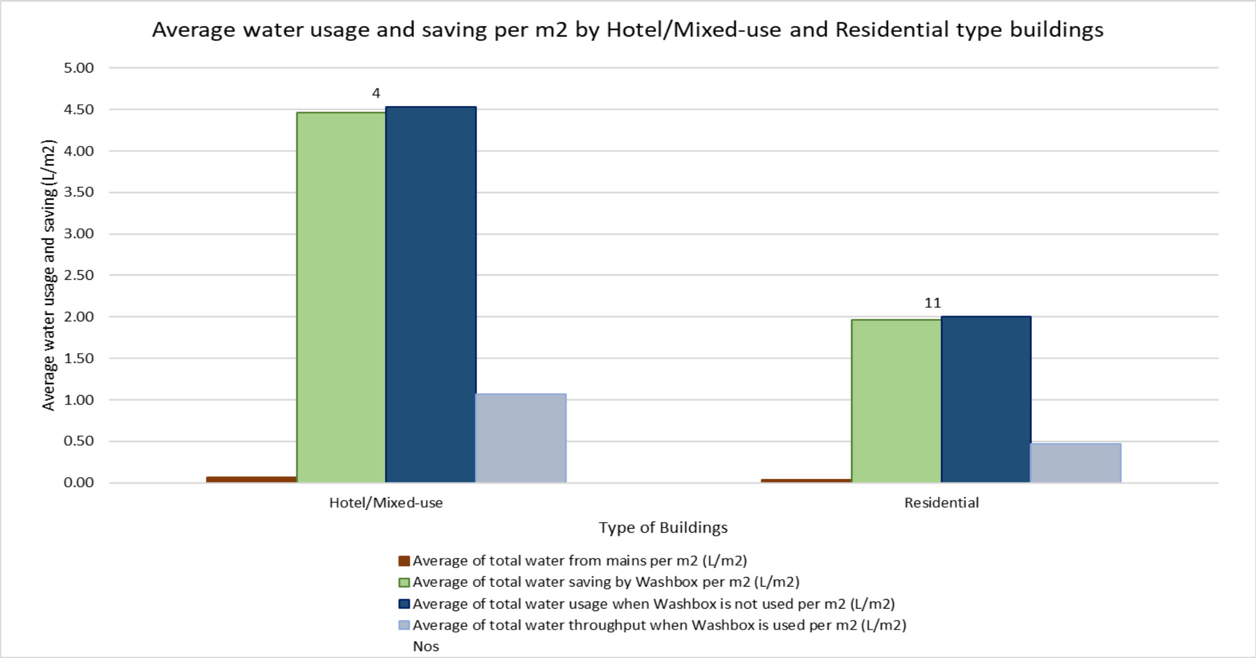

Figure 5.4: Comparison of average water usage and water saving per m2 of gross floor area for Residential and Hotel/Mixed-use buildings

A greater level of water efficiency is indicated in the Hotel/Mixed-use category compared to residential may also indicate that there is greater scope for improvement of water efficiency in residential projects (Figure 5.4). However, this may have been a product of Residential buildings involving a greater number of wet finishes compared to Hotel/Mixed-use that adversely affect efficiency.

5.3 Analysis of water usage by organization type

Figure 5.5 indicates that there is slightly greater water usage in projects delivered by medium-sized builders compared to large builders across all types of projects. This is an interesting result and could be due to systems and processes adopted. It needs further investigation to identify whether the systems and processes adopted in the two situations are different for this result to manifest.

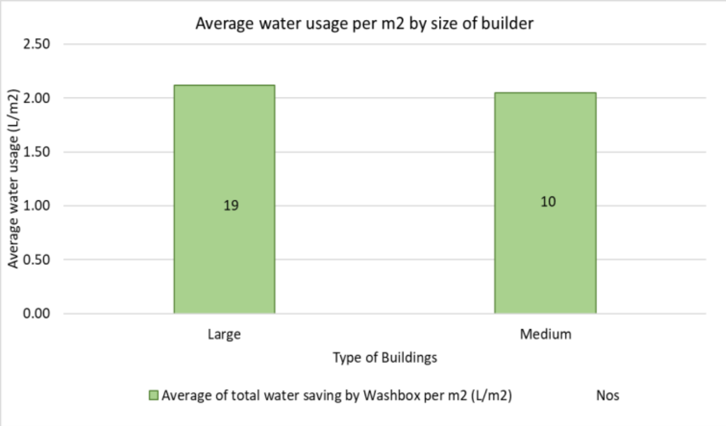

Figure 5.5:Average water usage when Washbox is used per m2 of gross floor area by user

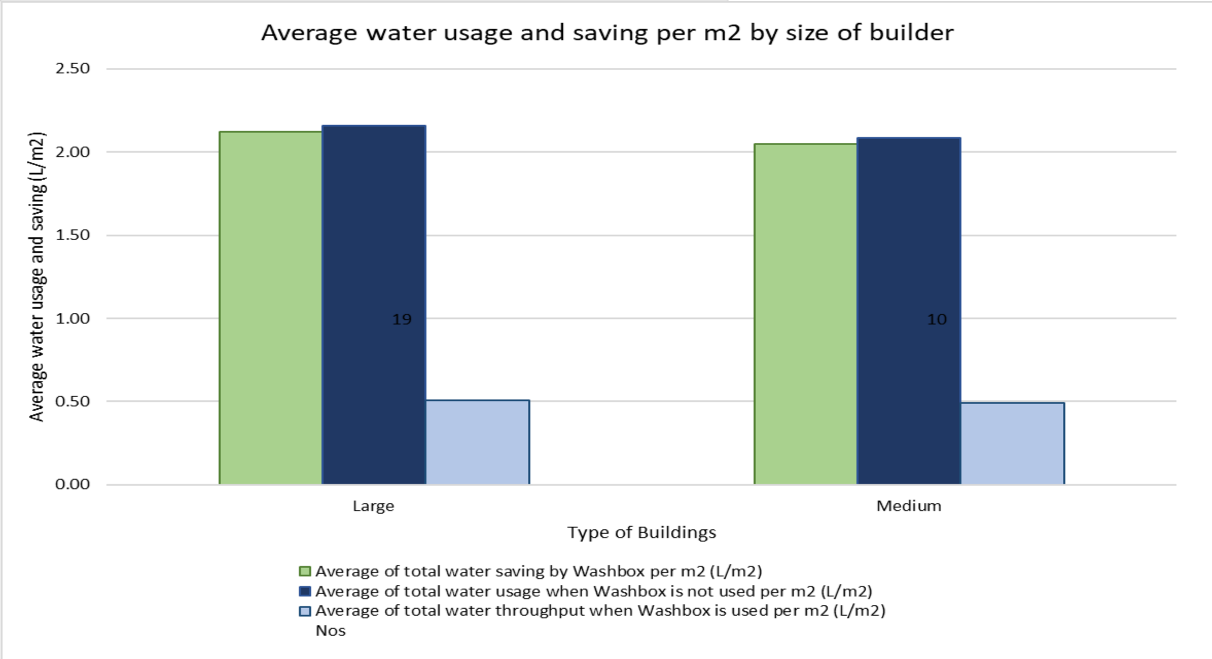

Figure 5.6:Average water usage and saving per m2 of gross floor area by user

The water usage may also be affected by factors such as; larger sites may have a rogue washout behaviour or under-reporting of water use. In smaller projects, it is often difficult to have alternative water use methods and there is a smaller number of trades on site providing greater control.

6 CONCLUSIONS

This research investigating the practice of liquid waste management in construction involved a detailed review of literature consisting of a review of relevant legislation. It also involved the analysis of views of three onsite professionals involved in site management to understand issues and the practice of liquid waste management in construction sites. It was followed by a limited data analysis from water usage data gathered from 29 projects.

6.1 Main Findings (Literature)

The following are the main findings arising out of the literature review.

1. An appropriate definition of liquid waste is important to provide a consistent means to determine whether or not liquid waste generated on-site is suitable for disposal at the landfill or to the public sewerage network. Definitions for liquid waste have generally been developed based on its content and source.
2. The composition of liquid waste is greatly varied and depends principally on its source. The three main sources generating liquid waste are Residential, Commercial and Industrial areas.
3. Liquid waste can be classified into different categories based on its origin, destination and content. However, one method itself is not adequate to categorise the liquid waste as there are limitations under each category and the combination of one or more other methods of classification are required in order to characterise a waste completely.
4. In Australia, liquid waste is divided into three main streams: sewage, trade waste, and hazardous liquid waste. The waste classification system in Australia varies across jurisdictions. There are considerable inconsistencies in waste classification and waste definition across the different states and territories. However, liquid waste classifications and definitions for sewage and trade waste were found to be reasonably consistent at the national level. At the same time, trade waste has not been included as a liquid waste stream for the construction sector consistently across the jurisdictions.
5. The key pathways for managing waste are common to both solid and liquid waste and the processes involved in these pathways include generation, movement, treatment and/or solidification, and reuse, recycling, energy recovery and disposal.

6.1.1 State of legislation

1. The NSW EPA provides guidance that helps to regulate the overall processes of liquid waste management including handling, segregation, storage and processing of liquid waste under the Protection of the Environment Operations Act (POEO Act) 1997.

2. Waste classification systems grouped by jurisdiction classifies liquid waste into several categories which vary across the states. The construction industry, being an industrial sector has not been included either under the category of discharging industrial trade wastewater or commercial trade wastewater in NSW. As such, there is no specific waste category available to include wastewater generated from construction activities on-site.
3. According to the Environment Protection (Water Quality) Policy 2015 (South Australia) and hence by law, certain types of pollutants that are relevant to the building and construction industry should not be discharged into the stormwater system from any construction sites.
4. The Code of Practice for the Building and Construction Industry (South Australia) strongly recommends all construction sites to carry out erosion, sediment and drainage control management practices at sites to ensure the pollutants do not enter the stormwater system and also to fulfil the legal obligations and general environmental duties related to the Water Quality Policy.
5. In order to comply with the regulations related to water quality, most jurisdictions require pre-treatment and approvals from relevant authorities prior to the discharge of trade waste to the sewerage network.
6. The review found that not all the EPAs across the nation have inclusions on the trade waste related aspects that are specifically associated with construction activities. EPAs of VIC, QLD and SA and the Department of Water & Energy of NSW Government have only addressed some of the legal requirements, procedures and guidelines relevant to sediment control and discharge of contaminated water from construction sites.
7. The review of legal requirements, policies and guidelines from relevant documents published by several legal authorities across the different states and territories revealed that not all the jurisdictions have established regulations related to stormwater water pollution prevention and approval for the discharge of trade wastewater generated particularly from construction sites. While the liquid waste classification system in Australia varies across jurisdictions, there are considerable inconsistencies in regulations related to liquid waste generated from the construction sector across the different states and territories. However, general requirements and guidelines have been established for all the businesses and/or other industries that intend the installation of a wash down area which will be connected to the sewer.

6.1.2 Current Practice

The following conclusions are derived from the expert interviews conducted to ascertain the practice of liquid waste management in construction sites.

1. The wet trades which produce Liquid Waste (LW) from construction projects typically include **excavation** (sediment slurry runoff from rock excavation/piling), **concreting** (liquid from classic concrete washout), **painting**/s**taining (**washing of brushes, rollers, trays tins, etc.), **tiling (**washing tools), **rendering/plastering (**washing tools), **plasterboard-gyprock (**washing tools used for joining), **brickwork (**washing tools used for bonding and waster from acid washing**. Others sources** that generate wastewater are water runoff from hydraulic and mechanical sprinklers during testing and water used for cooling concrete cutting and machines.
2. Plans for managing LW on-site is not specifically considered at the development application stage of a project and planning is carried out during the construction stage only. Hence, there is usually no separate section included for LWM in the general Waste Management Plan (WMP).
3. Managing LW on-site is generally handled by the principal contractor (PC) of the project. Typically, the PC hires wheelie bins or 44-gallon drums and installs them on-site for washing. The LW removed from the site by a specialised contractor is managed off-site. In a project site where there are no proper washout services employed to manage the LW on-site, the LW generated from tool washing and washout from concrete and brick/blockwork is discharged to the main sewer once the solid is settled out, but without treatment and inspection by any authorities unless it is reported by third parties. Often it is common practice that discharge happen even before solids are settled. However, some environmentally conscious PCs have started to employ special washout systems like Washbox to facilitate LWM on-site.
4. Washbox is a closed-loop circuit system that recycles the wastewater once the box is filled. As such, water wastage is very minimal and 98% of the water is saved and the water is only going out by evaporation and spillages. It is a stand-alone and mobile system. It does not require plumbing connections and discharging wastewater into the main sewer/stormwater. Also, a shovel is not required to remove the waste from the box. When a trade uses a Washbox system for tool washing closer to the workable area, productivity improves with a cleaner working area, safe working zone, improved safety and fewer defects. In particular, this fulfils the legal compliance required for handling LW on-site.
5. There has been no formal reporting involved with LW generated from the trades such as painting, tiling, plastering/rendering, plasterboard and acid washing, except for the LW which

is managed off-site by a specialised contractor.

6. Normally there is no additional cost allocated in the budget to employ any washout facilities, like Washbox on-site. Therefore, the cost of employing a washout facility becomes a burden to the PC where the cost is not recoverable under the contract.
7. The major barriers for implementing proper LWM methods in construction projects are;
   - Perceptions of higher cost involved in employing a washout facility like Washbox.
   - The developers are not required to account for measures in managing liquid waste in their sustainability goals and as such, there is no allowance provided in tender conditions.
   - Lack of strong sustainability and/or environmental policies in some builders' organizations that encourage efficient LWM or apathy in implementation of such policies where these do exist.
   - Lack of systematic inspection procedures and fines for not fulfilling compliance.
   - Lack of education or training in the tertiary education sector to improve the awareness or knowledge on the impact of LW generated in particular from construction projects and for LWM.
   - Lack of demand from the client to initiate the services and pay for the services.
8. Compared to solid waste management, following legal compliance in handling, processing and discharging LW is still in its infancy. There are generally no fully sustainable practices followed by the contractors to manage LW generated from construction projects. However, some sustainable water-saving practices are followed to reduce water consumption in other daily activities. The developers should be held accountable to ensure their development meets the sustainability goals and the builder should then abide by that and have an allowance for the cost of managing LW in their tender.

6.1.3 Water Savings

The following are some of the salient points that can be derived from the limited data analysis carried out using data collected from 29 projects.

- Since the Washbox system is a closed-loop system that recycles the water once the wash box is filled, 98% of the water is saved through the Washbox system.
- Residential buildings water usage is 0.03 l per m2 when Washbox system is used. This is indicative of a 1.97 l per m² saving. This is significant.
- The average water saving for all projects stand around 2.1 l per m².
- When the water savings are extrapolated for multi-storey residential (Class 2) projects across NSW the total annual savings are estimated at 10 million litres.

- Small to medium builders seem to be slightly more efficient in water saving than large builders.

6.2 Recommendations

LWM is a collaborative effort. The builder is required to inform the local council about the type of washout facilities that they are installing on-site and the local councils and the EPA should take the responsibility to check whether the builder has met the required conditions or not. Based on checking they should issue the certificate. This can be done by including a section for the liquid waste management plan which makes part of the WMP in the DA. The liquid waste management plan needs to include the minimum requirements and set the targets for environmental performance. The builder/developer who earns from development should be accountable for checking the compliance requirements.

There should be a step change in working towards full legal compliance with regards to liquid waste management related legal compliance, the demand for washout services should come from the client which should be helping in achieving corporate sustainability objectives. The client who has the power to raise this issue and being an investor needs to be environmentally conscious to demand suitable washout services. At the same time, systems such as Washbox system needs to be made the standard practice. Consequently, washout facilities need to be more competitively priced.

Cost should be allocated for managing LW in the budget and the builder should not be disadvantaged by being required to bear that cost. The builders who use efficient washout facilities should be considered as environmentally conscious sustainable builders.

The efficiency of washout facilities employed in sites should be continuously measured and such data should be utilised to create acceptable efficiency benchmarks for construction sites. Saving of water is not reported to local authorities (e.g. council) and therefore not acknowledged. There will be no management required if the LW is not measured, reported and checked. Therefore, reporting of LW managed on-site and off-site needs to be mandated. It is desirable to introduce rewards such as Green star credit points for projects which save water through the development and implementation of water-saving plans.

Summary of recommendations:

- Legislation governing LWM should specifically mention LWM from construction sites as the impact of discharging partially or untreated liquid waste from construction sites could be considerable.

- All construction projects should have a mandated requirement to produce a LWM plan.
- Costs of LWM should be identified and accounted for in tenders as separate items.
- Incorporate the LWM process as a recognised component in Greenstar evaluations.
- Educate developers and builders on the technologies and processes available for onsite LWM.
- Further research needs to be carried out to evaluate and establish LWM practices in construction projects for both building and infrastructure development projects.
- Further research needs to be carried out to evaluate in detail the state of legislation with respect to LWM in construction projects and to evaluate the environmental consequences of LW generated from construction projects.

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