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Research Article

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Natural Polymers for Biodegradable Dressings to Save the Environment

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Abstract
The current fashion system uses high volumes of non-renewable resources to produce clothes, being responsible for 10% of the global greenhouse gas emissions into the atmosphere every year and 20%of the global water wasted. At the same time people are buying 60%more clothing than 15 Years ago, which going in the landfills, causes 92 million tons of waste each year. This waste has been further increased by the surgical masks used for COVID-19 pandemic. Thus, a new way of designing and producing clothing needs to be incorporated into the current system to facilitate its recycling making it more circular. New tissues, therefore, are proposed made by natural polysaccharides, embedded by micro- Nano capsules of chitin Nano fibrils and Nano lignin all obtained as by- products from food and forestry waste respectively. Thus, pollution and waste will be reduced and the natural raw materials will be maintained for the future generations.

Keywords: Chitin Nanofibrils, Lignin, Environment, Pollution, Waste, Hyaluronic Acid, Polymer, Polysaccharides, Greenhouse Gas Emissions, Plastics, Climate Change, Biodiversity, COVID-19

Introduction
Waste generation, air and water pollution, and soil degradation with the consequent climate changing have reached alarming levels exerting an increasingly impact on human health and the environment [1]. Regarding the soil, every second more than 100 trees disappear worldwide from tropical forest, altering the oxygen/carbon dioxide equilibrium and the biodiversity [2]. Thus, while on the one hand humans converted nearly half of the world's land into agriculture using forests for resources, on the other hand animals venturing out of their habitats to raid crops, are increasing transmission of animal-to-human diseases [3]. Regarding air pollution, data indicate a strong link between particulate (i.e.PM2.5) and the food delivered with lost after its consumption, especially for the current use of plastic p a c k a g i n g [4]. Moreover, this inhaled-pollution, consisting of dust, dirt, smoke, organic compounds and metals, may also cause loss of smell decreasing social interactions, depression, and general anxiety [5]. Research studies in fact, have shown the existing connection between waste and climate change, which may create favorable conditions for the spread of certain infections, including malaria, dengue fever and the recent COVID-19 pandemic [6]. Therefore, in a Planet continually invaded by pollution and non-biodegradable waste, It has been increased the need to maintain in equilibrium the natural environment, reducing the global greenhouse gas (GHG)emissions, modifying workability, live ability and infrastructures with both food and dressing systems [5, 6]. Thus, it became a must the adoption of the circular economy that, bettering all the social, environmental, and economical aspects of our life [5-7], could result fundamental to maintain the future health and wellbeing. Consequently, the necessity to use natural biodegradable polymers first of all in main sectors, such as packaging, building & Construction, and textiles, in substitution of the actual great consumption of non-biodegradable polymers petrol-derived(fig1) [8-10]. Thus Production of some natural polymers, such as chitin and lignin, to make tissues for medical, and cosmetic use is reported and discussed.

Chitin, Lignin and Their Block-Polymeric Complexes

Among the natural polymers, chitin and lignin obtained from fishery's byproducts and plant biomass respectively, have shown interesting physicochemical and biological characteristics useful to produce biodegradable tissues. Chitin is a natural polymer showing to possess antioxidant, antiinflammatory, immunomodulation and skin repairing properties, especially when used in its micro-nano size and crystallin form [11-14].

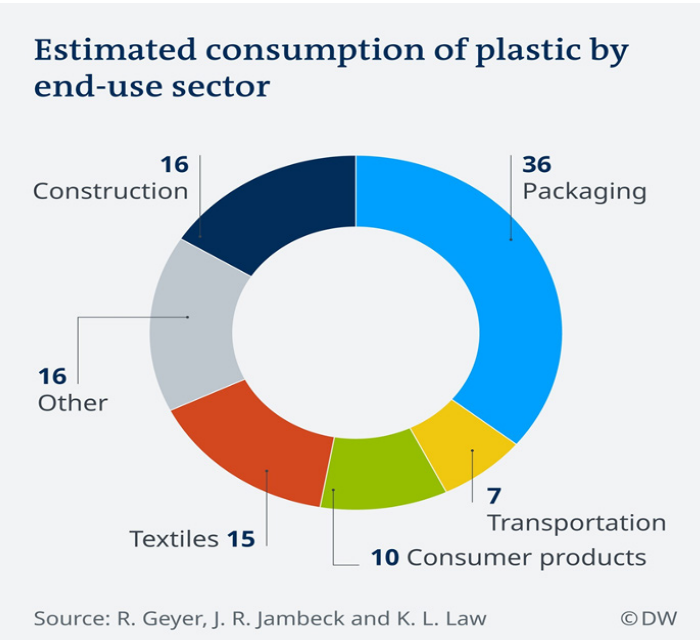

Figure 1: The sectors producing plastics waste (By courtesy of Geyer et al)

The presence of parasites in both vegetal and animal organisms, in fact, due to their content in chitin causes a fragmentation of the polymer, so that its larger fragments(40-70millimicrons) interact with a variety of macrophage receptor systems to produce a variety of pro-inflammatory citokines and mediators, including IL-17 and TNF-alpha. The resulting inflammatory response induces a further degradation of the polymer with accumulation of small chitin (<40 millimicrons) resulting in the production of anti- inflammatory cytokines IL-10 (fig 2) [12-14].

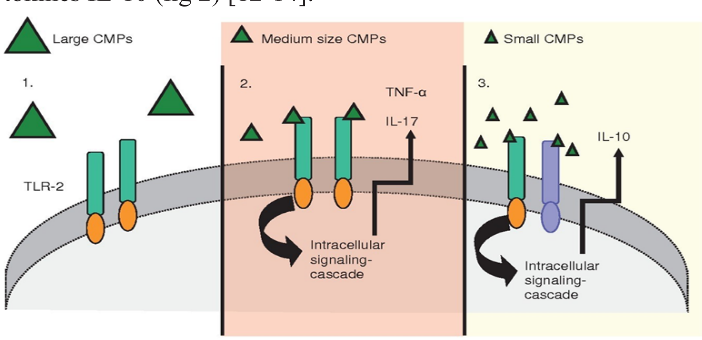

Figure 2: Small size chitin releases IL-10 with a skin anti-inflammatory effectiveness (by courtesy of [13])

In conclusion it has been shown the small size chitin has an anti-inflammatory effectiveness because of its increased surface per mass area, while in its medium size it possesses an inflammatory activity, having no activity when in large size.

However, chitin, that represents the second more abundant natural polymer available in the world after cellulose, is a fundamental component of the crustaceans' exoskeleton, insects' cuticle and fungi and yeasts' cell membrane, giving resistance and elasticity to their protective structures. It consists in a matrix of chitin-protein-mineral fibers which, present as crystalline and amorphous needles, are organized to form a composite twisted structure (fig 3) [15].

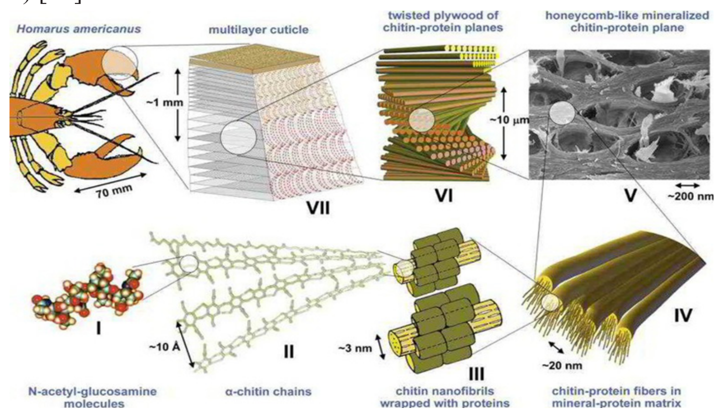

Figure 3: The chitin fibers organized in a twisted structure (by courtesy of Raab et al [15]

Industrially, it has been possible to obtain pure crystalline needles of chitin with a mean size of 240x7x5 nanometers, free of proteins and minerals (fig4). Due to the protonated amino groups of the chitin Nano fibrils (CN)surface, an electrical double layer is formed in water around these crystallites which, preventing their flocculation, yields a stable colloidal suspension. These ionic positive electrical covering their surface, have the ability to easily bind electronegative polymers, such as hyaluronic acid and lignin forming block polymeric complexes (fig.5). Particularly, the nano-chitin-nano-lignin complexes may be considered not only interesting carriers for the ability they have to entrap, load and transport various active ingredients, but also compounds because of their effectiveness shown as antioxidant, antibacterial, and skin repairing compounds [12-14].

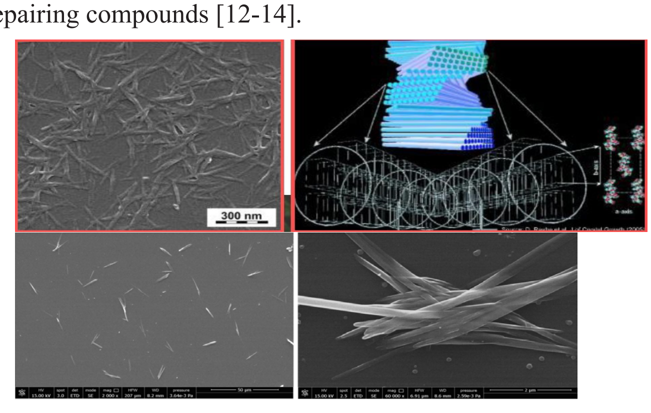

Figure 4: Chitin Nano Fibrils' Needles at TEM (Up) And SEM (Down) With Their Supposed Structure

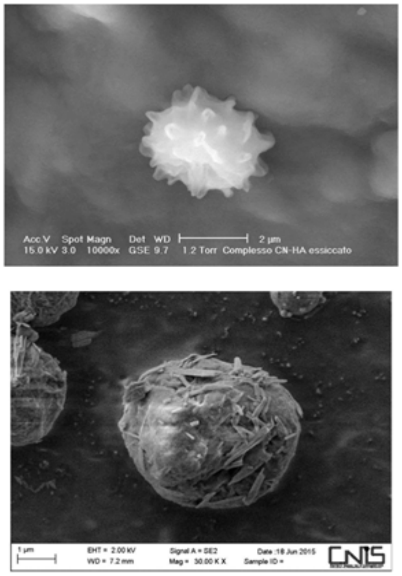

Figure 5: Chitin-Hyaluronic acid (up) and Chitin-LigninCN-LG) (down) block polymer complexed at SEM

Chitin nano-fibrils, in fact, have shown to notably increase their-specific activities when complexed with nano-lignin to form micro/ nano capsules [11], which may be further stabilized by a corona of polyethylenglycol(PEG), used to obtain CN-LG in powder by the spray dried methodology [16, 17]. Moreover, by this technique it is also possible to further stabilize the active ingredients encapsulated, protecting them from the environment' aggressiveness. At this purpose, it is to remember that lignin, is an aromatic polymer composed of many polyphenol units which, for its specific structure, has shown to possess antioxidant, anti-inflammatory and photo-protective properties, similarly to nano-chitin [17, 18].

But what's the mechanism of action of chitin-lignin(CN-LG) nanoparticles (NPs)? Because of the chitin-lignin dimension and the electrostatic interaction between NPs and the stratum corneum layer, the well-organized lipid lamellae is disturbed. Consequently, the penetration through the skin layers is improved and the natural antioxidant defense mechanisms may be activated together with the production of the stem cells of both skin and hair, as reported from some of our studies also [19, 20]. Moreover, the supply of N-acetyl glucosamine to the extracellular matrix may favor the histological architecture features of the skin issue, inducing an orderly arrangement of collagen fibers (fig 6) [21].

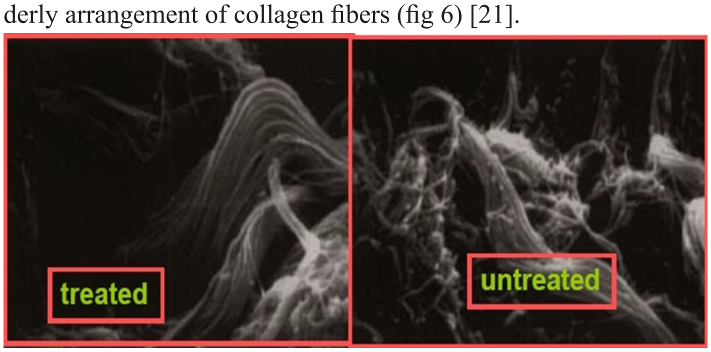

Figure 6: Orderly arrangement of collagen fibers of skin treated by chitin nanofibrils (by the courtesy of [21])

However, due to their particular physicochemical bio-characteristics, these NPs may be enclosed into emulsions or linked on the surface of non-woven tissues' fibers, which will result totally biodegradable when obtained from natural polymers [22, 23]. Polysaccarides, in fact, as well as nano-chitin and nano-lignin are metabolized by human and the environmental enzymes to compounds free of toxicity and side effects, being also utilized as cell nutrients or cell-energy materials, useful to facilitate cell division and turnover [24, 25]. For all these reasons, nano-chitin, nano-lignin and their derived compounds and complexes could be used in the medical, cosmetic and food fields as healthy ingredients, embedded into emulsions or bound to specialized fiber/tissues to make innovative medical devices, medical dressings, surgical and face beauty masks [11, 13, 26-29]. Naturally, the different physicochemical and biological activity of the obtained emulsion/ tissues have to be characterized by the various polymers used and the embedded active ingredients selected [22, 23, 30, 31]. Therefore, due to the specific structure of both the CN-LG block polymeric complexes and the smart tissues realized, they may have the ability to release the encapsulated ingredients in the dose and time designed, when applied on the skin in normal or diseases conditions [32].

Biodegradable Dressings

As previously reported, the dressing' textiles, represent an important source of the microplastics recovered in the oceans. The cause of this waste is due for 73% to the clothing produced that are sending to landfill or incinerated, while less than 1% of material used comes from recycled sources. Circularity for the fashion industry in textile-to-textile recycling, in fact, presents a complex challenge based on the actual technology that, however, need to be incremented [33, 34]. Just to remember, around 65 million tonnes of clothing are brought globally every year, expected to be more than 93 million tons by 2030 and 160 million tons by 2050. In 2015 the EU community, for example, brought 6.4 million tons of clothes (~13 Kg/person), 30% of which were not used for at least a year [33]. Moreover, while the fashion industry uses high volume of water (fig. 7), releasing in air 10% of the global Greenhouse gas(GHG) emissions (around 2.1 billion metric tons in 2018) (fig. 8), it accounts also for 35% of all the microfibers recovered in the oceans, which release microplastics and toxic ingredients (fig.9) [34].

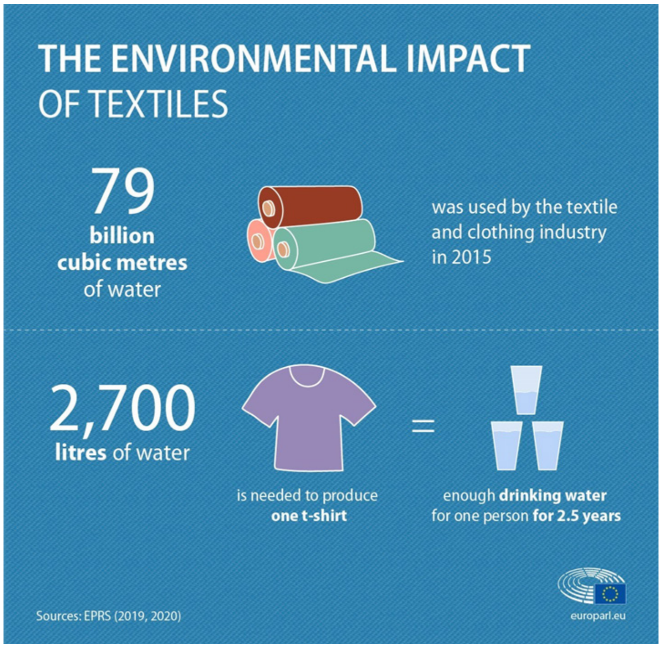

Figure 7: Water consumed from clothing Industry (by the courtesy of EU [34])

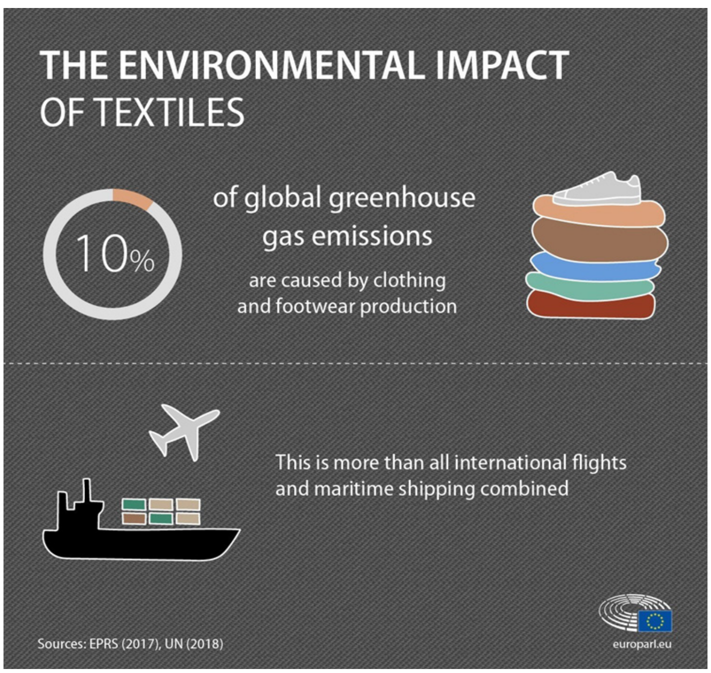

figure 8: The Global Impact of textiles on the greenhouse gas emissions (by the courtesy of EU [34])

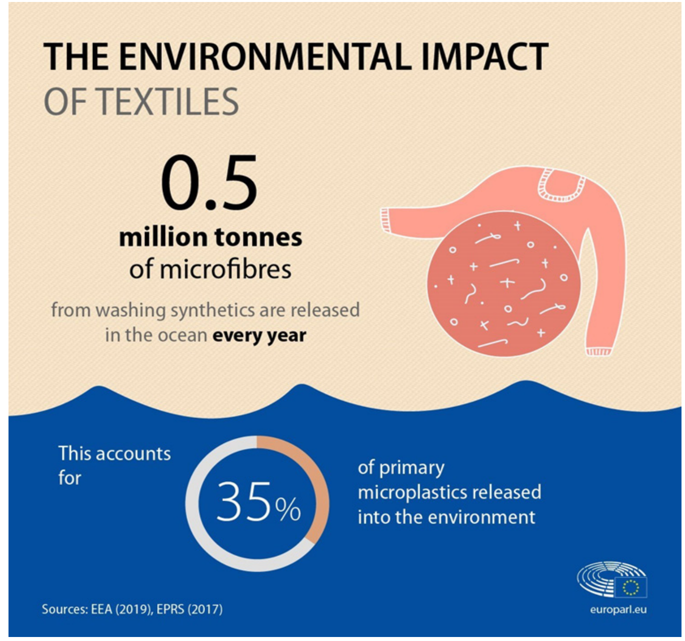

Figure 9: The microfibers released in the oceans by Textile Industry (by the courtesy of EU [34])

Therefore, it has been estimated that at this current trends the quantity of clothing waste could range 250 million metric tons by 2025! [35]. As a further negative consequence, these tiny plastic debris are ingested by many different species of organisms, from zoo-plankton to fish, sea mammals and birds, involving also human food with consequential healthy problems, jet largely unknown [36, 37]. Therefore, the possible chemical plastic recycling with the alternative use of biodegradable materials have become an urgent need [38, 39]. For each kilogram of plastic that is not reused or recycled, in fact, another kilogram is produced from non-renewable and non-biodegradable materials, including synthetic polyesters that accounted for 16% of all the fibers used for clothes [39]. Consequently, plastic industry is moving beyond the use-once-and-discard approach to achieve a 50%recovery by 2030, with a supposed waste-recovery capital investment from about USD 15 to 20 billion [40, 41]. Many studies, in fact, underlined the necessity to found zero waste strategies, reducing production and consumption of plastic [39], also for the actual unsolved problems of recycling. However, a comprehensive approach to waste management should prioritize prevention by re-use, compost and recycle goods, minimizing its negative environmental impact by the Circular Economy. So doing, it seems possible to obtain a zero waste solution, reducing the economic costs and creating further jobs (fig. 10) [42].

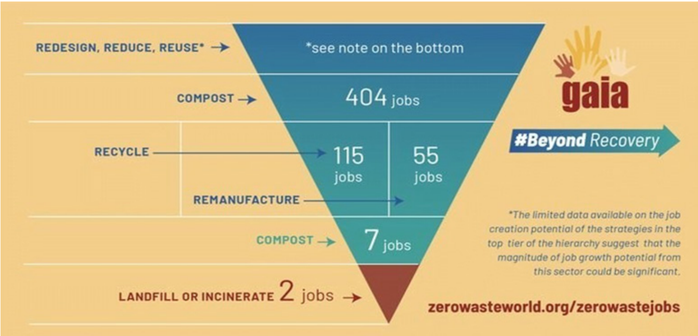

Figure 10: Supposed Jobs obtainable by remanufacturing, Redesigning and recycling clothes (by courtesy on Newman et all [42]).

Unfortunately, it has been shown, how the polymers obtained by mechanical plastic recycling are not in line with the industrial necessities, while the today chemical recycling, not only releases dangerous toxic chemicals into the environment, but also does not fit in a circular economy, for various technical and economic reasons [40, 41]. However, plastic waste debris is emerging as a truly global challenge, the solutions of which have to be effective with a required full view of the integrated life cycle, able to involve together scientists, politicians and consumers [41]. For all these, reasons we are proposing the use of the reported nano-capsules and tissues, made by natural polymers to produce first of all innovative biodegradable dressings for the medical and cosmetic sectors, [11, 13, 14, 22, 23, 26-31], including surgical masks and one-day use medical dressings [29, 43-45] or beauty masks [26-28, 30, 43-45]. This solution appears to be an interesting alternative to save the environment from the plastics' invasion [35-41]. If we don't go in this direction, it has been supposed than in the oceans there could be more plastic than fishes (by weight) by 2050 [38].

Effectiveness and safeness of the reported tissues have been underlined by different studies of our research group also, who have shown the interesting anti-aging, antibacterial, anti-inflammatory activity these complexes have. They, in fact, embedded for example into emulsions or bound to the fibers of advanced non-woven tissues, have evidenced an interesting skin regeneration activity on skin aged, or affected by wounds and burns [31, 46-49]. Therefore, by the first obtained experimental results, the use of these smart tissues, is raising the hope for solving the great problem of the non-biodegradable plastics utilized in cosmetic, pharmaceutical, medical and other important economic fields. The reported biopolymers, in fact, may be of help to produce biodegradable textiles, necessary for reducing the adverse effect of plastics on human health and the environment, recently further increased for the massively use of the surgical masks during the COVID-19 pandemic (fig.11) [29, 43-45, 50] Thus, the interest for polysaccharides and other natural ingredients, such as the reported chitin and lignin are increasing day by day, thanks to their particular effectiveness as antibacterial, anti- inflammatory, biodegradable and skin friendly active carriers, also because obtainable from waste materials at low cost [51-55]. In conclusion, their more intensive use may help to preserve the natural raw materials for the future generations, safeguarding human health, environment and the Planet Biodiversity.

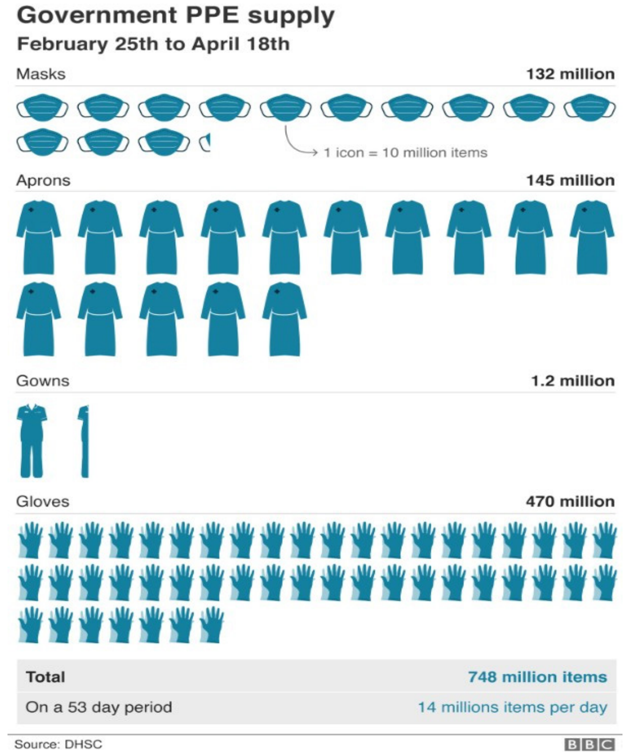

Figure 11: An example of the consume of masks, aprons, gowns and gloves in a 53 days' period (by courtesy of DHSC)

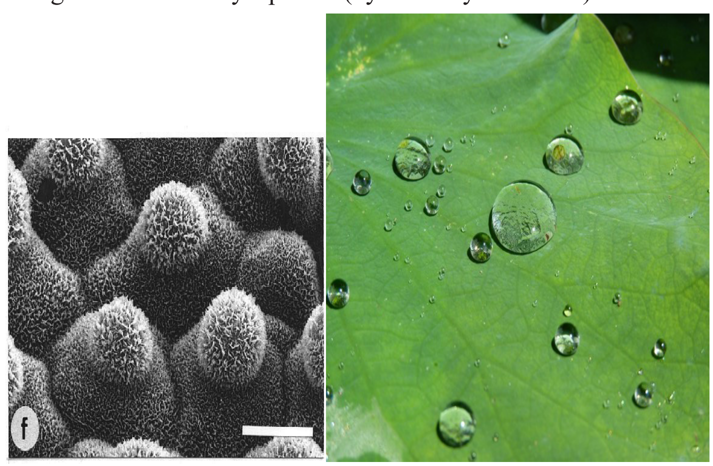

Figure 12: the water-repellent lotus effect on the leave

Conclusion

Breakthrough and creativity are represented by a series of cascading challenges that lead to a better understanding of the world and the human needs.

Therefore, it should be necessary to make textiles and dressings trying to copy nature that does and has been done for millennials a lot of things better than humans can do, utilizing the right energy and raw material without producing waste. Thus, the use of science by the bio- nanotechnologies has become a need to achieve the goals for creating cleaner, safer and smart tissues. It could be possible, for example, to include in textiles nanoparticles effective for reducing odors, or realizing self- cleaning or water-repellent fabrics, thus coping the so-called lotus effect [56]. This effect, in fact is due to the presence on the lotus' leaves of nanostructures which repel water by creation of a rough surface (fig 12). Naturally, these innovations would take advantage of the specific nanoparticles' properties, such as the high surface area per volume, that increases their exposure to the environment. This new way of producing is the top-of-mind concern to worldwide consumers and scientists who wish to obtain and maintain personal health and economic wellbeing, shaping for tangible, innovative and sustainable products environmentally-friendly [57].

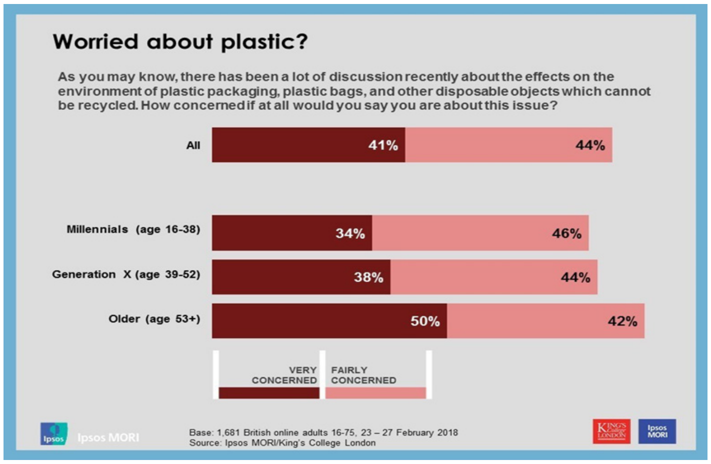

Figure 13: Warries about plastic waste of Millennals and Generation Z (by courtesy of Ipsos MORI/King ‘College)

New consumers, including specifically millennials (20-40 Years old) and generation Z (24 Years old) of AsiaPacific (APAC) area and the exuberant American generation, are looking for top quality products and transparency, being focused on wellness, remaining sensitive for price [58, 59]. Consequently, they are purchasing cosmetics and clothes health- oriented and able to enrich their easy daily live [58, 59]. Moreover, Generation Z and Millennials who worried about plastic waste (fig 13), represent a quarter of APAC consumers,also comforted by the digital world, rely on social media and influenced by video. However, on the other hand they are preferring brands that, maintaining their personality and uniqueness, are able to preserve a clean environment [57-59]. In conclusion the proposed new tissues and dressings seems to go in this direction, involving new bio- nanotechnologies by the use of discarded natural raw materials for a more sustainable future [60, 61]

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Preparation PM, GM; writing - review and editing PM, GM, QR, GM, AG, MBC; Supervision PM, MBC; all the authors have read and agreed to the publishing version of manuscript.

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