The use of geomembranes in the storage of potable water

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Abstract. In the USA and Australia in particular, water authorities prefer geomembrane lined and covered earthen constructions over concrete and steel constructions because of a myriad of benefits across installation, environmental, and project cost criteria. Floating covers for water reservoirs obstruct sunlight, which prevents algae and reactive by-products from interfering with water taste and odor, prevent the evaporation of water and disinfectants, and prevent dilution from precipitation. In addition to technical background on geomembranes used for liners and covers, this paper compares the installation costs and carbon footprint for geomembrane lined and covered water reservoirs with concrete constructions.

1 Introduction

Floating covers have a long history of use. In 1953, the American Water Works Association (AWWA) recommended that all new reservoirs used for storage of potable water should be designed with a cover and that existing reservoirs should be covered or provided with a post-chlorination facility [1]. The advantages of a flexible lining and cover are low capital cost, reduction of algal growth, reduction of chlorine demand, prevention of airborne and groundwater contamination, and prevention of evaporation and seepage losses [2]. They are inert and so inherently more resistant to a broad range of chemicals. They are environmentally stable and, therefore, can be used in a wide range of temperatures while exposed to extreme UV light. The use of geomembranes for floating covers and liners have now been validated by decades of successful, applications in the USA and Australia. However, especially in the Middle East, steel and concrete tanks are still widely used for potable water containment despite their various disadvantages as the pricier, more cumbersome alternative to geomembranes.

The geomembranes that are used for liners and floating covers are typically made by applying a polymer coating on both sides of woven or knitted fabrics. Compared to unreinforced plastic liners, fabrics provide improved mechanical properties (i.e., tensile strength, tear resistance, and puncture resistance). These fabrics are typically made from polyethylene terephthalate (PET, polyester), nylon, or combinations of the two. Listed in increasing performance (and cost), the polymers that are used for the coating are polyethylene, polypropylene, polyvinylchloride-ethylene interpolymer alloy (PVC-EIA), and chlorosulfonated polyethylene (CSPE).

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Geomembranes are less expensive than concrete tanks. Typical project costs for a geomembrane lined and covered water reservoir can be up to four times lower than building concrete constructions. These calculations include the increased operations and maintenance costs and a shorter design life of 20-30 years for lined and covered reservoirs compared with 50-60 years for concrete tanks,

Flexible materials are easier and quicker transported than concrete materials and come with a less invasive installation. Where the construction of concrete tanks is associated with high noise levels, high emissions, and the need of a lot of equipment, installation of lined reservoirs and floating covers has a lower impact on surrounding environment and wildlife. The carbon footprint of using geomembranes in water management applications is 80-95% lower than for concrete constructions [3].

When existing concrete tanks and impoundments are already in place, geomembranes can also be used to line the existing structures and to replace fixed covers with floating covers to extend the lifetime of these concrete structures. This will also come with the benefits of lower costs and easier installation [4].

2 PVC-EIAs for geomembranes

Reinforced PVC is the most suitable choice for liners and floating covers for potable water applications. Reinforced PVC has strong dimensional stability and tensile strength, ensuring that the geomembrane conforms and/or elongates without breaking when subjected to an uneven subgrade or localized subgrade subsidence. Additionally, reinforced PVC's high puncture resistance will prevent damage when exposed to hydraulic pressure on the geomembrane over a rock or sharp protuberance. PVC performs well in both high and cold temperatures. It has excellent weathering and chemical resistance properties. Because of the extreme flexibility of reinforced PVC, the membranes can be prefabricated into large panels and folded for transport to the construction site thereby minimizing field seams [5].

To render PVC with the desired flexibility for use in geomembranes, plasticizers are added to decrease the glass transition temperature (Tg) of the material. Traditionally, phthalates have been used to decrease the Tg, but lately, these have been largely replaced by low-health concern alternative compounds. However, these low molecular weight, liquid plasticizers can slowly migrate out of the polymer matrix, contaminating the water and making the PVC brittle with the risk of cracks and other damages.

In the 1970s, DuPont developed ketone ethylene esters (KEE), high molecular weight polymers that are miscible with and plasticize PVC. The KEEs form an ethylene interpolymer alloy (EIA) with PVC and, because of their high molecular weight, the KEEs do not migrate out of the polymer matrix. Thus, geomembranes made with these PVC-EIA materials will not only maintain their flexibility much longer, but also maintain a higher, safer, product lifecycle than PVC materials made with traditional liquid plasticizers. The KEEs have been used in PVC compounds and have shown proven performance for geomembranes and single-ply roofing products for more than 30 years. Cooley Group worked together with DuPont to develop a high performance (HP) KEE polymer, composed of different monomers than regular KEE, specifically designed for use in PVC-EIA materials for potable water applications.

Using HP KEE instead of the regular KEE makes geomembrane less stiff and PVC-EIA(HP) materials can withstand 200,000 flex cycles at -5°C and pass a -40°C bend test where typical industrial PVC-EIA at similar concentrations fail the bend test at -30°C. The higher thermal stability of the HP KEE also guarantees higher service temperatures and a longer service life in hot environments. Furthermore, the use of HP KEE contributes to an increased melt strength and impact strength of the PVC-EIA. Combined with using a 9x9, 2,000x2,000D fabric, which is much stronger than the 9x9, 1,000x1,300D knitted fabric that typical industrial PVC-EIA membranes use, reinforced PVC-EIA(HP) geomembranes show excellent physical properties [5].

The long-term performance of PVC-EIA(HP) materials is guaranteed by using relatively high concentrations of high-quality heat and UV stabilizers that ensures that, after more than 35,000hrs of exposure, there is minimal color change and no signs of cracking. Comparatively, typical industrial PVC-EIA materials start to crack after 25,000hrs.

Exposure to chemicals may curtail the life of geomembranes, especially when low molecular weight plasticizers that migrate out of the polymer matrix are used. Thus, PVC-EIA(HP) materials have a much wider spectrum of chemical resistance than PVC materials containing liquid plasticizers and can be used as primary and secondary containment materials such as oils, gasoline, diesel, kerosene, and many other sensitive substances. Especially for potable water applications, the resistance against chlorine and chloramine that are used as disinfectants is important. Immersing PVC-EIA(HP) in solutions with these chemicals or exposing them to vapors show a much better performance of these materials than typical industrial PVC-EIA. Even compared to chlorosulfonated polyethylene (CSPE), another material that is frequently used for potable water reservoirs, PVC-EIA(HP) did not show any changes upon exposure to chloramine vapors for up to 120 days, where CSPE materials showed the formation of bubbles and delamination after 60 days.

With the outstanding physical properties, longevity, and chemical resistance PVC-EIA(HP) geomembranes have an expected service life of more than 30 years. This makes these materials an excellent choice to be used as liners and covers in earthen potable water reservoirs as an alternative to concrete or steel tank construction.

3 Economic comparison

When comparing the costs for geomembrane floating covers and aluminum and concrete roofs on potable water tanks, a service life of 30 years is assumed for the geomembrane solution and a 60-year lifetime for a concrete roof. For a storage volume of about 500,000 m^3 water, a surface area of about 5.7 hectares will be required when an earthen construction using geomembranes liners and covers is put in place. The installation time for such a water reservoir is typically 1.5 years, whereas a concrete tank park construction would take about 4-5 years. The lifecycle costs for a geomembrane-based water reservoir that includes a full replacement of the liner and the cover would be about $35 million ($0.067/liter) compared to about $140 million ($0.268/liter) for a concrete solution.

Similarly, a cost comparison was made between a water reservoir using geomembrane liners and covers of 378,500m^3 in Oregon, USA and a concrete tank park for 2 million m^3 water in Jeddah, KSA. The total project costs for the water reservoir in Oregon was about $16 million ($0.0422/liter) whereas the costs for the Jeddah storage facility was about $200 million ($0.10/liter). If one also higher costs factors such a concrete construction would cost about $0.167/liter when built in the US (~60% cost premium versus KSA). As in the previous example, the costs of building a geomembrane-lined and covered water reservoir are about four times lower than building a concrete tank farm.

Thus, although especially in Africa and the Middle East, steel tanks and concrete tank constructions are still widely used for potable water storage, from an economic perspective, water reservoirs should be preferred over concrete tank farms. Furthermore, water reservoirs using liners and floating covers are more sustainable option.

4 Sustainability

Generally, the (concrete) construction industry is responsible for 11% of the world's man-made CO_2 emissions. If concrete was a country, it would be the third largest carbon emitter in the world[3]. Life cycle analyses (LCA) with a cradle to grave approach comparing different methods of construction have shown that constructions with geosynthetics can reduce CO_2 and other emissions, reduce natural resources depletion, and reduce energy demand. Furthermore, they reduce the impacts for residents near constructions with lower noise levels and lower emissions.

5 Conclusions

New developments in the use of plasticizers, UV and heat stabilizers, and different type of fabrics in PVC-EIA geomembranes have generated materials with improved physical properties (extra high strength and low temperature flexibility), weathering performance, and chemical resistance. Furthermore, these materials are all qualified for safe use in potable water applications though e.g., NSF standard 61 and AS/NZS 4020 certifications. Thus, reinforced PVC-EIA(HP) geomembranes are excellent materials of choice for liners and floating covers for potable water applications. Furthermore, the lower costs and the merits of being a more sustainable choice, the use geomembranes would be a preferred option over concrete and steel tanks.

References

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