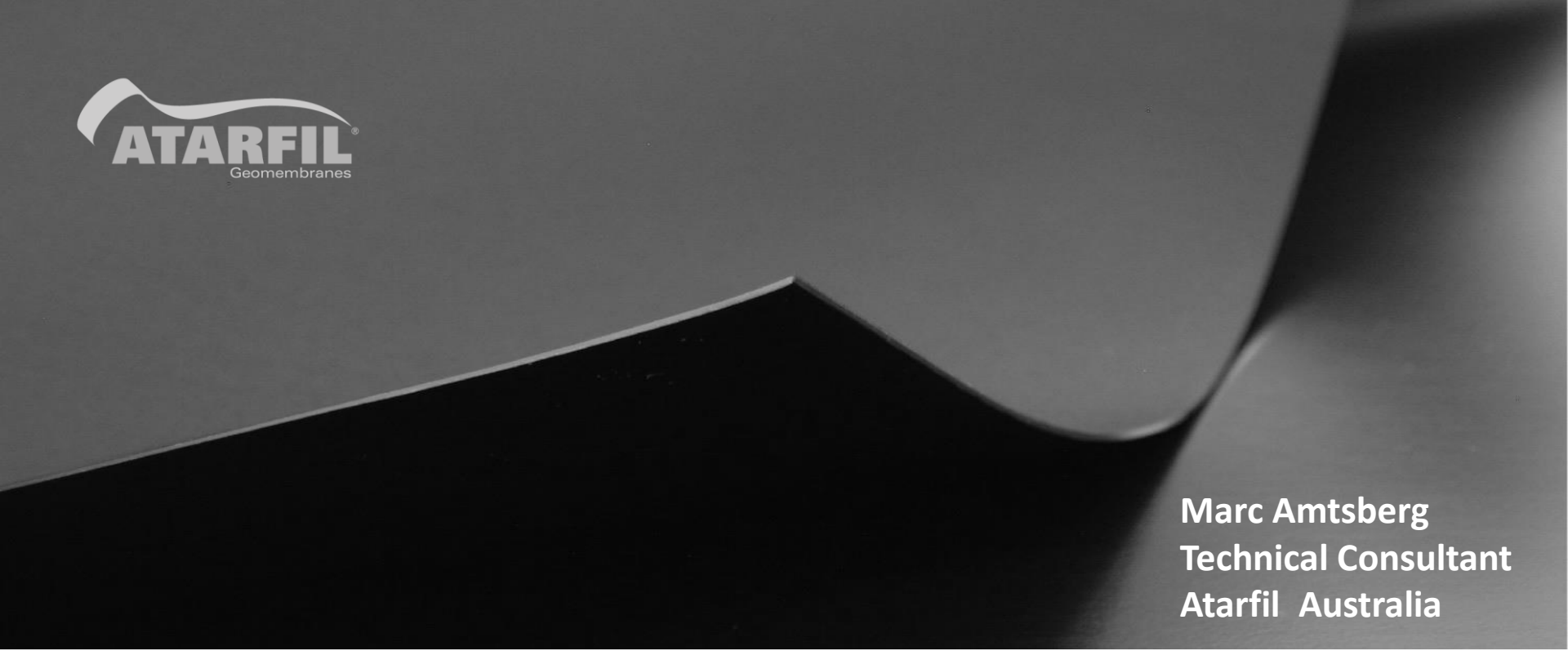

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Geomembranes in Australian Landfills

- EPA and R&D

A BRIEF SUMMARY FOR TODAY;

1. What is a Geomembrane?
2. What do Australian Regulatory Guidelines specify when prescriptive?
3. Do Australian Regulations help understand Geomembrane service lives?
4. What is the opportunity in the current framework for R&D?
5. R&D Future – Emerging contaminants /PFAS and options

What is a Geomembrane?

The primary hydraulic barrier (liner) that protects groundwater from contaminants.

Basic Geomembrane choice is;

Resin type – most landfills are Polyethylene
Formulation – added to the PE to establish durability
Thickness – Benchmark for mechanical properties

E.g. Most common Landfill Baseliners are 2mm Smooth, HDPE
(HDPE = MDPE resin + Carbon Black + Range of Additives)

So what is the intent of Geomembrane Liner specifications/regulations?

Understanding Geomembrane Hydraulic Service Life long term;

Holes – risk of puncture, stress and poor installation

Polymer changes – risk of structure changes due to chemistry, UV, oxidation, temperature.

If the installation limits holes;

The challenge becomes parameters for short tests to model stress/polymer changes long term.

How do Australian Landfill Guidelines address this for Geomembranes?

- “Prescriptive” values in Vic / NSW (upgrades planned) and SA
- Risk Based - Low prescription guideline Qld, Tas and NT
- Note WA – no ‘guideline’, prescription around chemical contaminants for waste classification
- Note prescription intended as min. guidance

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Geomembranes

What Geomembrane properties are prescribed?

- Polymer for site conditions, CQA tables defer to HDPE or LLDPE
- Mechanicals and MQC to meet GRI-GM13
- Baseliners - Min 2mm Thickness
- Resin source requirements - sheet and weld rod
- Shear and Cushion Testing

- Destructive Weld testing
- Leak Location Surveys
- CQA – intervals and tests prescribed
- Prescribed Leakage Rates by Landfill Category

Properties	Test Method
Thickness - (min. ave.) - mm • lowest individual of 10 values - %	D5199
Formulated Density (min. ave.) - g/cc	D 1505/D 792
Tensile Properties *(1)* (min. ave.) • yield strength - kN/m • break strength - kN/m • yield elongation - % • break elongation - %	D 6693 Type IV
Tear Resistance (min. ave.) - N	D 1004
Puncture Resistance (min. ave.) - N	D 4833
Stress Crack Resistance *(2)* - hr.	D 5397 (App.)
Carbon Black Content (range) - %	D 4218 *(3)*
Carbon Black Dispersion	D 5596
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 3895 D 5885
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885

Do these properties reveal longevity?

GRI-GM13 properties - (a std driven by manufacturers);

- ✓ Sets min. mechanical properties to resist stress and for MQC
- ✓ Measures Carbon Black / Benchmarks SCR - UV and OIT

- ❖ No mention of hydraulic performance or testing

Thickness recommendation 2mm –

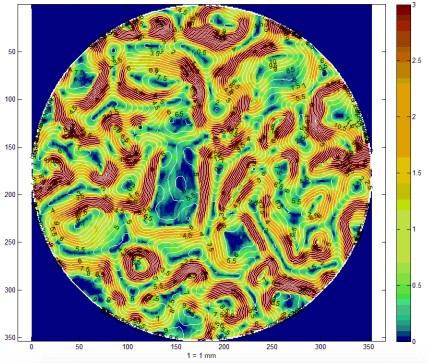
- ✓ Good for range of Landfill Leachates - diffusion
- ✓ Cushion GT testing, better than 1.5mm

(going thicker than 2mm does not seem to add same benefit)

Does current Cushion Testing improve longevity understanding?

Analyse Geotextile ability to limit aggregate stress impacts;

- ✓ Australian methods remove variables better than overseas.
- ✓ If the designer has empiricism and understands test conditions
- ✓ If testing aligns to aggregate placement onsite.
- ✓ Designers are challenging the 6% GM strain prescription.



- ❖ Can become a tick box not a design tool.
- ❖ Stakeholders question lower strain specifications
- ❖ Short term vs 1000 / 10,000hrs

Does specified SCR and UV improve our understanding of Longevity?

Stress Crack Resistance GRI-GM13– > 500hrs (often CQA / 10,000sqm)

- A fundamental measure of resin quality.

✓ If installation and leachate has no impact - yes based on GRI-GM13

❖ What about leachates that accelerate SCR?

❖ Does this value keep up with modern resins, it doesn't reveal the actual value?

UV (HPOIT retained after 1600hrs);

✓ A fundamental measure of the ability of HALS performance in UV light

Prescribed Longevity Measures

Do they reveal enough?

- HPOIT and OIT (non oven aged) CQA
  - Required by all prescriptive standards
  - Intended to evaluate exothermic oxidation = effective Antioxidant (AO) packages

- HPOIT and OIT Oven Aging
  - Required per formulation for GRI-GM13 and for LLDPE CQA only in BPEM
  - Measures AO / HALS depletion rates over 90 days in Oxygen at elevated temps

✓ Provides a representation of AO Packages and HAL Packages

❖ Certain stakeholders contend need for both HPOIT and OIT, I don't from testing

❖ Residual values are largely ignored.

❖ An oven test in oxygen, does not consider leachate

Do these prescriptive properties improve longevity understanding?

Product/ Installation CQA and Leak Surveys

- Yes, no doubt product quality has improved. Manufacturers now “fear” the test value is pass/fail and surveys are effective (Beck 2 papers 2012)

- Yes if the specification is written without ambiguity.
- Yes if experienced operators understand timeframes

- ❖ What about wrinkles?
- ❖ And do we align Geomembrane product testing to site or CQA everything?

In summary: Will this EPA prescription result in better Geomembrane longevity?

- ✓ Higher Geomembrane product and installation quality. (clearly evidenced by region)
- ✓ When treated as min. guidance as intended – still requires expertise

- ❖ Prescription requires new expertise from designer, contractors, auditor and suppliers.
  - biggest costs I have observed when this is underestimated

- ❖ Can CQA testing link better to site constraints? – focus client costs on key properties

- ❖ Risk of default to GRI-GM13, not site specific - challenging leachates

- ❖ Risk that prescription impacts innovation, what is available now in R&D?

And where is the opportunity for Geomembrane R&D?

Within the current EPA Guideline framework?

- Does prescription allow us to know what product is actually onsite or being tested in lab?
- Challenging Leachates
- Testing within timeframes and cost

AND

Future EPA Guidelines?

- Can we understand product recipes?
- Will manufacturers reveal the Geomembrane Mix?
- Do they need to?

Photo courtesy ExcelPlas

Current R&D – What options exist?

Historic R&D options include;

- Mason Jar Testing
- Pot Immersion
- Atlas Cell Testing
- Queens University – GLLS = leachate / temp and aggregate

But the challenge;

- Time frames and cost. (historically 3-12 months)
- Leachate – new cells does it exist? Can we synthesize?
- How do you ensure the product that reaches site is same?

Emerging Short Term Tests – Using thickness and temperature;

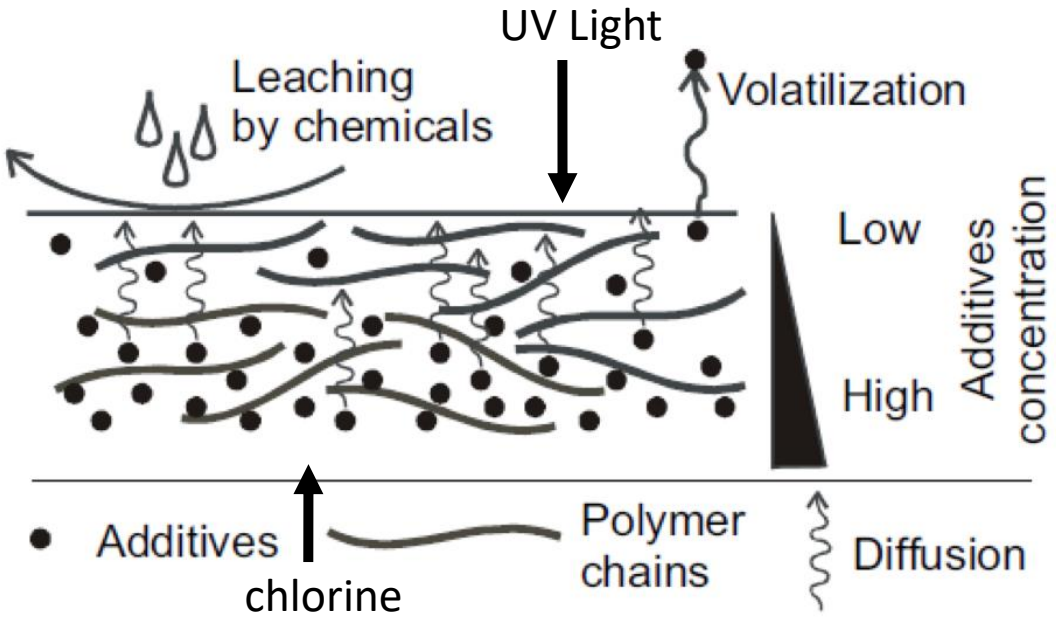
SCR through Strain Hardening – 40 days min. vs multiple tests of 48hrs
- makes high SCR resins more accessible, requires manufacturers R&D

90 Day Oven Aging at 85º in Leachate – OIT/HPOIT comparisons to oven only.

Ficks Second Law - diffusion is proportionate to path length, therefore thinner samples model long term performance of full Geomembrane thickness;

- **TFAI Thin Film Accelerated Immersion** - Compress 2mm to 250 µm
  - Agitate to prevent stagnancy,
  - Temperature up to 85deg.

Additive Loss Mechanisms



Emerging Short Term Tests

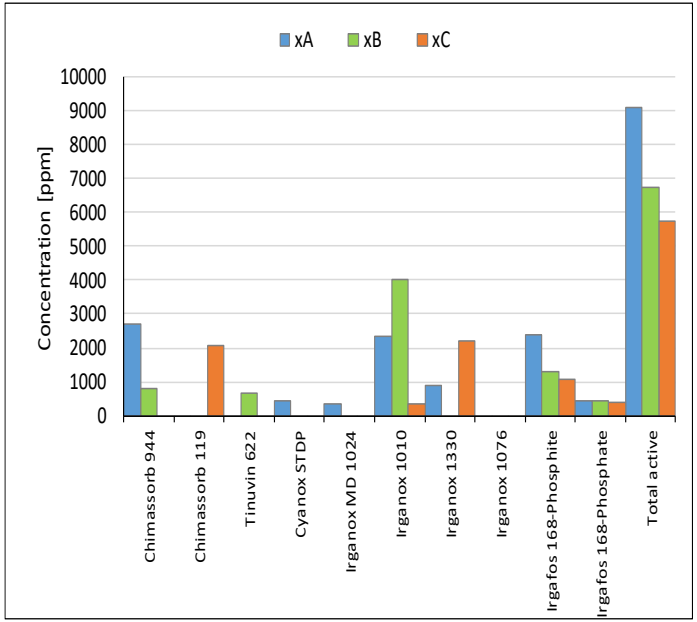
HPOIT and OIT - Functionally attempts to identify the additives. OR

Deformulation Analysis – pre and post oven and/or immersion

Quantitative Nuclear Magnetic Resonance (NMR) and High-Performance Liquid Chromatography (HPLC)

- certainly needs lab expertise to analyse
- probably needs manufacturer R&D

(not a cheap test but what is at stake?)



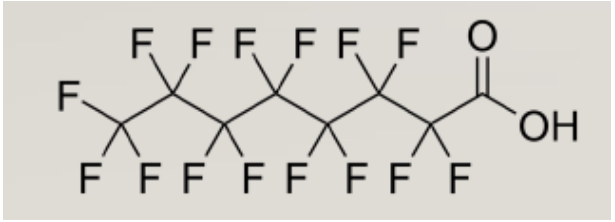
Will industry move towards specific Geomembrane recipes for high risk chemistry?

Do overseas regulations present the future?

- The fundamental challenge for all geosynthetics is that manufacturers protect their IP – **recipes take investment**

- BAM in Germany have Geomembrane Certification;
  - Legally bound to reveal resin / additives
  - Tracer additives
  - Pre-qualification
  - 100 year design lives

Does this prescription work better, still have to adjust recipe to challenging leachates?



And do Emerging Contaminants (eg PFAS) challenge all this?

Yes. Why? (Bouazza 2020)

- 5000+ chemicals
- Bio-accumulate – how do we account for precursors and what leachate?
- Diffusion risk through PE GMs – Determined by Concentration and Type
- Different behavioural expectations – Short chain – remain in solution / rapid
  Long chain – absorption to surface
- Diffusion dependent on the solvent – water v organic v HDPE

Results in a dilemma;

Regulation currently assumes minimal diffusion – how do I demonstrate this?

What leachate do we test?

PFAS – What is the current regulatory guidance?

In Australian Landfill Leachates;

- Short chains in greater concentration (Long Chain regulations phased out manufacturing)
- Long chain higher concentrations at Airports and AFFF (Aqueous Fire Fighting Films)
- PFAS NEMP 2.0 Jan 2020 –

Table 7 : Landfill Acceptance Criteria

Type – Unlined / Single and Double Composite + Leak capture

Specific Short and Long Chain Concentrations prescribed;

Concentrations -	leachable	0.7 µg/L PFOS + PFHxS
		56 µg/L PFOA
	Total Conc.	50 mg/kg

(Note a microgram is 1 millionth of a gram)

- Without Geomembrane data, the NEMP mitigates leak potential through traditional means;
  - Known low liner leakage with > 300mm acting head.

PFAS – A brief summary of PE Geomembrane Research;

Queens Uni – Di Battista et al 2020 – LLDPE 0.1mm – (PFHxS and PFOA – both long chains)
- Limited Contaminant Partitioning/diffusion (400 days)

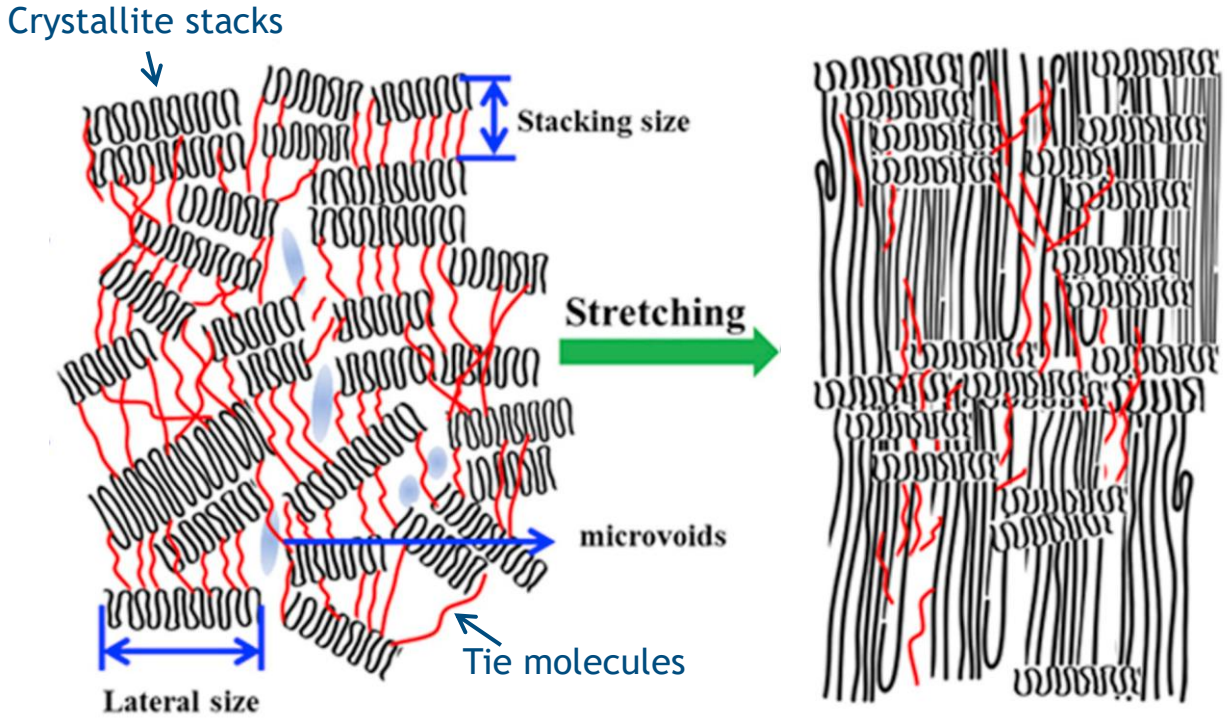
ExcelPlas – Atlas Cell – HDPE – PFAS is a powerful Stress Cracking Agent
Comparable to Igepal – (used to accelerate SC)

Boyd Ramsay – "Assessment of Barrier Systems for PFAS Containment in SWR" (EPA.SA)

Monash University – Bouazza (2020) and ACIGS Youtube / future PhD work (see Malek)

US TRB recommend for AFFF: XLPE – HD XL Cross-linked PE,
- superior SCR and chemical performance
(based on ACRP 2017, Bouazza 2020)

HDPE Chain Pull-Out in Igepal



R&D Options Now – Does the client know Geomembrane properties onsite?

GRI-GM13 requires most test values to be >. Does that reflect properties onsite?

Property	GRI-GM13 / EPA requirements	CQA Results BPEM 2mm HDPE GM
Stress Crack Resistance (NTCL)	> 500hrs	**8000hrs**
OIT ASTM D3895	> 100 mins (55% ret OA)	**211 mins (78% retained OA)**
HPOIT ASTM D5885	> 400 mins (80% ret OA)	**600 mins (96% retained OA)**
UV Resistance	> 50%	**100% retained**

Get data to provide product failure results, not simply >=;

Huge ramification for: Understanding current risk

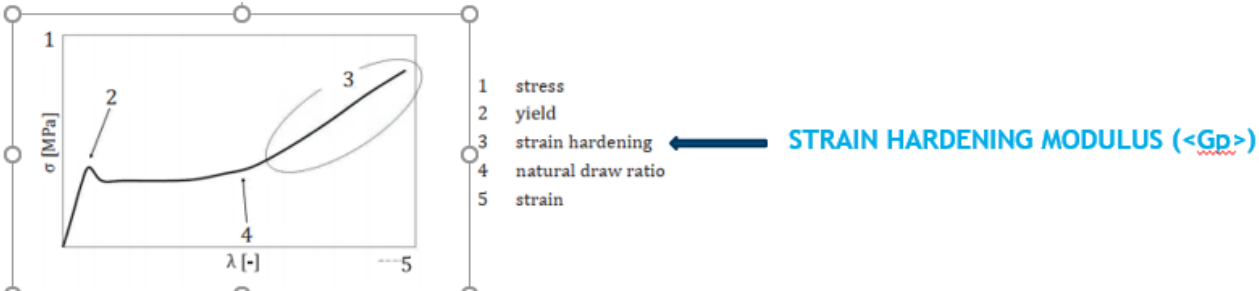
PFAS Licensing Applications if SCR is 8000hrs.

It is critical that R&D and academic studies now go beyond GRI-GM13.

R&D Option Now – Can we implement immediate measures?

- Weld coupons in your leachate ponds
  - Presents a Double Sided Immersion (2/3x more conservative than installed) in the highest PFAS concentrations onsite (particularly for short chain data)

- Stress Crack Resistance – review within the current HDPE space
  - High SCR sources are accessible
  - Obtain Strain Hardening Modulus Data



“Thoughts on EPA Geomembrane Prescription?”

- It has set important minimum guidance that has demonstrated benefits
- They should be used as a min benchmark as intended.
- The stakeholder must still perceive the need for expertise.

There is a risk that;

- We limit ourselves to prescribed testing and costs.
- Challenging leachates are not accounted for.
- We can underestimate the product onsite with >

Do they address PFAS?

I would suggest simply having a min level of confidence is a huge benefit.

Thankyou

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