The Home of
Geosynthetics

Sustainability Benefits
of Geosynthetics

Contents

Introduction

This paper forms part of the contribution of the International Geosynthetic Society to the European Commission's consultation on *Microplastics pollution – measures to reduce its impact on the environment.*

We set out the sustainability benefits of geosynthetics in the following aspects:

- SDGs as a whole, including examples
- Circular economy
- Prevention of microplastic and chemical leakage
- Carbon reductions
- Hydraulic applications

Understanding Geosynthetics

> "In complete contrast with single-use disposable consumer plastics, geosynthetics are highly engineered, robust and highly durable.

Our contribution to the consultation includes an explanation on what Geosynthetics are, and how they function. We summarise the main points here.

Geosynthetics are durable synthetic products manufactured to the highest standards to deliver demanding levels of performance. Geosynthetic materials can provide long, useful lifespans for the projects that use them, maintaining performance for decades. Where required they have the potential to perform their design function for over 100 years.

Some plastics bring very minimal human benefit. They are often very light and easily lost into the environment where they decompose quickly into microplastics. Examples are plastic carrier bags, packaging, disposable cups, cutlery and drinking straws. There is evidence that in some coastal regions, such materials make up over 70% of plastic waste (by number of objects) entering the environment.*

In complete contrast with single-use disposable consumer plastics, geosynthetics are highly engineered, robust and highly durable. They are not easily lost into the environment, and they typically do not contain harmful chemicals. Geosynthetics can be responsibly recycled or disposed of at the end of their design life.

Read more: IGS - Did You Know - Durability

* Source: Plastics Entering the Global Ocean (National Oceanography Centre, 2021)

Geosynthetics and the SDGs; Sustainable Outcomes

The IGS shares the UN's ambitious blueprint 'to achieve a better and more sustainable future for all'. The appropriate application of geosynthetics can make significant contributions to the SDGs, including preserving resources, access to clean water, emission reduction, climate change and other environmental issues.

Read more: IGS - Did You Know - SDGs
Read more: IGS Sustainability eBook

Feeding the world; SDGs 2, 12, 13, 14, 15

Geosynthetics benefit agricultural production for example:

- Prevention of soil erosion
- Prevention of pesticides releasing into irrigation water
- Maintenance of suitable water saturation and soil stabilization
- Managing and preventing contamination from animal waste and methane
- Providing waterproof barriers for urban agriculture

Ensuring fresh water supply; SDGs 1, 6, 14, 15

Geosynthetics help prevent water scarcity:

- Increasing agricultural efficiency
- Preventing leaks from irrigation canals (performing ten times better than cement concrete)
- Preventing contamination of reservoirs

Protection against natural disasters; SDGs 1, 11, 14, 15

Geosynthetics play a vital role in protecting human life, property and livelihoods from the impacts of natural disasters and a warmer climate:

- Preventing coastal erosion
- Providing safe offshore artificial reef environments
- Protecting against long term flooding
- Providing short-term flood defences
- Protecting against landslides
- Stabilizing natural and constructed slopes against earthquakes and winds erosion

Read more: IGS - Did You Know - Landslides

Connecting people; SDGs 1, 8, 9, 10, 11

Geosynthetics allow communities to develop through cost-effective and durable infrastructure:

- Enabling road construction in challenging environments
- Improving performance and longevity of railways
- Helping to reinforce bridges, ensuring no bumps in the approach and no damage from seasonal thermal expansion or contraction

Economic development; SDGs 1, 8, 9, 11

Geosynthetics enable economic development by delivering high quality outcomes more quickly and at reduced cost. Cost savings arise from:

- Reduced quantity of soil required for civil engineering projects
- Faster construction
- Better long-term performance, with less disruption from repair and maintenance
- Economic growth resulting from greater value for money
- Resilience through protection from extreme weather events
- Environmental cost savings through reduced material usage

Geosynthetics; Sustainable Approaches

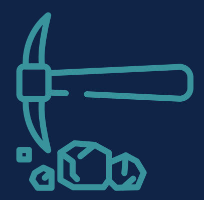
In contributing to the sustainable outcomes to achieve the SDGs, the use of geosynthetics supports sustainable approaches, including circular practices, environmental protection from harmful substances, and reduced embodied energy.

Circular economy; SDGs 8, 10, 12

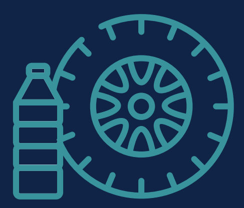
Every year, humankind generates more than 10 billion tons of waste from construction and demolition, much of which ends up in landfill. Mining produces around 200 billion tonnes of waste annually, which also goes to landfill or is piled up in unsightly slag heaps.

Geosynthetics allow us to follow circular principles and good use of recycled and re-used materials to deliver wider sustainability benefits. Typically, these materials include:

Construction and demolition waste (CDW)



Waste from mining activity



Used consumer products such as plastic bottles and vehicle tyres

Geosynthetics and construction, demolition and mining waste

Combined with geosynthetics we can:

- Re-use CDW as infill to construct unpaved roads on soft ground, reducing landfill and the need for quarried stone
- Construct more stable slopes, for example in railway cuttings, using a combined geosynthetic/CDW system
- Create a sub-ballast layer for railways by blending geosynthetics with fine mining waste mixed with local soils. This increases track stiffness, reduces maintenance and cuts demand for quarried ballast

Read more: IGS - Did You Know - Circular Economy

Re-use and re-cycle to prevent microplastic and chemical leakage; SDGs 6, 9

Many of the one million plastic bottles sold every minute end up in our waterways and oceans. Each year hundreds of millions of tyres are manufactured. After use they are often discarded in stockpiles that are prone to fire, releasing toxic fumes. Both these waste materials have valuable qualities that can be unlocked with geosynthetics.

Geosynthetics enable re-use of consumer waste that could otherwise generate microplastics to:

- Form drainage systems in landfill sites, where these materials are already abundant. Testing shows a greater drainage capacity compared to traditional gravel layers
- Construct river flood defences using baled tyres
- Build infiltration trenches that reduce flood risk in urban areas when used with plastic bottles

Geosynthetic products can recycle consumer waste:

- Waste tyres can be converted into rubber grains and used to manufacture geosynthetics, with savings in the use of bentonite, which would otherwise have to be mined and transported in bulk
- Geosynthetic products designed to strengthen road asphalt and extend road lifetimes can be manufactured from 100% recycled plastic originating from bottles

Such geosynthetic products can themselves be recycled at the end of their useful life, typically through milling and re-manufacture.

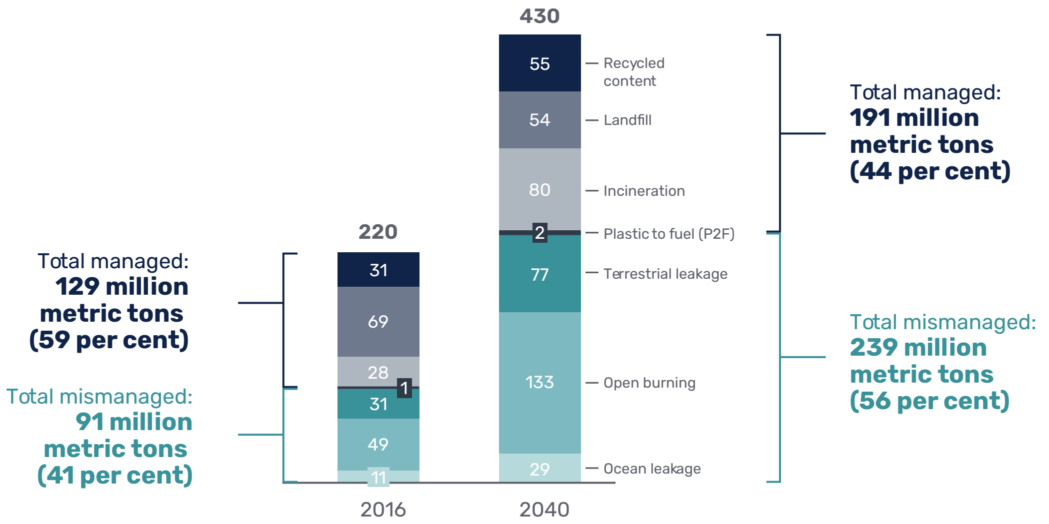
Containment prevents leakage of microplastics and toxic substances; SDG 6

The world creates more than two billion tonnes of municipal solid waste a year with at least a third of that not managed in an environmentally safe way. With waste expected to grow by at least three billion tonnes by 2050 it's vital that it is managed responsibly to prevent disease and groundwater contamination.

Figure 4: Fate of all plastic waster under Business-as-Usual

Mismanaged plastic waste will grow from 91 million tons in 2016 to 239 million metric tons by 2040

Million metric tons of plastic waste (macroplastic and microplastic)



A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution*

> Geosynthetics prevent the leakage of microplastics and toxic chemicals into the environment from landfill sites.

Estimates in a recent study (see diagram) suggest in excess of 54 million tonnes of plastic waste will go to landfill each year, by 2040. The same study suggests up to 239 million metric tonnes annually will be mismanaged, much of which could potentially have been handled by landfill.

Geosynthetics prevent the leakage of microplastics and toxic chemicals into the environment from landfill sites. As well as providing appropriate drainage and other functions, geosynthetics offer an effective and highly durable barrier function. Used in landfill over the past 60 years, geosynthetics have successfully contained waste, protected groundwater and provided sanitation.

Read more: IGS - Did You Know - Landfill

* Source: Breaking the Plastic Wave (Pew Charitable Trusts & Systemiq Ltd, 2020)

> In some cases, geosynthetics perform better than conventional dewatering technologies.

Containment geosynthetics enable more efficient and effective **treatment of sludge** from sewage and industrial wastewater, through collection, dewatering and disposal. Permeable geosynthetic tubes separate fluid waste from solids, minimising waste volume and reducing costs and time for transportation of sludge to disposal sites. In some cases, geosynthetics perform better than conventional dewatering technologies.

Read more: Geotextile Tube Dewatering Performance Assessment (Ardila et al, 2020

In addition, re-usable geosynthetic nets are used as **"trash traps"** to catch plastic waste from drainage systems. These are typically deployed to capture debris in stormwater runoff, and are effective in trapping pollutants as small as 5 mm.

Geosynthetics have been used to prevent contamination by **radioactive waste**. Following the 2011 earthquake off the Pacific coast of Tohoku in Japan, and resulting damage to the Fukushima Daiichi nuclear power plant, 1,600 temporary storage units were constructed using geomembrane liners.

Low embodied energy and low carbon; SDGs 13, 10, 12

Sustainable techniques using geosynthetic products ensure reduced energy consumption and emissions through various means:

- Reduced on-site excavation and placement
- Reduced transport of bulky construction materials
- Faster and simpler construction
- Extended infrastructure life
- Reduced maintenance
- Other construction materials can be replaced or reduced, typically:
    - Sand and aggregate
    - Concrete, lime and cement
    - Steel

A survey of 25 applications demonstrated an overall average of 65% reduction in carbon footprint using geosynthetics:*

Application Area	No. Cases Described	Average Carbon Savings
Walls	6	69%
Embankments and Slopes	4	65%
Armoring	4	76%
Landfill Covers	3	75%
Landfill Liners	2	30%
Retention	3	61%
Drainage Pipe	3	40%
TOTALS	**25**	**65%**

* Source: Geosynthetic Institute White Paper #41 (Koerner, 2019)

> **"** In drainage applications, use of geosynthetics resulted in lower impact for all indicators.

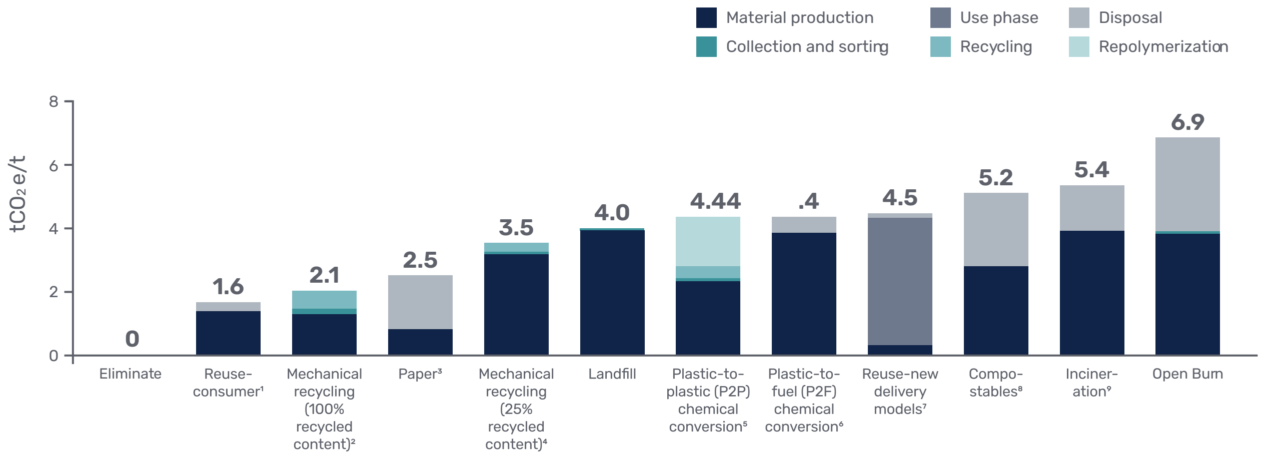
Analysis by Wallmann and others compared geosynthetics with the environmental performance of common alternative materials (concrete, cement, lime or gravel), applying life cycle assessments in accordance with ISO standards 14040 and 14044. Indicators included cumulative energy demand, greenhouse gas (ghg) emissions, ozone and particulate formation, acidification, eutrophication, land competition and water use. In drainage applications, use of geosynthetics resulted in lower impact for all indicators, except land competition (approximately the same in each case). Non-renewable cumulative energy demand per square metre was reduced by 56% and cumulative ghg emissions were 67% lower (10.9 kg CO2-eq vs 3.6 kg CO2-eq.)*

Transport and handling strongly influence the carbon footprint of geosynthetic versus conventional construction products. Construction of a landfill project of 32 ha size using a geosynthetic capping system required 165 truckloads of geosynthetic roll to be delivered in place of 21,000 truckloads of clay and gravel.**

Geosynthetics enable responsible disposal through **landfill**. Estimates show that landfill disposal results in lower ghg emissions of plastic waste by 42% compared with open burn; 28% compared with incineration; 23% compared with compostables.

Figure 20: Greenhouse gas emissions of 1 metric ton of plastic utility*

Different treatment options have vastly different greenhouse impacts



* Source: Environmental Benefits by Using Construction Methods with Geosynthetics (Büsser et al, German Geotechnical Society (DGGT); 2014)
** Source: Geosynthetics in Geoenvironmental Engineering (Müller and Saathoff, 2015)

* Source: Breaking the Plastic Wave (Pew Charitable Trusts & Systemiq Ltd, 2020)

Replacing and supplementing aggregates to reduce impact; SDGs 9, 12, 13

There are many ways that geosynthetics deliver reduced energy and resources use. One powerful example is the use of geosynthetics to replace or supplement aggregates.

Aggregate is essential for the construction of highways. But use of aggregates can be highly problematic in terms of energy and wider environmental considerations. Depending on geology and planning restrictions, suitable construction aggregates are unlikely to be available immediately adjacent to construction sites.

Aggregates have to be extracted via quarrying or dredging. Quarrying can impact geomorphology, water quality, biota diversity and groundwater. Quarries are a visible blight on the landscape and generate significant heavy-load traffic through local communities. Dredging and marine dumping cause direct disturbance and physical changes to the seabed, lead to the suspension of sediment and associated changes in water quality, release and remobilise contaminants on or in the seabed, and alter local hydrodynamics and settlement patterns of sediment.

Geosynthetics can typically reduce the use of aggregate in infrastructure construction by over 50%, and up to 90% in some cases. Given their much lower density, just 32kg of geosynthetics can replace 30 tonnes of aggregates, while delivering better performance.

For example, geosynthetic drainage layers are generally a few millimetres thick and can replace granular drainage layers of several hundred millimetres. Geosynthetics can also strengthen and stiffen compacted aggregate layers to such an extent that they exhibit better load bearing performance while reducing the thickness of aggregate layers by 50%. For every kilometre of road, geosynthetics can save 1250 cubic metres of imported aggregate, avoiding 200 high-emission dumper truck movements.

Read more: IGS - Did You Know - Aggregates

Sustainable outcomes in hydraulic applications; SDGs 10, 11, 13, 14, 15

Geosynthetics provide lasting protection against climatic impacts including extreme weather events and rising sea levels. Communities in low-lying areas are especially vulnerable, with more than 10% of global populations living on coastal land less than 10 metres above current sea levels.*

Even in coastal regions many are at risk from flooding caused by storm run-off. The engineering challenge is to keep water within certain bounds. Sea defence dykes, emergency dykes, canal dykes, and all manner of streams and channels are an important element of land protection to allow for irrigation or navigation. Indeed, longitudinal dykes are one of the most often used structures designed and constructed to keep river water contained in the event of a flood.

Read more: IGS - Did You Know - Geosynthetics Prevent Floods

* Source: Columbia Climate School

Geosynthetics have been used in e.g. dams, canals and coastal protection for more than 30 years. Given the range of applications, a variety of materials and products have been developed, and their performance is well-understood. In order to meet the requirements of specific applications, geosynthetics are designed to perform functions including separation, filtration, draining and lining.

Use of geosynthetics in hydraulic engineering results in huge economic savings and sustainability benefits through:

- Substitution or reduction of selected soil materials
- Ease of installation
- Increased speed of construction
- Improved performance: increased longevity; reduction in maintenance
- Better conserving natural environments compared to alternative designs*

* Source: Hydraulic Applications of Geosynthetics (Heibaum et al, 2006)

CANALS

Demand for secure water containment and transport is growing. This problem is exacerbated by urban water demands and increased agricultural production in remote areas. To mitigate this problem, canals have been constructed to transport water to where it is needed. Many canals are lined with earth or concrete. Earthen canals are relatively inexpensive to construct but lose 50% or more of the water they transport to seepage. They also are prone to erosion and growth of unwanted vegetation. Concrete canals address the challenges of erosion and vegetation. But they are costly to construct, carbon intensive and prone to cracking. Once cracking occurs significant amounts of water are lost to seepage - up to 30%.

Geosynthetics, either alone or in conjunction with a concrete veneer, can greatly increase the effectiveness of a canal lining system. The "Canal-Lining Demonstration Project Year 10 Final Report", published in November 2002 by the United States Bureau of Reclamation, indicated that seepage could be reduced from 50% or more for earthen canals to 10% for geomembrane lined canals and less than 5% for canals using geomembrane in conjunction with a concrete cover. While the concrete veneer may still crack over time, the geomembrane remains in place underneath the veneer to prevent seepage until the concrete can be repaired.*

SOIL EROSION

Soil erosion can have a significantly negative impact on our water resources, biodiversity and the soil's ability to support vegetation growth. Leaching can impair water used for drinking, navigation, recreation and irrigation. Around 60% of all the soil that is washed away ends up as sediment in our rivers, streams, and lakes. This directly impacts aquatic wildlife habitat, encourages excess algae growth, and makes all these bodies of water more prone to flooding. Eroded soil also often carries excess fertilizers, herbicides, pesticides and other toxic chemicals into our surface waters.

Therefore, soil stabilization is vital in preventing erosion, re-establishing vegetation, and curbing all the negative effects associated with soil degradation. Geosynthetics can successfully prevent erosion, either indefinitely or until vegetation can establish itself, in a variety of applications.

Geosynthetic products can resist the kinetic impact of rainfall, control the amount of water infiltration, and protect vegetation seeds from being dislodged. A geosynthetic-reinforced vegetative root structure is able to keep soil in place at higher hydraulic shear stresses than would be protected otherwise.

Read more: IGS - Did You Know - Erosion

* Source: Canal Lining with Geosynthetics (Geosynthetics Magazine, 2009)

DYKES

Dykes or levees are often constructed from a variety of locally available natural materials. However, while local soils are a cost-effective construction material, they are often of unsuitable quality, with variable permeability. Traditionally, surface erosion of dykes has been prevented using quarried rock armour. This rock armour must be placed with other soils in graded layers to prevent loss of finer soil particles. However, this leads to further challenges, as the correct stone grades are often difficult to source and place.

Geosynthetic products improve dykes. Used in combination with natural materials they have been shown to provide:

- Improved strength and flexibility
- Superior barrier and drainage functionality
- High durability and reduced degradation
- Almost complete removal of risk of dyke failure due to internal erosion processes

Geosynthetics enable the construction of dykes where they would not otherwise be feasible. There may be insufficient space to construct a stable dyke profile solely of soil, for example where buildings, watercourses and other obstacles are expensive or impossible to move. In such cases, geosynthetics can be used to increase the stability of the dyke, increase its slope angle, or replace a thick layer of clay soil to reduce a dyke's footprint.

Read more: Sustainable Use of Geosynthetics in Dykes

COASTAL PROTECTION

Coastal protection structures may include groynes, breakwaters and revetments, all designed with the purpose of absorbing the energy of incoming water. Traditionally, such structures are "stone fill", comprising a core, filter layers and a top layer.

Using geosynthetic products, coastal protection structures can be created with optimal structural geometries and cross-sections. These geosynthetic-based structures use locally sourced materials such as sand, reducing the need for expensive transport of armour stone and concrete.

Geosynthetic products also lend themselves to use in remedial protective measures, e.g. scour fill at the toe of slopes or the stabilisation of eroding cliffs. Prefabricated sinking mattresses or sand mats can also be used for conventional stone revetments to optimise construction thickness or ensure controlled installation. Geosynthetic products can also be used to create safe off-shore artificial reef environments for sea-life, attracting marine plants and life soon after construction.

The installation process for geosynthetics is straightforward, and products can be specified to deliver improved performance over typical mineral filter layers. Furthermore, geosynthetic filtering protects the core material from erosion.

It is commonly accepted that geosynthetics with proper stabilization with antioxidants will last in underwater structures with limited oxygen supply and temperatures at constantly low levels for at least 100 years.*

* Source: EI GEO Environmental Impact of Geosynthetics in Aquatic Systems (3rd Baltic Earth Conference, 2020)

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