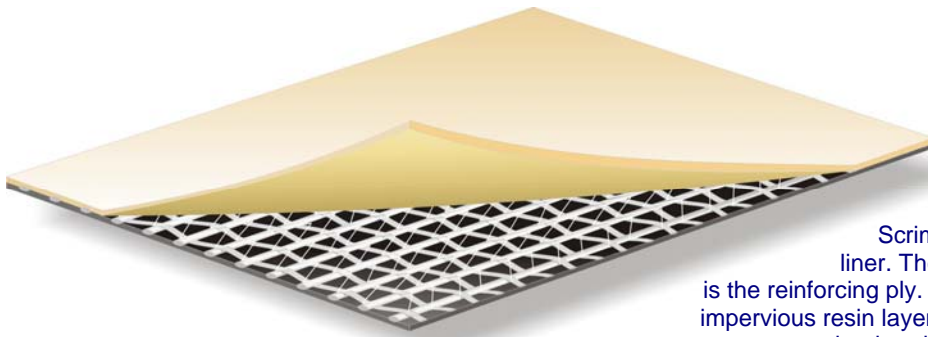


Membrane Liner Alternatives for Algalculture Raceway and Support Ponds

CLI is probably the most experienced developer, provider and installer of impervious membrane liners for algalculture applications with 15 years of experience in this application. We understand the economic constraints facing the algae industry especially for biofuel production. It is our goal to provide the most value for the money invested with the most viable options.

Some of the more economical options available are Linear Low Density Polyethylene (or "LLDPE") based membranes. Polyethylene based membranes have been around for decades and until recently, have not been available in a form suitable to this application. This is largely due to advances with LLDPE based resins in conjunction with effective UV stabilizers and scrim reinforcement options now available. High Density Polyethylene (or "HDPE") is the most commonly encountered geomembrane in the world. HDPE is not suitable to raceway ponds as these membranes are rigid and have a high coefficient of thermal expansion and contraction whereby the material very visibly shrinks and grows with changes in ambient temperatures. Scrim reinforced LLDPE exhibits significantly less thermal expansion and contraction than HDPE especially when the exposed to sunlight side is white in color. For earthen raceway ponds an unreinforced LLDPE product should be suitable. For raceways with constructed walls a more conservative approach using a scrim reinforced material should be considered. The scrim reinforcement helps contribute to reduced material expansion and contraction.



Example of a 3 layer Scrim reinforced membrane liner. The middle layer (or "ply") is the reinforcing ply. The two outer plies are impervious resin layers that are heat bonded to each other through the scrim layer.

Additional caveats with polyethylene materials is that when compared to Hypalon[®], EPDM rubber and PVC based membranes, LLDPE is a considerably lighter membrane and therefore more subject to wind related damage in ponds that sit empty. It shall be noted that any lined pond sitting empty (or not having ballast of any sort) is a candidate for wind damage that can be catastrophic. Heavier materials do offer a somewhat better degree of resistance to wind damage.

An important factor to consider in membrane liner selection is repair-ability. Of all materials available, Hypalon[®], EPDM, polypropylene and PVC based membranes are amenable to bonding or repairing with membrane specific tapes and adhesives. Polyethylene based membranes can only be bonded with heat and or extrusion welding process. With LLDPE membranes it is possible to make repairs using patches cut from the same material and apply them with specialty hand held heat gun (such as a Leister Triac or Forsthoff Quick LE) and a seam roller.



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A note on warranties:

Almost all geomembrane warranties address weathering resistance against the effects of UV exposure (exclusively). With the exception of Hypalon®, most all warranties are on a Pro-Rata Basis (or "PRB"). Only Hypalon® is offered with a full replacement for 15 years and an additional 15 years on a prorata basis (30 year total) on their 45 mil thickness product.



Hypalon®

In terms of durability (especially UV) and ease to work with, Hypalon is the gold standard material. Offsetting this is that it has traditionally been the most expensive material available. The current UV exposure warranty period for 45 mil (1.14mm) thickness Hypalon® is 30 years. 36 mil (.914 mm) thickness Hypalon® is available with a 20 year PRB warranty. The current truckload price for 45 mil thickness Hypalon® is about \$1.20/SF (\$13.00/M²)+ freight & installation costs.

EPDM

EPDM (non-reinforced) synthetic rubber (or Ethylene Propylene Diene Monomer) is another contender but is only available in black unless 10' wide white roofing grade material is ordered in 60 mil thickness. 45 mil (1.14mm) thickness EPDM is less than ½ the cost of Hypalon (roughly \$.50/sf (\$5.38/m²) for 45 mil thickness material + installation labor). This is a very flexible material that offers excellent dimensional stability. In black the UV exposure warranty period is 20 years PRB.

Polypropylene

Polypropylene (sometimes referred to as Thermoplastic Polyolefin or "TPO") can be used in both reinforced or non-reinforced versions. The minimum practical thickness for this product in an un-reinforced version is 30 mil (.762 mm) thickness. If a high amount of foot traffic over that liner is anticipated a 40 mil thickness may be more advisable. This is a very flexible material that offers excellent dimensional stability. For white un-reinforced polypropylene based geomembranes, the applicable warranty period is 10 years PRB. In reinforced form, 36 mil (.762 mm) thickness white color, the warranty period is up to 15 years PRB and in white 45 mil (1.14mm) thickness, the available warranty coverage 20 years PRB. Truckload Polypropylene costs range between \$.32 and \$.45/sf (\$3.44 and \$4.84/m²) + freight and installation. In large quantities freight is included with un-reinforced versions.

Reinforced PVC

A specialized reinforced PVC membrane liner is available for this application. This is a highly modified PVC product formulated with copious amounts of titanium dioxide for UV resistance. The warranty period 10 years PRB. The current truckload cost is about \$.80/sf (\$8.61/m²) delivered + installation costs. The advantage of this material is that it is solvent adhesive weldable and it is easily repaired. It is also a very strong and durable product but it is not available in potable water grades. The thickness of this product is 30 mils (.762mm).

Linear low Density Polyethylene

LLDPE in reinforced and un-reinforced versions are the current low cost leaders that are viable in this application. If this material is selected it should be used with a light/heat reflecting color as it does have less dimensional stability than all other materials referenced herein (especially in un-reinforced form). Typical encountered thickness are: 30 mils (.762 mm), 36 mils (.914 mm) and 45 mils (1.14mm). In truckload quantities LLDPE prices range from \$.25 to \$.37/sf (\$2.69 to 3.98/m²) delivered within the US mainland+ installation costs.

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Note on Potable Water Certification:

Most materials referenced herein are available with US National Sanitation Foundation – Standard 61 (NSF-61) certification for suitability in potable water applications. The exceptions are un-reinforced polypropylene, un-reinforced LLDPE, and reinforced PVC.

The unsupported materials are manufactured with the same resins as their reinforced counterparts but lack this rating because certification is an expensive annual expense. The un-reinforced materials are not often used in engineered potable water applications and therefore manufacturers typically don't opt for the additional \$40,000 /annum cost to register these products.

We offer an algae specific LLDPE product that is manufactured as a laminate by co-extrusion process. This product is exclusively available through CLI-Clearwater construction.

Note on Pricing

The pricing provided herein shall be regarded as comparative reference data only. The cost of membrane resins are tied to petroleum costs and are subject to change at any time without notice.

Please feel free to contact me with any questions or comments about these or any other products.

Thank you for your time.

Best Regards,



Andre Harvey,
Regional Manager
Colorado Lining Construction, Inc

