TECHNICAL PAPER

A History of Geomembrane Floating Covers in Australia

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THIS PAPER WAS ORIGINALLY PRESENTED AT THE 2019 GEOSYNTHETICS CONFERENCE | HOUSTON, TX, USA

ABSTRACT

Geomembrane floating covers have been in use for many years and have played an important role in the protection and conservation of water, the collection of obnoxious odors and biogas, dilution reduction and protection of fauna. There has also been a significant variance in service life being achieved. Factors including design, material selection, installation quality, maintenance and environmental factors have a significant influence on the life expectancy outcomes.

It is an important design tool to review and analyze previous installations to ensure lessons learned are applied to new projects. Australian environmental conditions also tend to accelerate degradation process with higher ambient temperatures, higher liquid temperatures, very high UV exposure and generally higher chemical loading, primarily due to the length of water pipeline supply networks.

This paper provides a history and an insight into the successes and failures of floating covers in Australia, predominately in municipal potable & wastewater applications. The paper is intended to provide general conclusions on life expectancy and outline some notable failures and failure trends.

THE HISTORICAL BACKGROUND

Floating covers were first installed in the 1950's in North America with patents lodged from 1964. The defined sump geomembrane floating cover commonly used today was first patented by Burke Industries in the USA in 1975. The technology was significantly advanced by C.W. Neal in the USA and widespread adoption of the technology accelerated in the 1970's as different flexible materials became available.

FLOATING COVERS IN AUSTRALIA

As far as can be ascertained, the first defined sump floating cover was installed in Australia in 1981 on a potable water storage in Victoria. Both Victorian and South Australian water authorities were early adopters of the technology in municipal potable water applications. Initially these covers were designed by North American suppliers supporting local installation companies. As

acceptance of the technology grew in Australia a small number of installation companies developed expertise and capability in the design and installation of floating covers building on the experience of North American suppliers.

The first storage facilities to receive floating covers were primarily chlorosulphonated polyethylene (CSPE) covers for potable water storage to protect drinking water supply. This was followed by wastewater covers, to provide odor control in built up areas, and then more recently for cogeneration activities. Successive droughts in various regions of Australia have encouraged water conservation and recycling initiatives resulting in covers being installed on raw water and recycled water storages for evaporation and algae control. The approximate breakdown of cover applications is shown in Figure 1.

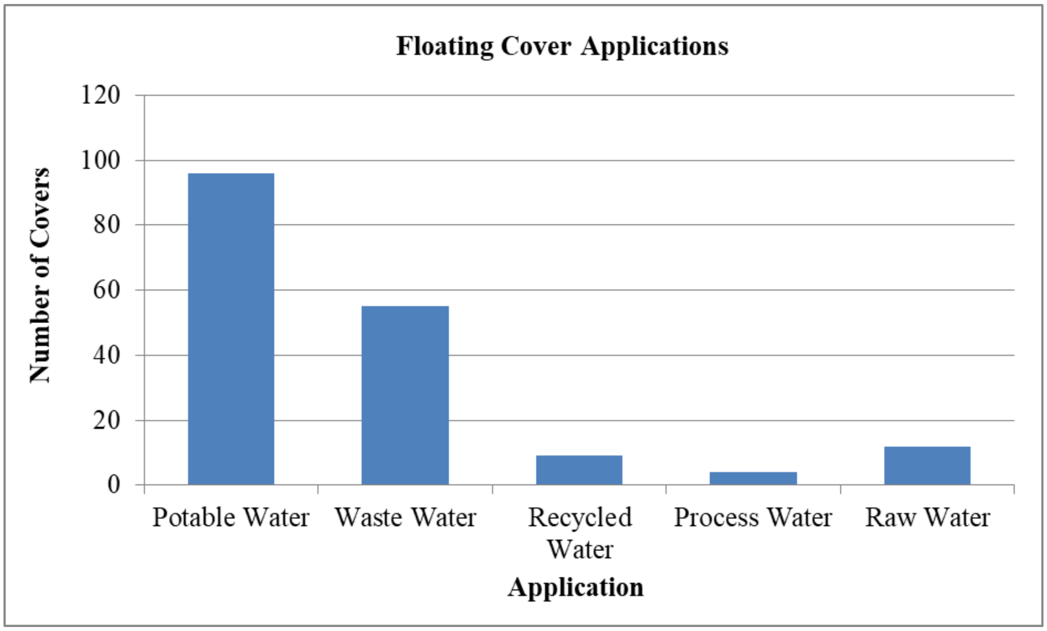

Figure 1. Floating Cover Applications

PRIMARY FUNCTIONS OF FLOATING COVERS IN AUSTRALIA

The function of floating covers varies according to the application. The typical functions are shown in Table 1.

Water Storage Type	Functions
Potable Water	Eliminate evaporation. Eliminate algae growth. Significantly reduce chemical dosing requirements (chlorine) and associated operational costs. Protection from airborne contaminants. Protection from wildlife contaminants. Security of water source.
Raw Water	Eliminate evaporation (& associated salinity increases). Eliminate algae growth. Reduce chemical dosing requirements (chlorine) Protection from airborne contaminants.

Recycled Water	Eliminate evaporation. Eliminate algae growth. Reduce chemical dosing requirements (chlorine) Odor capture.
Wastewater	Odor capture. Biogas capture.
Minerals Processing	Eliminate evaporation. Eliminate algae growth. Elimination of increased process water inventory with rainfall in storage pond. Fauna protection (drownings, poisoning).

Table 2. Functions of Floating Covers

DISTRIBUTION OF FLOATING COVERS IN AUSTRALIA

The population of Australia is concentrated in major cities around the costal fringe predominately on the Eastern and Southern coasts. The largest states by population are shown in Table 2. Interestingly the adoption of floating covers does not reflect the population density in Australia but has been influenced more by water distribution network length, need for large potable treated water storages and, designer preference (refer Figure 3.).

State/territory	**Population (2016 census)**	**Land area**		**Population density**		**% of pop. in Sate capital**
		km²	**mi²**	**per km²**	**per mi²**	
New South Wales	7,797,800	800,642	309,130	8.64	3	63%
Victoria	6,244,200	227,416	87,806	23.54	9	71%
Queensland	4,883,700	1,730,648	668,207	2.50	1	46%
Western Australia	2,567,800	2,239,170	864,548	0.89	0	73%
South Australia	1,717,000	983,482	379,725	1.62	1	74%
Tasmania	519,100	68,401	26,410	7.24	3	41%
Australian Capital Territory	406,400	2,358	910	151.49	58	100%
Northern Territory	245,000	1,349,129	520,902	0.16	0	54%

Table 2 – Australian Population Data

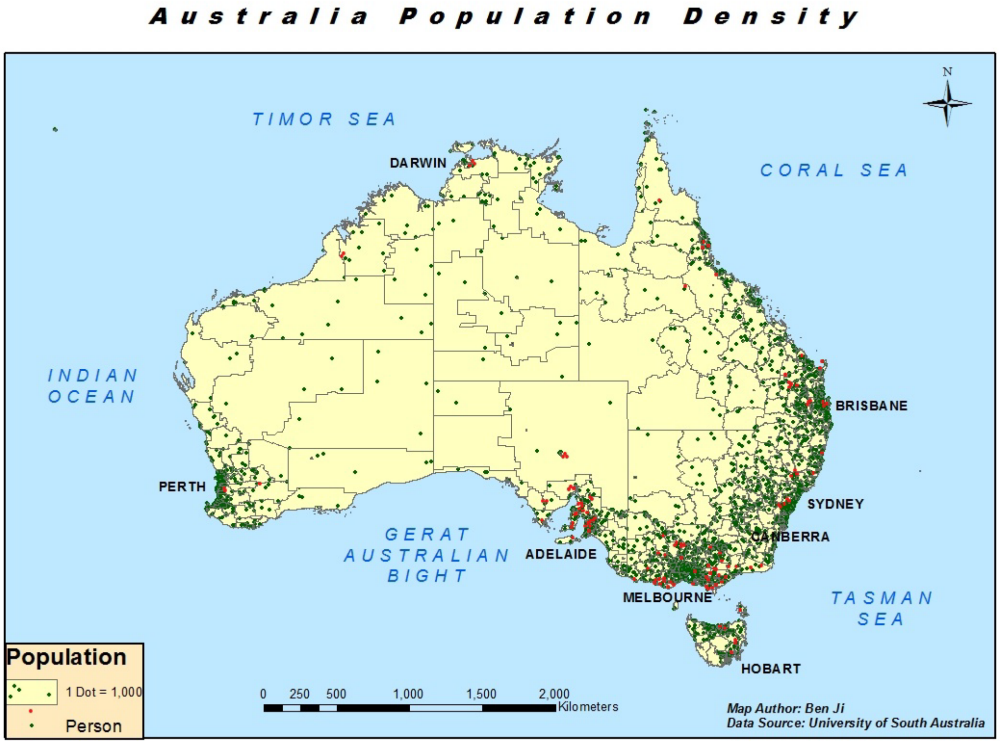

Figure 2. Australian Population Density

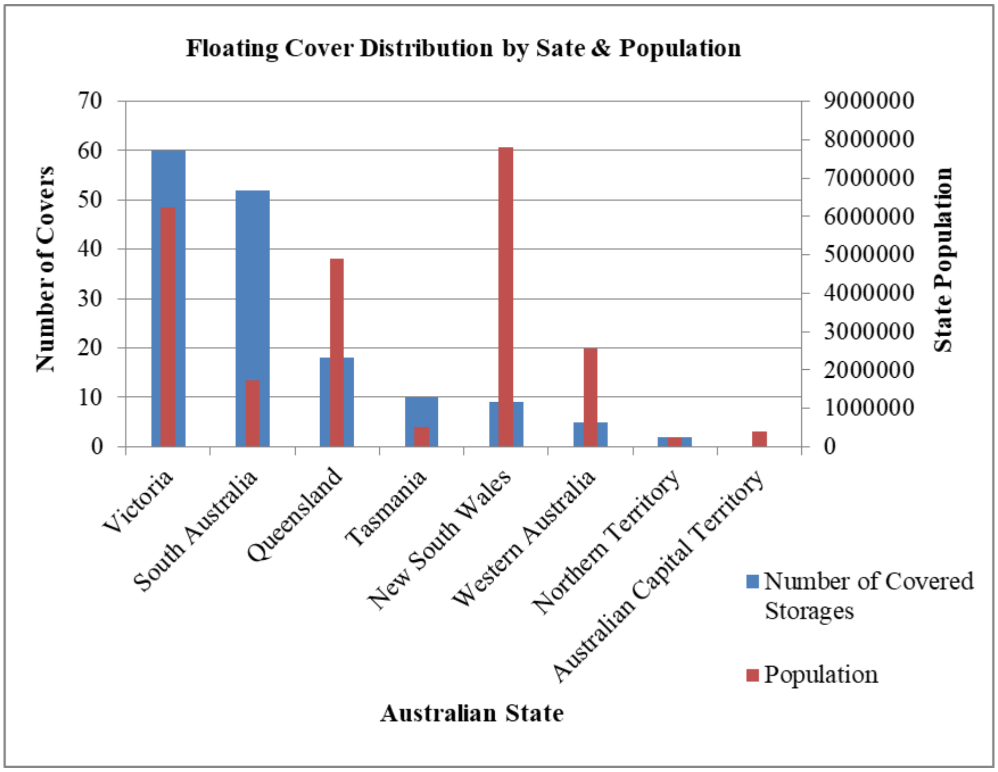

Figure 3. Floating Cover Distribution Compared to Population

The most common type of floating cover adopted in Australia has been the defined sump cover with central plate defined sump being used in particularly large covers (greater than 15,000m^2) or were the storage shape has been less regular. These covers have been used on all the potable water storage covers as well as a significant number of wastewater covers subject to seasonal level fluctuations.

Odor/biogas covers are the next most predominant cover type. These are static covers with significantly greater strings of ballast without the deep gutters in the defined sump cover. As these types of covers are static and do not need to flex, HDPE has generally been used, however more recently fortified polyethylene materials are being specified to provide greater chemical resistance and flexibility. This style of cover has also been used for molasses and caustic soda storages.

Other cover methods including floating disks, suspended shade cloth (sails) and bubble type covers only make up a very small proportion as shown in Table 3. due to their ineffectiveness to meet some design criteria.

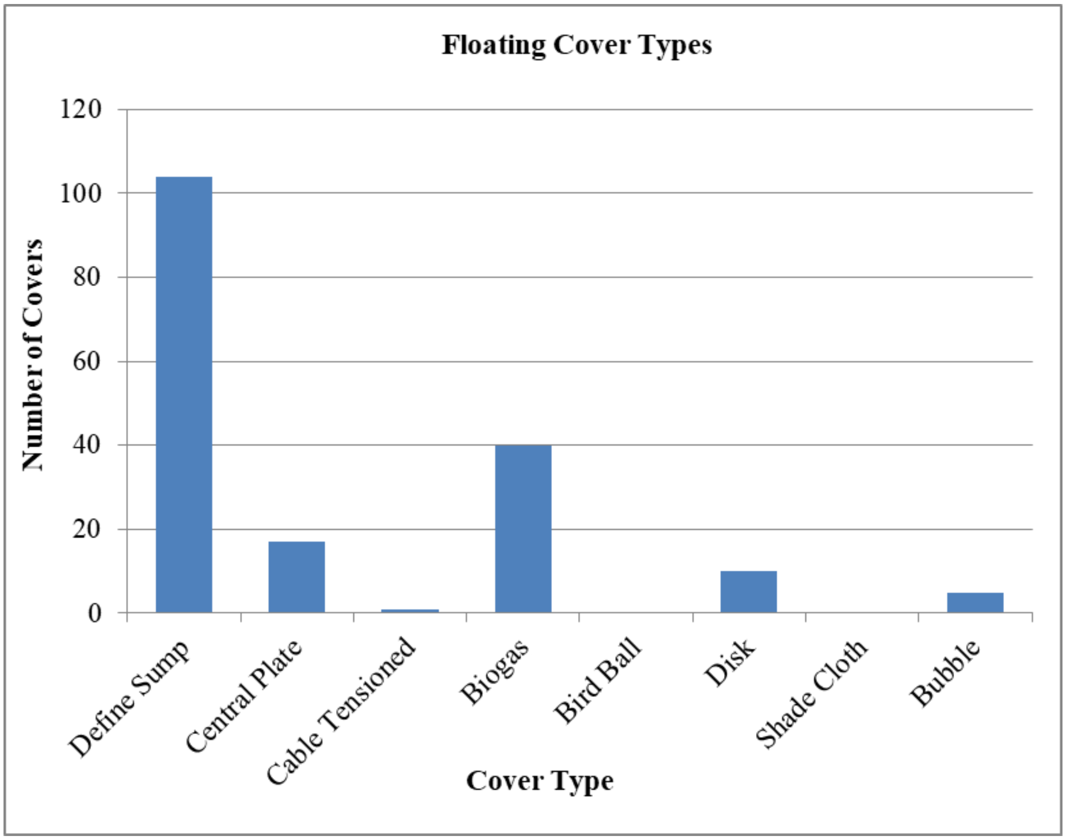

Figure 4. Floating Cover Types

Cover Type	Advantages	Disadvantages
Defined Sump and Central Plate Defined Sump Cover	Simple operation. Easily maintained. Suitable for potable water. Eliminates water contamination. Provides protection from wildlife. Eliminates odor. Eliminates evaporation. Eliminates algal growth. Reduces chemical losses.	Competent designer required. Competent installer required. Regular cleaning beneficial.
Cable Tensioned Cover	Cover lays flat. Suitable for irregular shaped storages. Suitable for potable water. Eliminates water contamination. Provides protection from wildlife. Eliminates odor. Eliminates evaporation. Eliminates algal growth. Reduces chemical losses.	Expensive initial capital outlay. Competent designer required. Competent installer required. Regular cleaning beneficial.
Biogas Cover (negative & positive pressure)	Simple operation. Easily maintained. Captures biogas for re-use. Provides protection from wildlife. Eliminates odors.	Competent designer required. Competent installer required. Regular cleaning beneficial. Storm water management issues. Prone to distortion with scum buildup under cover.
Air encapsulated Cover (Bubble Cover)	Simple to install. Eliminates evaporation. Can harvest rainwater. Eliminates algal growth if opaque.	Low strengths. Cover is not generally accessible. Poor life expectancy. Does not provide contamination protection.
“Bird” Balls	Easy installation. Minimal design requirements. Reduces algae growth. Can be easily retrofitted on existing storages.	Not suitable for potable water. Not suitable for odor control. Balls roll increasing evaporation. Balls can blow off in high winds. Supply constraints. Does not reduce contamination.

Disks	Easy installation. Minimal design requirements. Reduces algae growth. Can be easily retrofitted on existing storages.	Not suitable for potable water. Not suitable for odor control. Disks can become beached. Does not reduce contamination.
Shade Sails	Provides protection from wildlife. Reduces evaporation. Reduces algal growth. Reduces chemical losses.	Not suitable for potable water. Not suitable for odor control. Relatively expensive for larger installations.

Table 3. Advantages and Disadvantages of Cover Types

COVER MATERIALS

Material selection is one of the most important aspects of cover design and appears often to be compromised for perceived cost advantages without the full lifetime costs being taken into account. In Australia initially floating covers were constructed almost exclusively from reinforced chlorosulphonated polyethylene (CSPE) based on experience in North America. CSPE is a very flexible, extremely durable synthetic rubber with outstanding UV resistance, with warranty periods up to 30 years available.

As the market expanded and floating covers became accepted practice, alternative materials were developed and soon became more cost competitive. Flexible reinforced flexible polypropylene (fRPP) became the material of choice in the late 1990's to early 2000's due to cost advantages with a number of manufacturers supplying product these products.

While fRPP material was of similar flexibility to CSPE, being an amorphous polymer the chemical resistance was not equivalent. Significant levels of hindered amine light stabilisers (HALS) were added to provide longer term UV stability.

Other materials used have been proprietary linear low density polyethylene (LLDPE) based polyolefins, e.g. Layfield's Enviro Liner and HDPE. In Australia EIA's have only been used three times with limited success. High density polyethylene (HDPE) has generally only been successfully used in static wastewater or molasses storage applications due to the stiffness of the material.

The recent trend has been CSPE material being used when replacing prematurely failed fRPP covers in chlorinated water applications.

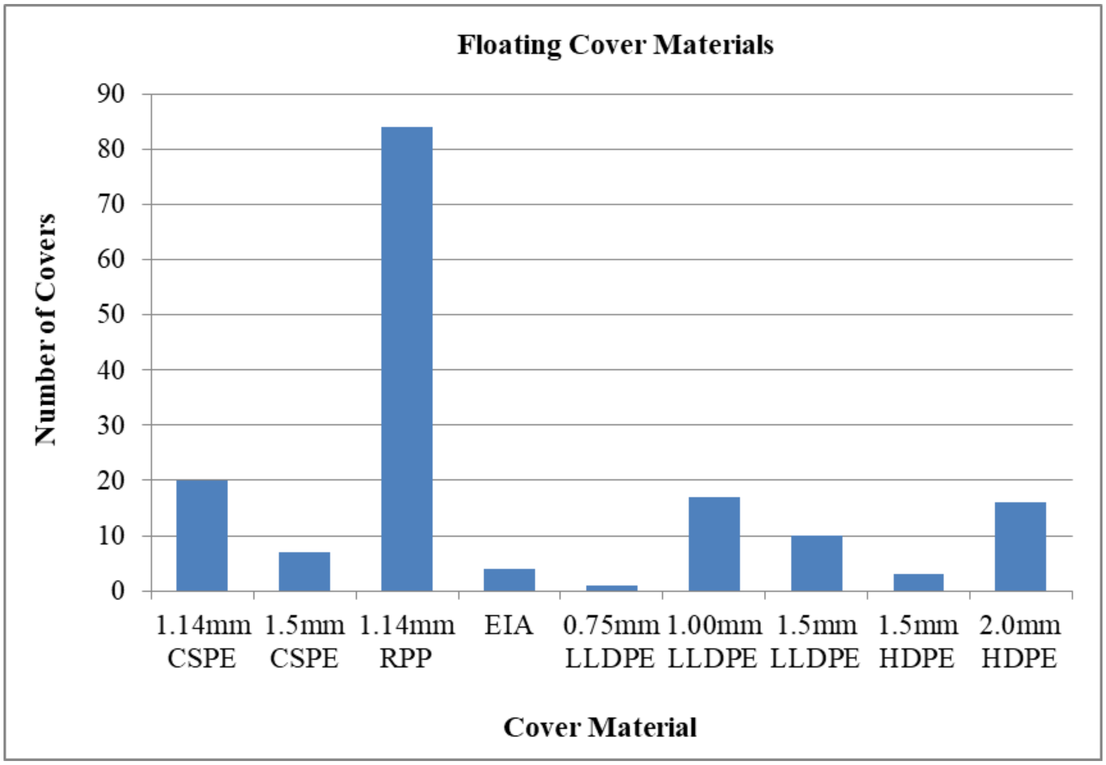

Figure 5. Floating Cover Material

Typically 1.5mm or 2.0mm thick HDPE has been used for biogas covers on static wastewater lagoons. While 1.5mm thick material is adequate in most of these applications, designers have tended to over specify and adopt 2.00mm thick material.

FAILURES

While a complete census of all cover failures in Australia is not possible, conclusions can be drawn from the information that is readily available. The average age of CSPE floating covers at replacement in Australia is 27.25 years compared to fRPP at 11.3 years. There are a number of examples of CSPE covers in Australia exceeding 35 years still in service whereas all the remaining fRPP floating covers are showing serious signs of degradation.

Across all applications the predominant cause of failure has been chemical attack, leading to stress cracking and loss of mechanical properties ultimately resulting in tearing and breach of the cover. A small number of other failures have occurred due to bird damage or fire and flood damage.

Potable & Recycled Water Applications

The original CSPE installations have predominately achieved their asset lifetime requirements with several installation passing 35 years, however since the introduction of fRPP, operational experience has shown that fRPP significantly underperforms. Complicating analysis, there has been wide variances in the lifetimes achieved by fRPP in service. In potable applications, some RPP installations have failed in as little as four years while others have managed to achieve seventeen years of service. Nearly all fRPP covers in Australia have failed or degraded prematurely. The majority of failures have been due to chemical attack from chlorine exposure. Systems with chloramine disinfection have been particularly affected. Other chemical attach mechanisms have been through very pure water generated by reverse osmosis desalination plants (negative or low Langelier Saturation Index water). These fRPP failures have been accelerated by high UV exposure and high ambient temperatures. This has been apparent in bridged areas of some covers where the top skin layer has completely disintegrated exposing the scrim. In some locations the perimeter of covers not exposed to water show distinct discoloration compared to areas that are kept cool by the thermal mass of water underneath.

There have been a number of floating covers that have inexplicably attracted an Australian parrot species that have attacked fRPP covers damaging large sections, particularly at floats, walkways and seams. This has not been apparent on CSPE covers.

Wildfires have damaged several covers beyond repair and there has also been some failures attributed to poor design with wind entering under some covers continually flexing the material.

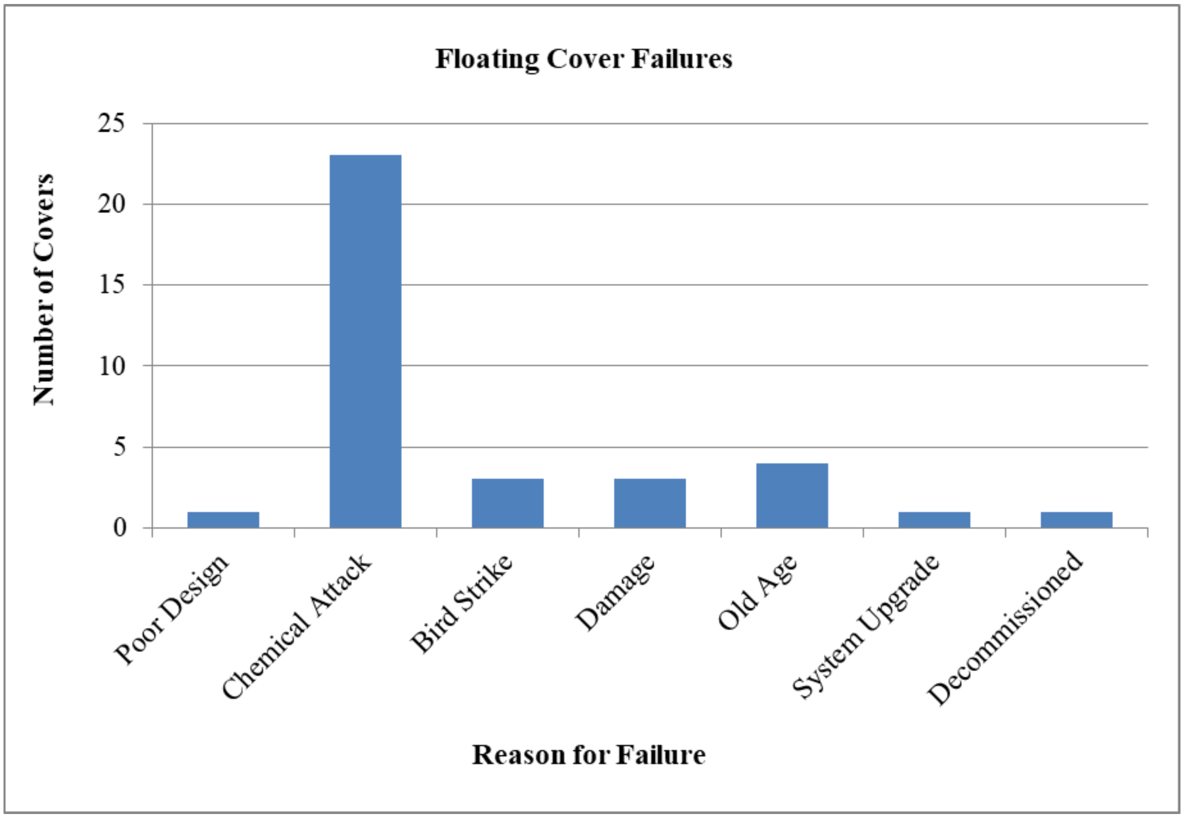

Figure 6. Floating Cover Failures

Wastewater & Process Water Applications

A variety of materials have been used in wastewater applications. In this type of application fRPP has also shown reduced life expectancy with covers degrading through chemical attack. Cases have been reported of areas of complete delamination at the scrim layer, and catastrophic tears. As with potable and recycled water covers there have been cases reported of bird damage.

Several HDPE covers have failed in wastewater applications due to chemical attack. This is predominately associated with human waste. Scum buildup under wastewater covers causes significant disruption to storm water management systems and often blocks emergency gas relief vents and other appurtenances. In some cases the scum buildup is so large it has ripped open covers at appurtenances. In other cases, covers have been over inflated when blocked vents have not released gas. An EIA cover in this environment has also been significantly affected.

CONCLUSION

Australia's climatic conditions as well as operating practice pose significant challenges to floating covers. Very high UV exposure, very high ambient temperatures and raised water temperatures are common. Higher than average chlorine dosing levels to accommodate long network lengths are also common.

The service life of Chlorosulphonated polyethylene has exceeded every other material used to date with several covers still in service after 35 years, whereas virtually all flexible reinforced polypropylene covers have either already failed prematurely or exhibiting serious degradation earlier than expected. EIA materials, while nor used extensively in Australia, have also shown relatively short asset life and appears dependant on the formulation.

Based on previous performance it is evident designers should take into account total lifetime cost and should not compromise the integrity of a long term cover asset based on initial material cost only. Designers should use caution when assessing the long term performance of materials, based on test data alone and should place great emphasis on previous long term history.

ACKNOWLEDGEMENTS

David Jaensch, SA Water, Adelaide, SA. Australia.
Paul Vince, WSP, Adelaide, SA. Australia.
Mark Bennett, Fabtech Australia, Richmond, SA. Australia.