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GEOSYNTHETICS, SUSTAINABILITY AND PLANETARY BOUNDARIES: REAL GLOBAL BENEFITS AND POTENTIAL POLICY RISKS IN EUROPE

1. Introduction

This paper places the contribution of geosynthetics towards meeting human needs as defined by the UN Sustainable Development Goals within the context of remaining within the planetary boundaries that must be respected to ensure a safe future for humans. It looks at two of these boundaries - climate change and novel entities (certain pollutants). In the former case, safe limits are well defined in quantifiable terms, and geosynthetics offer well-established and measurable benefits that amount to a competitive advantage over non-geosynthetic applications, materials and products. By contrast, in the case of novel entities, safe limits are not yet defined and while geosynthetics deliver quantifiable benefits, they risk being incorrectly associated with emissions of microplastics, despite their demonstrable role in preventing microplastic emissions from established sources.
In the second part of this paper, we explore the risks posed to the responsible use of geotextiles in Europe, resulting from European policy-makers' potential over-reliance on contested and implausible findings based on research conducted by non-experts in the field of geosynthetics. We note the absence of reliable boundary estimates of potential microplastics from geotextiles in real hydraulic applications, which could provide a sound basis for policy and related regulation. While this report is focused on the European Union, this work could form the basis for other regional studies.

2. Global Sustainability Challenges

2.1. Sustainable Development Goals

The United Nations' 2030 Agenda for Sustainable Development expresses human development needs in terms of 17 Sustainable Development Goals (Fig. 1). At the same time, human demands are outstripping the planet's supply of resources, while failing to deliver equitable development: in 2021 an estimated 698 million people or 9% of the global population were living in extreme poverty ($1.90 a day); over one fifth were below the higher poverty line of $3.30 a day, and over two fifths below $5.50.
Absolute poverty is defined by the UN as "a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to services".

Fig. 1 - The UN Sustainable Development Goals.

2.2. Planetary Boundaries

In 2009, the Stockholm Resilience Centre at Stockholm University produced a "planetary boundaries concept" defining nine planetary boundaries within which humanity can continue to develop (Fig. 2). The Centre

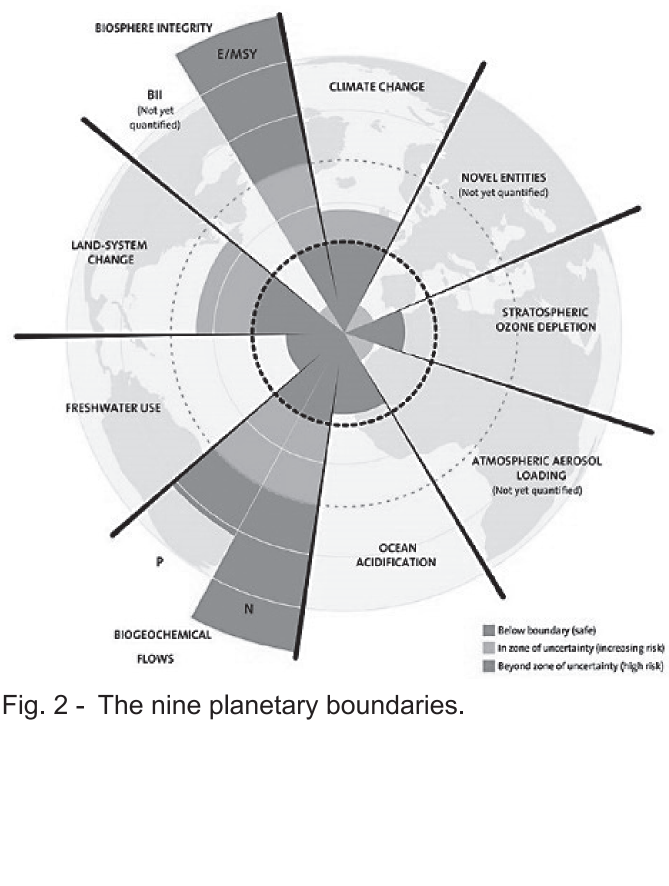

Fig. 2 - The nine planetary boundaries.

states that “crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes”. The framework was updated in 2015 and is now well-established.
While the SDGs are interconnected and overlapping, there remains a fundamental tension between the minimum resources required for human development and the planetary boundaries. This tension is addressed in a paper by Kate Raworth “A safe and just space for humanity” in which she proposed a “doughnut” model (Fig. 3) to represent the balance between interconnected and competing human and planetary needs.

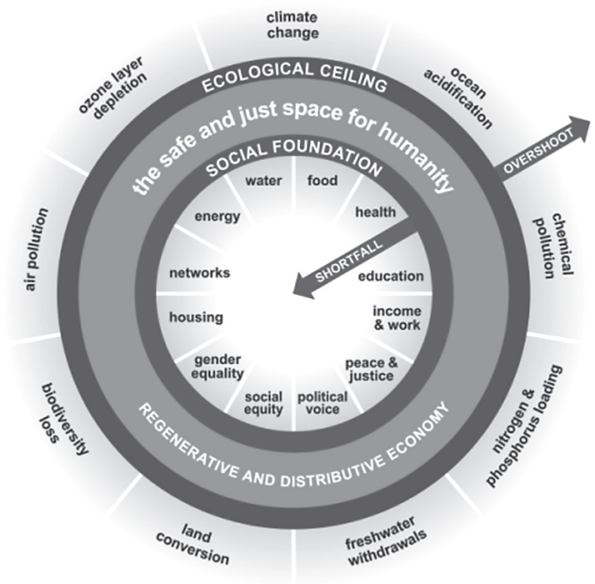

Fig. 3 - Raworth’s doughnut model.

The Doughnut consists of two concentric rings: a social foundation, to ensure that no one is left falling short on life’s essentials, and an ecological ceiling, to ensure that humanity does not collectively overshoot the planetary boundaries that protect Earth’s life-supporting systems. Between these two sets of boundaries lies a doughnut-shaped space that is both ecologically safe and socially just.

3. Geosynthetics and sustainability

3.1. Overview

Clearly the core challenge for engineers is to deliver infrastructure that is essential for societal development and individual advancement while minimising impact on the planetary boundaries, and ideally restoring natural systems. There are many ways in which geosynthetics provide benefits for human development with reduced environmental impact compared to alternative approaches.
Broadly, these include:

– Energy and resource savings through: reduced on-site excavation, reduced transport of bulky materials, faster and simpler construction, extended design life and reduced maintenance;
– Surface and groundwater preservation e.g. through landfill lining, containment of hazardous waste, sludge dewatering and purification, sludge and tailings lagoon capping and grey water storage for re-use;
– Replacement/reduction of other construction materials, typically sand, aggregates, concrete, lime, cement and steel (Fig. 4);
– Environmental protection and resilience, e.g. nuclear waste disposal, sustainable urban drainage systems, green and blue roof construction, cost effective flood defences, avalanche and rockslide prevention and protection, and earthquake resistant infrastructure.

Fig. 4 - Geosynthetics reduce aggregates use in road building.

3.2. Geosynthetics and the planetary boundaries - climate

One planetary boundary where geosynthetics can be shown to have a particularly positive impact is climate change.

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%

Tab.1 - Carbon savings when using geosynthetics. Analysis by Wallmann and Büsser 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.

The use of geosynthetics in many cases results in reduced carbon emissions.
A survey (Koerner, R.M. et al) of 25 applications demonstrated an overall average of 65% reduction in carbon footprint using geosynthetics (Tab. 1).
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 CO_2-eq vs 3.6 kg CO_2-eq.).
In addition to the mitigating impact on climate change, geosynthetics also deliver adaptation benefits (Fig. 5).

Fig. 5 - River erosion protection using geosynthetics under construction.

Geosynthetics provide lasting protection against climatic impacts including extreme weather events and rising sea levels. Even in coastal regions many people 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.
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 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. Geosynthetic products can successfully prevent erosion, either indefinitely or until vegetation can establish itself, in a variety of applications. They 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.

3.3. Geosynthetics and the planetary boundaries - novel entities

One of the planetary boundaries refers to the level of "novel entities" in the environment. These are chemicals and other new types of engineered materials or organisms not previously known to the Earth system as well as naturally occurring elements (for example, heavy metals) mobilized by anthropogenic activities. In contrast with the climate boundary where limits have been rigorously quantified, the safe limit for novel entities is unknown.
In January 2022, Persson et al published the first assessment of the impact on the stability of the Earth system of synthetic chemicals and other "novel entities" entering the environment.
This study asserts that the "safe operating space of the planetary boundary of novel entities is exceeded since annual production and releases are increasing at a pace that outstrips the global capacity for assessment and monitoring". The researchers conclude that humanity is currently operating outside the planetary boundary.
Novel entities include plastics waste, about which there is heightened public concern, notably over microplastics (plastic particles of size 1 µm to 5 mm). A Eurobarometer survey of European attitudes in March 2020 found that "88% are worried about the environmental impact of microplastics, and a similar proportion (89%) are worried about the impact of plastic products on the environment". The same survey found that "80% say that big companies and industry are not doing enough to protect the environment, and around two-thirds (67%) feel that citizens themselves are not doing enough".
While these figures are high, they make no distinction in product type, product characteristics (e.g. durability), or industry sector. Indeed, in expressing concerns about microplastics, there is no evidence that survey respondents are aware of the main sources of plastic waste in the environment.

3.4. Novel entities - estimates of microplastics in the environment

According to research by the UK National Oceanographic Centre (NOC, Horton et al), global plastics production in 2019 was 368 Mt, of which 58 Mt were produced in Europe.
NOC researchers found that estimates for the amounts of plastic input into the ocean vary hugely. In 2015

estimates ranged between 4 and 13 Mt of plastic entering oceans each year. A study published in 2020 estimated that between 19 and 23 Mt of plastics entered wider aquatic systems (rivers, lakes and the ocean) annually, with a forecast increase of 53-90 Mt by 2030.

A recent study commissioned by the EU (Hann) established the greatest sources of microplastics to the marine environment as: tyres (48%); pellets (28%); textiles (fibres released during laundering, 8%) and road markings (7%).

While proportional sources vary slightly compared to those set out in a 2017 IUCN report on microplastics, dominant sources (textile fibres and tyres) are generally the same (Boucher and Friot). There is a significant difference for pellets which IUCN estimates account for 0.3% of ocean microplastic.

A number of national studies have addressed the same question. One European example is by the Fraunhofer Institute, which in 2018 estimated a per capita emission rate of primary microplastics in Germany of around 4 kg. Fraunhofer concluded that in Germany, when considering 51 sources of microplastic, the ten biggest emitters were: tyre abrasion (1,285g/head/year); waste disposal (303g); abrasion of polymers and bitumen in asphalt (228g); loss of pellets (182g); sports and playgrounds (132g); construction sites (117g); shoe soles (109g); abrasion of synthetic packaging (99g); road markings (91g), and washing clothing (77g).

Of the 117g per head per year ascribed to German construction sites, 90g is due to demolition work; 25g due to on-site processing of plastics, and 1.7g due to losses from insulating materials.

As the Fraunhofer findings align with regional and global figures, they may give an indication of national emission patterns across European economies, although absolute amounts will undoubtedly vary significantly. Fraunhofer cite studies that estimated European national per capita rates of 2200-5130g (Germany); 1590g (Norway); 1670-3880 (Sweden); 965-2440g (Denmark). These compare with the IUCN study's estimated annual global emission rate per capita of 236-660g.

3.5. Novel entities - European Commission action on microplastics

The European Commission has a long track record in acting to reduce pollution. It is therefore unsurprising that the Commission is acting on plastics waste.

In March 2022, the European Commission proposed a series of measures in support of the European Green Deal (EGD) and the Circular Economy Action Plan (CEAP). These measures aim to make most goods in EU more durable, circular and energy-efficient across their full lifecycle. The aim is address resource-intensive sectors, including electronics and ICT, batteries and vehicles, packaging, plastics, textiles construction and buildings, food, water and nutrients. The latest proposed measures focus on (i) making sustainable products the norm; (ii) sustainable and circular textiles; and (iii) future construction products.

The Commission is also accelerating work on a common dataspace covering product value chains, to help enforce sustainability requirements, through inspections and market surveillance.

The EU's approach includes a Strategy for Sustainable and Circular Textiles, aiming to ensure textile products have a longer life, made from recyclable material and free of hazardous substances. Such products would be covered by a dataspace. A key goal is to reduce unintentional release of microplastics. While this is aimed at consumer and domestic textiles, similar measures may yet be suggested for geotextiles.

In any event, the Commission proposes to tighten sustainability requirements under the existing Construction Products Regulation. Greater attention will have to be paid to design of packaging and to minimum recycled content requirements and products will be expected to suitable for re-use, remanufacturing and recycling.

3.6. Novel entities - geosynthetics mitigate plastic waste

Geosynthetics play a significant role in preventing plastic waste and associated chemicals from entering the environment. This includes applications such as landfill and sludge management.

Containment prevents leakage of microplastics and toxic substances.

Estimates in a recent study (Fig. 6) suggest in excess of 54 Mt of plastic waste will go to landfill each year by 2040. The same study suggests up to 239 Mt annually will be mismanaged, much of which could potentially have been handled by landfill.

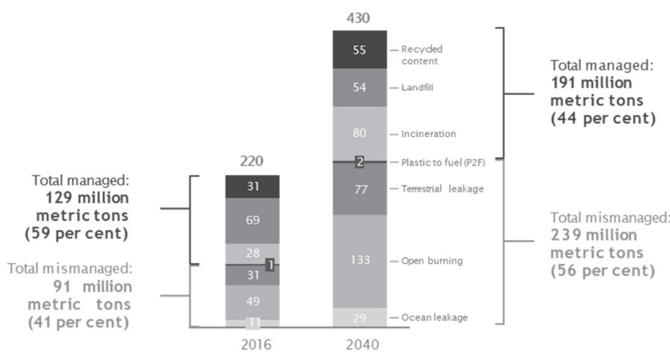

Fig. 6 - Destination of plastic waste under business as usual (Pew Charitable Trusts & Systemiq Ltd, 2020).

Geosynthetics prevent the leakage of microplastics and toxic chemicals into the environment from landfill sites (Monkul and Özhan).

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.

Furthermore, estimates show that landfill disposal results in lower greenhouse gas emissions of plastic waste by 42% compared with open burn; 28% compared with incineration and 23% compared with compostables (Fig. 7).

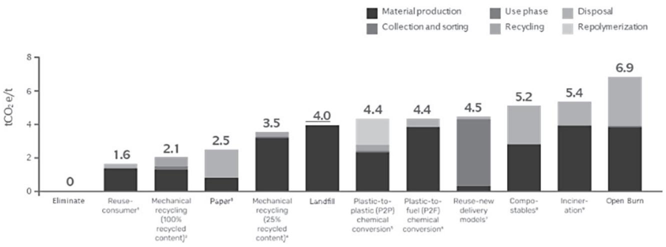

Fig. 7 - Greenhouse gas emissions per tonne of plastic utility (Pew Charitable Trusts & Systemiq Ltd, 2020).

Wastewater treatment plants play an important role in the removal of microplastics from the environment. Tanga and Hadibirata reported a “consensus that membrane bioreactors have a microplastics removal efficiency of 99.4% and above” and conclude that the adoption of membrane filtration alongside other measures has been found to further increase the efficiency of microplastics removal from treated water.

Containment geosynthetics enable more efficient and effective treatment of sludge from sewage and industrial wastewater, through collection, dewatering and disposal (Fig. 8). Geomembranes are used as barriers to prevent filtered contaminants from leaching back into the environment at various stages of the treatment process. Permeable geosynthetic tubes separate fluid waste from solids, including microplastics (Ardila et al, 2020).

Fig. 8 - Geotextile tubes used capturing and further dewatering sludge for disposal in solid form.

4. Advice to European policy makers

4.1. Scope of Commission investigations

Despite all known reputable studies showing that the vast majority of microplastics originate from sources other than geosynthetics, and an absence of studies demonstrating microplastic loss from any type of geosynthetics in real applications, the European Commission decided to widen their investigation into sources of microplastics to include paint, laundry and dishwasher capsules, and geotextiles.

In contrast to geotextiles, the case for including paint appears to be well-founded. Since 2016 at least six national, regional and global scientific studies have identified paints from all uses ranging from marine, architecture, automotive, road markings, and industrial as a source of microplastics emissions. Estimates are mostly in the range of 9.6-14% of total emissions, but two reports estimate the proportion to be 21% and 58% respectively. A report by EUNOMIA in 2019 (Hann) estimated that European emissions of microplastics originating from paint at 20 kT per year. However, the Commission also cite figures of up to 394 kT per year, of which an estimated 217 kT reaches the ocean and waterways.

The Commission’s investigation into laundry and dishwasher capsules does not cite any existing research into these products as a source of microplastics. However it is self-evident that these products enter the environment in dissolved form and are thus difficult – if not impossible – to remove from grey water. The Commission cites a European market size of more than 20 billion tabs, releasing around 20 kT of single-use water-soluble plastics through the washing cycle.

4.2. Commission assumptions about geosynthetics

The Commission’s approach to geotextiles assumes a baseline estimate of 58-158 kT per year. This would place geotextiles up to an order of magnitude higher than single-use laundry and dishwasher capsules, and the same order of magnitude as paints.

Further, the Commission has assumed that “There are no barriers between geotextiles and the environment, any microplastic released is directly released into the environment and cannot be removed” and that “Geotextiles’ end of life is not considered and they are not disposed of when worn out”. Their starting position assumes geotextiles cause harm, as set out in the materials that were presented at the public consultation stating “The issue will likely worsen without policy action at EU level. Microplastic emissions from geotextiles are likely to increase in Europe without policy intervention as a result of the increased geotextile demand”.

The Commission’s figures for market share are plausible, albeit subject to potentially significant margins. Freedonia’s estimates for market volumes suggest that Western Europe accounts for 11% of global market share by square metre coverage, with Eastern Europe an additional 6%. Freedonia estimate that geotextiles account for around 67% of global geosynthetics sales and around 855 million square metres in “Western and Eastern Europe”, which would place geotextiles at around 20% of global volumes based on the Commission’s upper estimate for global market size. It should be noted that

Freedonia's figures are for 2019 and include European countries outside the EU.

While quoted figures for market size are within reasonable bounds, the estimate for global PET release has no credibility. Analysis by the IGS raises serious concerns about the research cited by the Commission, which the IGS has shared with them, and has also raised directly with the paper's lead author and publisher.

The Commission's estimates are based on disputed research by Bai, Xue et al, which claims an estimated PET release of 0.24 - 0.79 Mt worldwide from "geotextiles used for coastal reclamation", combined with an estimate that the EU represents 20% of a global geotextile market of 1.4 - 4.3 billion square metres annually. A further paper by the same lead author titled "A*nalysis of microplastics in coastal tidal-flat reclamation in Dongtai, China*" appears to be a continuation of the first and estimates that an annual discharge of "*geotextile-originating microplastics*" *of 2465.52+/-960.77 tonnes* from an area of 66.7 square kilometres (n.b. the English translation incorrectly states 404 square kilometres) covered with geotextiles. Experts in geotextiles would immediately recognize that such discharges imply a level of decomposition that would quickly render the products in question non-functional.

Other areas of concern relating to these papers relate to estimates of market size. The authors quote a global market of 14 billion square metres, a misquote of their original source, which cited 1.4 billion square metres, a more plausible figure. The authors compound their error by claiming that 17% of geotextiles are used for drainage and then incorrectly assume that all "drainage" means "coastal reclamation". The EAGM's response to the Commission's consultation states that "hydraulic applications represent less than 7 % of the European market, around 11.5 kT in 2020".

Furthermore, the authors incorrectly assume that all geotextiles in coastal applications are subject to UV degradation, which is manifestly not the case. For this reason, the geotextiles in question are not exposed to the form of degradation examined in the paper and hence cannot form part of any microplastic release estimates. Moreover, where geosynthetics are exposed to UV, they are suitably stabilized.

4.3. Policy risk

This analysis shows a fundamental risk to public policy making. The Commission has embarked on an investigation into an alleged source of microplastics (i.e. geotextiles) without any prior consultation with experts. Their analysis of the potential scale of microplastics emissions is grounded in disputed research, and without understanding of the extremely high durability of geotextiles, and the fact that in the conditions of concern (coastal erosion), geotextile structures are necessarily engineered for long term performance. The risk is that the Commission acts to prevent or restrict the responsible use of geotextiles (and geosynthetics more generally), thus diminishing or losing altogether the substantial sustainability benefits they offer.

4.4. Contributions to the Commission's consultation - written

Responses to the Commission's consultation by the governments of two EU Member States are available online. The Government of the Netherlands challenges the premise that geotextiles should be within scope, stating: "The Netherlands does, however, question the Commission's choice to include geotextiles…as (a) main source of microplastics in this survey." and "The Netherlands cannot support measures to prevent microplastics from geotextiles without a solid scientific knowledge base to support this".

The German Environment Agency welcomes investigation into tyre abrasion, pellet loss and synthetic textiles but also supports investigation into the construction and agriculture sectors. Their response makes no mention of geotextiles.

Despite their own published figures, and the absence of geotextiles from their 2018 report, a Fraunhofer Institute press release in March 2022 listed "Reducing the open use of plastics in the marine/coastal environment (e.g. geotextiles, corrosion protection of offshore installations)" amongst 28 measures proposed by The Roundtable on Marine Litter, co-led by Germany's Federal Environment Ministry.

The International Geosynthetics Society published an extensive response to the consultation in which it called on the Commission to ensure that policy was based on the best available scientific data and case studies, taking into account the entire lifecycle benefits of all products that use synthetic materials in their manufacture. The IGS further called upon the Commission to distinguish between single-use consumer plastics, which decompose rapidly and are often disposed of irresponsibly, with high-quality durable engineering products that deliver long-lasting benefits to entire communities.

4.5. Contributions to the Commission's consultation - workshops

The Commission's consultation included two workshops in which geotextiles were discussed. During these workshops, a number of measures were proposed, with the aim of reducing the unintentional release of microplastics from geotextiles into the environment (based on the disputed assumption that geotextiles release microplastics). Participants, which included non-experts were asked to vote for several options. The most popular were:

- Guidelines for correct use, installation and maintenance
- Ensure that materials are correctly specified for applications and durability
- Work with relevant industry groups to gather data
- End of life requirements to incentivise collection/recycling of used or damaged materials

– Develop standards for assessing (competing) solutions across the whole lifecycle
– Use biodegradable alternatives from secondary raw materials/waste
– Define appropriate testing protocols.

Other options suggested were variations on the above. Nonetheless a small minority of participants suggested that the use of plastics in contact with soil or water should be barred in all circumstances.

In its written response, the EAGM proposed two regulatory measures:

– The introduction of mandatory abrasion-resistance testing (ISO 22182) according to the CE standard for hydraulic applications, and
– A combined initiative by the Commission and the geotextile industry to further educate and assist on the correct application of geotextiles to avoid improper usage of these materials.

4.6. Outcome of EC consultation

At the time of writing, the Commission has yet to publish its conclusions, which will be based on over 400 survey results received and two rounds of public workshops. The Commission has stated that it aims for “adoption” in Q4 of 2022.

5. Conclusions

The geosynthetics industry is strongly placed to emphasise the benefits of its products in relation to human development and the cost-effectiveness of its products, especially where long-term considerations are important. Market data show that high-income countries such as the US, Canada, Italy, Germany, and UK generally have higher intensity of geosynthetics use relative to construction spending than developing countries, as they are more willing to invest more to reduce long-term costs (Freedonia, June 2020).

The fact that the World Bank specifies geosynthetics use in all road and highway projects it finances shows official recognition for the sustainability benefits that geosynthetics offer (Freedonia 2013).

However, there is a risk of adverse public perception based on wider environmental concerns, which may be driven by single-issue focus rather than a balanced holistic view. The very fact that the geosynthetics industry has high confidence in its products may mean there is limited independent research on geosynthetics and microplastics carried out by researchers who understand the performance and characteristics of geosynthetics in real-life applications. This opens the risk that a very small number of research papers by non-experts can result in misleading claims that may nonetheless shape public opinion and policy.

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RIASSUNTO

Geosintetici, sostenibilità e condizioni al contorno a livello planetario: effettivi benefici all' economia globale e potenziali rischi sull' evoluzione delle direttive in Europa

Il presente articolo riguarda il contributo dei geosintetici a soddisfare le esigenze umane così come definito dagli obiettivi di Sviluppo Sostenibile delle Nazioni Unite nel contesto delle attuali condizioni al contorno a livello planetario. In particolare viene considerato il ruolo dei geosintetici per affrontare due di queste istanze: cambiamento climatico ed azione di nuovi agenti inquinanti.
Il contributo esamina nel dettaglio anche gli eventuali rischi posti da un responsabile impiego di geosintetici in Europa ed evidenzia che la conseguente evoluzione delle direttive può essere malamente influenzata da pseudo-ricerche prive del necessario rigore scientifico e tecnologico.

ABSTRACT

Geosynthetics, Sustainability and Planetary Boundaries: Real Global Benefits and Potential Policy Risks in Europe

This paper places the contribution of geosynthetics towards meeting human needs as defined by the UN Sustainable Development Goals in the context of remaining within planetary boundaries. It considers the role of geosynthetics in addressing two of these boundaries - climate change and novel entities (certain pollutants). The paper goes on to examine the risks posed to the responsible use of geotextiles in Europe, resulting from European policy-making and regulation. The paper concludes that policy may be unduly influenced by misleading findings from research that lacks rigour.

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E APPLICAZIONI RESILIENTI

a cura di

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