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OPPORTUNITIES AND LIMITS OF RECYCLING IN THE PRODUCTION OF GEOSYNTHETICS IN A CIRCULAR ECONOMY PERSPECTIVE

1. Introduction

When it was introduced on the market, more than 60 years ago, plastic was welcomed as a wonderful material destined to change the world for the best. These promises have been kept to a certain extent, and we can admit that plastic has changed our lives in the right direction. Its properties still make it an extra-ordinary tool for the improvement of the living conditions of mankind.
After some decades of use, the popularity of plastics has dropped dramatically, essentially because of their treatment at the end of the service life, and polymers are now often represented as the responsible of a big part of the pollution around the planet.
Of course, plastic itself has no responsibility, and the whole problem comes from the human behavior, both in terms of abusing its application, and, mainly, in the way we treat it at the end of the service life.
Among the other useful properties, recyclability of plastics is quite an interesting one, and it has turned into an argument often presented by the industry to defend its production, and give a bit of green color to products otherwise considered with suspect by the public opinion.
In the specific world of geosynthetics there is already a tradition about the use of recycled materials, especially in the specific domain of products connected with the textile industry.
This circumstance, together with the growing commercial interest of the market for what can be labeled as "green" or "environmental friendly", makes it important to critically investigate the limits and the opportunities presented by the use of recycled materials.
This presentation examines the topic in relation with some of the pillars of Circular Economy, with the current European harmonized standards and with some possible consequences on the environment at large.
The effort is to keep in mind what should be the final goal of a responsible planning and designing.

2. Focus the general target and accept an impact

The bad image of plastics in the last years is a matter of fact. Everybody has in mind the images of turtles and dolphins struggling with waste plastic bags and trapped by pieces of fishing nets.
Mass media talk more and more also about microplastics and their possible sources and effects.
Important communication campaigns are set forward claiming a "plastic free" world, mostly based on emotional chords.
On the other hand we are all aware of the impossibility to go back to a life without plastics.
Applications in electric systems, waterproofing, thermal insulation, hygiene, weight reduction of vehicles, sanitary devices, etc. are all necessary and precious, and make our lives longer and safer.
It's not just a matter of practical feasibility, but a world without plastics would be by far less environmental friendly (Fontana, 2021). Even the technology to get renewable energy resources would not be the same without plastics (photovoltaic panels, windmills, hydroelectric reservoirs lined with geomembranes).
It means that reducing the use of plastics cannot be our final goal. This has to be one of the possible means in the perspective of a better environmental performance of our activities.
Even the United Nations 2030 SDG, Sustainable Development Goals, highlight the necessity of development (Touze, 2018).
It's just a matter of reaching our development goals in the most sustainable, or, better, less unsustainable way.
This means that we have to accept an impact of our activities, and we have to find and compare the possible alternatives to solve our problems, so to choose the less impacting solutions.
With such a perspective, it is necessary to adopt an approach considering the system where the products are destined to deploy their functions, and limit not our evaluation to a product-by-product assessment.
This attitude is even more important when we have to do with a complex product, as it is a construction work, like a road, a railway, a dam, or any other structure.

3. Geosynthetics and environment

The use of plastics in geotechnical works dates back already to more than 50 years ago.
During such a long period, geotextiles first and then geosynthetics have shown a great contribution to the reduction of the costs and to the improvement of the performances of the construction industry, especially, but not only, in civil engineering infrastructures.
More recently, after the turn of the century, with the growing development of the environmental sensitivity, the im-

pact of the use of geosynthetics has been studied more and more and has shown outstanding environmental results.
These studies also have the chance to evaluate the behavior of products installed already many years ago, so that the theoretical modelling of possible degradation can be enforced by real scale measurements.
Specific studies (Stolz & Frischknecht, 2019, Bilardi & Moraci, 2021) show great environmental benefits provided by geosynthetics compared with the traditional alternative construction technologies.
In fact, for many important applications, the average reduction of CO_2 emissions amounts as high as 75% and can reach 88% (Bilardi & Moraci, 2021).

4. Circular Economy pillars

Such a good cost/benefit balance offered by geosynthetics does not allow us to stop trying to make any effort to reduce the negative impacts, actual and potential, implied by the use of geosynthetics.
A very useful guideline to minimize the necessary impacts of our activities is provided by the Circular Economy principles.
Starting from the first standard made available on the topic, the French AFNOR XP X30-901, in the present contribution we'll try to analyze three of the seven so called pillars of Circular Economy, in relation with geosynthetics, suggesting possible limits and opportunities represented by the recycling technologies.
Of course, this self-imposed limit to the scope of this brief analysis does not mean that the other pillars cannot be applied to the geosynthetics.

4.1. Functional Economy

One of the most important recommendations of Circular Economy is about the focusing on the functions performed by the objects, rather than looking to the objects themselves. To this purpose it is necessary to concentrate on what the products are supposed to do for us. We should try to "dematerialize" as much as possible, to do more with less.
Is this perspective, when we ask to ourselves how to measure the impact of a product on the environment, the measurement of the impact of the production of any object related to the mass, e.g. eco-points per kg, is just a passage, finalized to assess the impact on the functional unit we are looking for.
In other words, it all depends on the system where the product is destined to be used.
Of course, at the end the system of the systems is the environment.
When we decide to buy a computer, we do not choose it on the base of the weight.
What we look for has to do with performances, its speed, memory capacity, connectivity and so on.
About the weight, we could consider the lighter the better, for sure not choosing the cheapest products in terms of Euro per kg of product.
Why should we adopt different criteria when choosing a geosynthetic, or any other product?
As a specialist in nonwoven geotextile production, I submit an example taken from this type of products.
Let's assume a certain impact X related to the production of a needle-punched nonwoven geotextile made with 100% virgin polypropylene (PP) fibres, one of the most common geosynthetics on the market.
An apparently similar needle-punched nonwoven geotextile made with 100% PP recycled fibres has an impact of approximately 50% compared to the virgin version (Manzardo et al., 2021) in terms of eco-points per kg: X/2.
If we would stop our analysis at this stage of the mass, we should prefer the recycled one from an environmental point of view.
The matter is that in our engineering design we do not need a certain number of grams of polypropylene.
What we need is a certain performance, enabling us to accomplish the function we want to give to the product for the entire life of the structure in which the geotextile is incorporated.
Let's assume we need 35 kN/m of tensile strength and re-examine the alternative of the virgin and the recycled nonwoven geotextile. Let's examine the data taken from the average performances declared in the technical sheets of the products available on the market.
In order to get 35 kN/m with nonwoven geotextile 100% virgin we need a mass per unit area of 500g/m2.
A similar grammage of 100% recycled performs 6 kN/m.
Consequently, in order to reach the defined tensile strength of 35 kN/m, we will need a geotextile having about 3000 g/m2 of mass per unit area.
It means that to get the same performance of a virgin product, with a recycled fibers product we'll need 6 times the quantity of mass per unit area.
Being the impact per kg of the recycled fibres geotextile one half of the virgin one, the impact in terms of functional unit, in this case tensile strength expressed in kN/m, is three times bigger if we use a recycled product, and still we have to transport to the gate of the work site six times the weight of products.
Different results could be calculated with different functional units, to be chosen in relation with the desired function.

4.2.1. Extension of the service life cycle

Every day of extension of the service life of any product represents a proportional achievement in reducing the use of natural resources and in reducing the production of wastes to be treated.
Geosynthetics represent one of the best examples of long-term use of plastics.
When we build a road, we usually want it to last for 100 years or more. It would not be very eco-friendly to be compelled to rebuild it every 5 or 10 years. Geosynthetics often replace the use of materials intended to last for

an indetermined time, like gravel, sand, concrete (all of them very impacting on the environment, by the way). The prevision of the life cycle is an important element to be taken into account when considering another pillar of Circular Economy, the Eco-design.
The virgin polymers are a precious and scarce resource that, in my opinion, could be possibly reserved to the long-term applications, representing a very tiny percentage of the plastics applications.
In the case of geosynthetics, the service life-time can be very near to the physical life of the material, and this should be carefully taken into account before treating any plastics in the same way, or setting the same rules for totally different products like a single use packaging and a pipe for sewage, just to mention another long term application of plastics in construction industry other than geosynthetics.
Durability is also one of the requirements indicated by the CPR, 305/2011, the European Construction Product Regulation, with the aim to establish a long-term use of natural resources.
The experience with geosynthetics dates back to more than 50 years ago, and the experience is confirming a very good behaviour in time (Delmas & Gourc, 2017; Cazzuffi & Gioffré, 2020), provided that designing and installations are made correctly.
The literature about the end of the life of geosynthetics is quite scarce, because only few installations arrived to the end of the life so far.

4.2.2. Durability and recycling

In considering the longest durability we have mentioned the recyclability of geosynthetics, assuming they are produced with virgin polymers.
Could the durability performance be the same when using recycled materials?
For an answer considering all possible implications, it would be necessary to make distinctions of the different kind of recycled products, post-consumer, post-industrial, obtained by pyrolysis, and so on.
The need of these distinctions already tells us something about the subtlety of the topic, in a world where too many contractors and installers look for the chance to buy something cheaper rather than what is correctly specified by the designers or by the authorities.
The answer of the current European law, through the Harmonized Standards, is clear:
it is not possible to state a service life of a geosynthetic product longer than 5 years when the content of recycled material exceeds 10%.
This statement is valid whatever the definition of recycled we can choose.

5. End of the life

Recycling is the third item in the priority of waste treatment, coming after Reduction and Reuse.
Too often the use of recycled materials is a typical defensive argument of the industry in the effort to look greener. A bit of recycled materials, and the homework about environment is done.
Of course, recycling is a commendable effort, and we all should aim to recycle as much as possible, so to reduce the rate of wastes to dispose. On the other hand, it should be taken into account that even recycling has to be just a tool, not a final goal in itself, being the real and final goal the minimization of the environmental impacts of our activities.
When talking about the use of recycled materials, it will be then necessary to evaluate if and when it is convenient to adopt them from the environmental point of view.
Recycling has its own environmental costs to be compared with the alternative solutions able to fulfill our functional goals. Imposing minimum contents of recycled materials has to consider also the limits of the availability of recycled stuff on the market. The effort of the industry is to reduce more and more the wastes, and to make the life cycles longer, so the availability of something to recycle is destined to fade away with the time. Recycled plastics are already turning into a scarce resource on the market.
One of the indications listed by CPR305/2011, basic requirement 7, Sustainable Use of Natural Resources, is recyclability. In a circular economy perspective, it is requested to forecast the end of the life of a product. As we have seen, the service life of geosynthetics is generally destined to last for decades and even over 100 years, but in some cases a minor part of the applications is destined to temporary uses, or could result as part of the wastes in case of deconstruction of a work.
In such a case the requirement of recyclability is always fulfilled by geosynthetics, with the theoretical exception of rare complicated composite materials impossible to separate back to the original components.
The major obstacles to recycle a geosynthetic product at the end of its life are the distance of the specific project location from the possible recycling facility and the necessary cleaning, but this is the problem of any other product, and has to be evaluated every time in terms of economic and ecological costs.
Final residual possibility remains the use of the wastes for the production of heat in the incinerators.
This residual and minimal quantity would end after its service life to the same destiny of the 96% of oil extracted in the world and immediately destined to produce fuels.
It is worth to observe that the use of plastics for geotechnical purposes is a good example of a particular circularity, as the oil taken from the underground is processed and used to reach our development goals, and then it returns to the underground, without the liberation of the carbon included in its molecules.
It is one of the few application of plastics, where the potential of CO2 emission due to burning is sequestered back to the soil.

6. Recycling balance of the whole work

In the effort to minimize the impact of our construction works, it has already been mentioned the opportunity to evaluate the impact of the unit of the final product, e.g. a km of road construction. Each product we have to choose has to be evaluated in the relations and effects it has with the other products and materials.
A product-by-product approach would lead to a much less effective result, so that, e.g., the imposition of a minimum percentage content of recycled stuff in each product could hardly make possible to go over that percentage.
A possible good example is the construction of a road in an area with bad soft soil, not susceptible to be used to build the roadbed. In this case, a big percentage of the excavated soil should be disposed in a landfill, and a sufficient amount of good gravel and sand should be imported to the work site.
The application of an appropriate 100% virgin geosynthetic product makes possible to totally reuse the “in situ” soil, with no need of transport and disposal of the removed soil and following importing of new granular material.
In such a case a very small quantity in weight of a 100% virgin geosynthetic product, allows to recycle 100% in weight of the local soil, otherwise impossible to use in the work.
With this solution, our kilometer of road will have a much lower environmental (and also economical) cost compared to a product-by-product approach imposing a minimum percentage of recycled materials.
Geosynthetics allow to recycle other materials otherwise destined to be disposed in a landfill, and doing so, it is possible to prevent the excavation and transport of other kind of virgin materials, like clay, gravel and sand, whose impact is strong not only in terms of CO2 emissions, but also for the landscape, and for the consumption of natural resources with an extremely long regeneration cycle.

7. Microplastics

In the last years the attention of the scientific community and of the mass media as well has shown a growing interest for the phenomenon of microplastics, especially when dispersed in the waters.
There is a lot of research and discussion about their definition, their measurement, their origins and their effects on animals and humans (NOC, 2021 - EC-JRC, 2021 - Tekman et al., 2022). Notwithstanding the many questions still open, it is a prudent and shared attitude to limit their production and release, both intentional, and unintentional.
There is some concern about the possible releases of microplastics due to the use of geosynthetics, as they are directly installed in contact with the soil, and they often filter and drain waters in the ground.
Geosynthetics are most of the times buried in the ground or hidden by other layers of materials, so that they are not generally exposed to the main agents of degradation: oxygen, high temperatures, UV rays. Even the mechanical stress due to abrasion is predictable only in some specific applications.
Some caution has to be paid in special circumstances, where the chemical conditions impose to carefully choose the kind of polymer, e.g. in contact with fresh concrete.
The responsible consideration of the possible production of microplastics is anyway another driver to be taken into account when choosing or specifying a geosynthetic product.
The chemical stability of the polymer is a recommended verification, both in terms of which kind of polymer we are going to use, and in terms of the possible different performance of a virgin and a recycled material.

8. Normative trend

A Request for Standardization is on its way from the European Commission to CEN and CENELEC on the themes of recycling. The provisional title is “Recycling of plastics and recycled plastics” and it comes within the so called “European strategy for plastics within Circular Economy”.
The procedure is at the stage of the consultation of the stakeholders, and it has identified more than 1100 initiatives of standardization.
It is interesting to note that the draft of this Request for Standardization specifically mentions that the subsequent standardization activity will not overcome the existing Harmonized Standard.
The content of this draft is essentially directed to two main economical fields: packaging and agriculture. Films and membranes are mentioned in relation to the agricultural activities, and are at the moment mainly focusing the PVC.
Geosynthetics are mentioned just in relation to agriculture applications.
The proliferation of standardization activities on environmental issues has determined the European normative institutes CEN and CENELEC to establish a special committee destined to give a bit of coordination and guidelines to produce the most possible coherent norms and definitions.
This group is active since 2020 as a Target Group on Circular Economy of SABE, Strategic Advisory Body on Environment, whose latest plenary meeting has taken place on the 14th of March 2022.
The committee is taking care in general of all fields and products.
About the applications in constructions, the draft of the guidelines is recommending an approach based on the assessment of the project as a system.

9. Conclusions

This paper has tried to give a contribution to a critical approach to the environmental themes.

Recycling makes no exception to the need of understanding and distinguishing the different situations. More use of recycled materials for the production of geosynthetics is possible, but, as for any other product, it has to be promoted if and when it is appropriate and useful to our environmental goals. Recycling is not a goal in itself, but it is a possible mean to be assessed for every project.
Also about geosynthetics, the technologies directed to better exploit the possibilities of the recycling will improve and will let us make the right designing decision, attentively considering:

– The impact per functional unit
– The contribution to the performance of the whole project
– The desired durability, also in consideration of the overall durability of the structure in which the geosynthetic is incorporated
– The probability of microplastics releasing
– The limits imposed by the current juridical rules

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RIASSUNTO

Opportunità e limiti del riciclaggio nella produzione dei geosintetici in ottica di economia circolare

È opinione comune che l'utilizzo di materie riciclate costituisca una priorità da promuovere ed incoraggiare in ogni circostanza. Tuttavia, nonostante l'apparenza, il riciclaggio non può rappresentare un obiettivo in sé, essendo soltanto uno dei mezzi possibili per perseguire lo scopo finale, che rimane quello di ridurre l'impatto delle attività umane dirette allo sviluppo.
Alcuni dei pilastri della economia circolare sono esaminati qui in relazione all'applicazione dei geosintetici nel settore delle costruzioni. Un approccio prodotto per prodotto non risponde ai principi dell'economia funzionale né alle esigenze relative alla massimizzazione del ciclo di vita. È raccomandato un approccio basato sulla valutazione del sistema rappresentato dall'insieme dell'intero progetto, tenendo conto delle normative legali e tecniche che governano l'applicazione dei geosintetici.

ABSTRACT

Opportunities and limits of recycling in the production of geosynthetics in a Circular Economy perspective

It's a common opinion that the recycling activities should be promoted and encouraged in any circumstances. This is something sounding good, but recycling cannot represent a goal by itself, being just one of the possible ways to reach the final goal which is to lower the impact of human activities directed to the development.
Some of the pillars of Circular Economy are examined in relation with the application of geosynthetics in construction industry. A product-by-product approach does not fulfil the principles of functional economy nor the requirements about the longest possible life cycles. An approach based on the evaluation of the system represented by the whole project is recommended, taking into due consideration the existing juridical and technical rules governing the application of geosynthetics.

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