THE ROLE OF HEMP PLASTIC IN THE FIGHT AGAINST CLIMATE CHANGE

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Author Note

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Abstract

In recent years, the use of industrial hemp has been gaining momentum as a natural, renewable, climate-friendly, and non-toxic alternative to fossil fuel-based products. With the rise in popularity of hemp seeds, leaves, and flowers as foods, cosmetic ingredients, and herbal medicine, there is a growing quantity of stems, seed husks, cannabis extraction fibre and other by-products being left behind as “waste”. However, these “waste” fibres have many potential applications in (hemp) plastic manufacturing and construction. A transition from petrochemicals and conventional building materials to hemp (plastic) could significantly cut carbon emissions by locking up carbon in the end products, alleviate pollution, and improve agricultural land and crop yields.

Keywords: hemp, plastic, bioplastic, hemp plastic, co2, carbon sequestration, industrial hemp, benhaim

THE ROLE OF HEMP PLASTIC

IN THE FIGHT AGAINST CLIMATE CHANGE

Flattening The Curve Of Climate Change

First, why care about greenhouse gas emissions, carbon included? It's no secret that climate change is a serious and worsening issue. In the 2019/2020 bushfire season, over 21% of eastern Australia's temperate broadleaf forests were burnt, compared to only 2% in a typical year[1]. Over a billion animals lost their lives, almost 3000 homes were destroyed, and 400 extra deaths were indirectly related to the fires. Over in California, there were 41,051 wildfires from January to September 8, 2020, burning 4.7 million acres[2]. This is up from 35,386 fires and 4.2 million acres in 2019.

[1] Will Steffen, 2020, The Science Behind The Climate Emergency, *Renew Magazine,* Issue 152.
[2] https://www.iii.org/fact-statistic/facts-statistics-wildfires

Nothing New

This is no sudden event, with Australia suffering above-average temperatures and below-average rainfall for several years beforehand. Temperatures have been steadily creeping up globally, with this trend following the same pattern as the increase in greenhouse gas emissions. Our current trajectory takes us to a 2.5 degrees Celsius warming of the global climate by 2100, with the worst case scenario being an increase of almost 6 degrees. Key systems at risk of hitting dangerous "tipping points" in the projected temperature increase include the arctic sea ice, Amazon rainforest, Indian summer monsoon and the Gulf stream. If these suffer significant damage, the climate may warm and become dysregulated even more than it is affected by human activity alone. This tipping point, or a snowball effect will be immensely more challenging for our species to recover from.

To "flatten the curve" of climate change, there must be no new fossil fuel developments of any kind from 2020. By 2030, a 50% reduction in greenhouse gas emissions is required, with 100% renewable energy. By 2040, overall net zero emissions must be the goal. While a growing number of nations, alongside private businesses in efforts such as the RE100 Initiative[3], have set goals similar to these timelines, adoption of these goals is still far from universal. Interventions that reduce carbon emissions and other pollution, as well as repair the damage already done, must be built into everyday life to make these goals more achievable and sustainable.

Hemp As A Carbon Sequestration Medium

Industrial hemp is an effective medium for carbon sequestration, because the carbon is permanently incorporated into the fibres used for plastics, building materials and other applications. In Germany, BMW is already using it to replace petrochemical plastics in car manufacturing[1]. It is currently integrated with plastic materials produced from oil. As hemp is constantly replanted after harvesting, it also meets the permanence criteria established by the Kyoto Protocol.

[3] https://www.there100.org/

How does it all work? If hemp is used as an alternative to raw materials made from fossil fuels, it would capture and store a significant quantity of carbon dioxide. During photosynthesis, plants like hemp take in carbon and use it to produce sugar and their structural components. Therefore, a high biomass rate means more carbon is stored in the plant, including the stems and roots processed into building materials. Hemp's rapid growth rate of four to five months, height of up to five meters and root depth of up to three meters[2] make it an efficient way to capture carbon.

How much carbon dioxide is captured? One tonne of hemp stem contains 0.7 tonnes of cellulose, which is 45% carbon; 0.22 tonnes of hemicellulose, which is 48% carbon; and 0.06 tonnes of lignin, which clocks in at 40% carbon[4]. This means 44.46% of the stem's dry weight is carbon taken from the atmosphere. Per tonne of hemp, 1.6 tonnes of carbon dioxide are captured (once the oxygen atoms of carbon dioxide are taken out). If a yield average of 5.5 to 8 tonnes per hectare is assumed, then 9 to 13 tonnes of carbon dioxide can be absorbed for every hectare of hemp harvested. The roots also capture carbon, but their absorption rate is still unclear.

The production of fossil fuel-based plastics contributes to carbon dioxide emissions too. The EPA states that around one ounce of carbon dioxide is emitted for each ounce of polyethylene terephthalate (PET) manufactured[5]. As for the life-cycle production of polyethylene terephthalate (PET), a 5:1 ratio for the generation of carbon emissions to its production is estimated[6]. Therefore, anywhere between one to five tonnes of carbon dioxide is emitted during the manufacturing of one tonne of this plastic. If you remove 1 tonne of fossil fuel based plastic and replace it with hemp, which in itself sequesters approximately

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[4] European Industrial Hemp Association, 2020, *Hemp, A Real Green Deal*.
[5] https://stanfordmag.org/contents/the-link-between-plastic-use-and-climate-change-nitty-gritty/
[6] https://onlinelibrary.wiley.com/doi/abs/10.1002/ep.10078

1.65 tonnes[7] of co2 you have essentially shifted up to 6.65 tonne from out of the atmosphere by simply choosing 1 tonne of hemp.

Overall, hemp is a carbon negative raw material!

The World Meets Hemp Plastic

Should We Transition To Hemp Plastic?

Despite a relatively high level of hemp cultivation, compared to recent years, most plastic is still made from fossil fuel based substances[8]. Humans have produced a lot of plastics since they were originally commercialized - more than 1 ton per person alive[9]. In fact the mass of these plastics represent almost as much as the mass of all humans alive today[10]. Consumption of petroleum has harmful effects on the environment, due to the destructive methods used in its extraction and the amount of waste created during the refinement process. Petroleum is also a finite resource. Hemp plastic uses more of the cellulose-rich fibres of the plant, and therefore has much less toxic effects on the environment. The continued use of petroleum requires new wells to be drilled once older ones have been depleted, meaning that natural environments must keep being damaged. In the case of hemp, where products cannot be reused or recycled, soils may be cared for and fields can simply be replanted after harvest to ensure a new supply.

Could hemp really replace fossil fuels in plastic manufacturing? Yes – plastic can be any synthetic or semi-synthetic organic polymer (carbon chain), where “organic” is defined as being made of carbon-based molecules. Despite the capacity for plastics to be produced

[7] Per tonne of a plastic blend with 25% hemp means 0.25 to 1.25 tonnes of carbon dioxide emissions are removed from the displacement of fossil fuel-based plastic. A further 0.4 tonnes is pulled from the atmosphere through 250kg of hemp cultivation (see above), giving a total between 0.65 to 1.65 tonnes of displaced carbon emissions.

[8] http://www.aph.gov.au/DocumentStore.ashx?id=ae6e9b56-1d34-4ed3-9851-2b3bf0b6eb4f

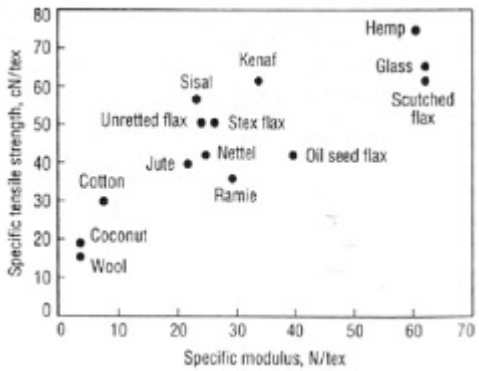
[9] https://slides.ourworldindata.org/plastic-pollution/#/3

[10] https://slides.ourworldindata.org/plastic-pollution/#/2

using almost any natural polymer, the vast majority of plastics are still made from petrochemicals. The word “plastic” simply describes its flexibility, as these products can be shaped or otherwise disfigured without breaking[11]. The polymers used to make plastics are typically blended with other substances, such as fillers, stabilisers, colours, plasticisers and fortifications. These affect the mechanical and synthetic properties of a plastic, as well as its structure and cost.

At this time there are various forms of hemp plastics[12] - from 100% compostable bio based polymers (when mixed with polylactic acid (PLA) or polyhydroxyalkanoate (PHA), or similar renewal plant based substance) to those where hemp replaces 25% of a polyproylene (PP) resin. Even the 25% hemp plastics are a stepping stone towards companies’ goals of producing 100% plant based compostable packaging.

Hemp plastics should replace petrochemical-based plastics for several reasons. These are its lack of toxicity, chemical inertness, recyclability, fewer manufacturing hazards and lower use of natural resources. Hemp plastics may also be more durable than their fossil fuel-based counterparts. In comparison to glass filled plastics, they do not create health and safety risks to manufacturers, they sequester greenhouse gases, they are typically lighter and can cause less wear and tear to the screw and moulds. Their superior flexibility also aids functionality.



[11] https://www.e3s-conferences.org/articles/e3sconf/pdf/2018/26/e3sconf_icacer2018_03002.pdf
[12] https://www.hempplastic.com/products/

However, hemp has enormous shoes to fill. Plastics revenue expected to be $560bn by 2024 and the smaller bio-plastic market is expected to be $68.6bn by 2024[13].

Global plastics production reached 311 million tonnes in 2014, with packaging and construction the two largest segments of the market[14]. If hemp bio resins replace just 25% of this quantity, it means that 77.75 million tonnes (0.25% is 777,500 tonnes) of fossil fuel-based plastic are not produced and do not contribute to pollution. As manufacturing processes improve and the ratio of hemp bioresin rises, an even greater amount of petrochemicals can be removed from annual production figures.

Only 30% of Europe's 25.8 million tonnes of plastic waste was re-processed in 2014. Variable properties of plastics and poor quality sorting criteria are two factors that affect the rate of plastic recycling. Incineration of plastic waste for energy production is the preferred method of keeping it from re-entering the environment in Europe, but this contributes to carbon emissions. Globally, approximately 40% of the world's garbage is burnt, in order to free up space in landfills. A substantial proportion of this is done at home in some countries, with 22% of China's particulate matter (PM10) emissions coming from domestic open waste burning[15]. Burning plastic releases chemicals such as polycyclic aromatic hydrocarbons (PAHs) into the air, which also persist in ash waste residue. The transition to bio-sourced hemp plastics, without toxic man-made pollutants, will assist in eliminating the need for waste burning. Durability and recyclability can reduce the need for potentially harmful disposal methods too.

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[13] https://www.ceresana.com/en/market-studies/plastics/plastics-world/ceresana-market-study-plastics-world.html

[14] https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/The-ocean-plastic-pollution-challenge-Grantham-BP-19_web.pdf

[15] https://pubs.acs.org/doi/abs/10.1021/es502250z

Hemp Plastic And Carbon Savings

Carbon savings from the use of hemp plastic begin with oil extraction. Data from 2012 shows that plastics accounted for roughly 4% of global oil consumption[16]. Research from Stanford University, covering 98% of the world's oil production, found that emissions equal to 1.7 billion tonnes of carbon dioxide were generated by the practice of oil extraction[17]. This accounts for 5% of emissions from fuel combustion. It is most likely an underestimation, however, as it does not fully capture leakage and venting of methane. As four percent of 1.7 billion is 68 million tonnes, transitioning away from pure fossil fuel-based plastic could significantly reduce greenhouse gas emissions by reducing the need for fossil fuels, potentially in an amount equal to Israel's entire estimated carbon dioxide emissions from fossil fuels (67 million tonnes in 2017).

The figure of 68 million tonnes can be added onto the amount of carbon sequestered by hemp. At a capture rate of 1.6 tonnes per tonne of hemp, replacing a "mere" 25% of fossil fuel-based plastics with hemp removes 124.4 million tonnes of carbon dioxide from the atmosphere, for a total emission elimination and sequestration of almost 200 million tonnes.

In manufacturing, net savings in energy costs come from the glass and matrix material's displacement by hemp. Some synthetic polymer, such as polypropylene, is still currently used as a matrix. Glass fibre manufacturing takes

[16] https://oilprice.com/Energy/Energy-General/How-Much-Crude-Oil-Does-Plastic-Production-Really-Consume.html

[17] https://news.stanford.edu/2018/08/30/measuring-crude-oils-carbon-footprint/

approximately five times the energy of that for hemp fibre production. Additionally, polypropylene (PP), acrylonitrile-butadiene-styrene (ABS), and epoxy resin require more than 10 to 20 times as much energy for the same weight, respectively, as hemp. Traditionally, the most common mineral fibres used for fibre-reinforced plastics are asbestos and glass, while flax and jute were the most common vegetable fibres used in automotive composites. Despite natural fibre blends becoming more common in this application, manufacturers often shy away from hemp because of reliability and price issues. However, the use of industrial hemp in thermosets and thermoplastics has still grown from virtually non-existent in the 1990s to a growing niche in the 21st century.

As hemp is lightweight and potentially as durable as steel, it is earning its place in vehicle construction. The first and most well-known car made from hemp structures was made in the late 1930s by Henry Ford, who built a car made from hemp fibres that would also run on hemp-derived biofuels. Much more recently, a limited number of custom-made cars were made by Renew Sports Car, all built entirely from hemp. Hemp fibres are also already used in vehicle interiors by several major European car brands. Use of bio-based raw materials as opposed to synthetic products leads

to both a significant reduction in emissions and a higher energy efficiency. The lighter biomaterials have the potential to deliver a reduction of 40,000 tonnes of carbon emissions, with an additional 325 million kilometres' worth of range collectively added to the same

quantity of fuel. Hemp fibre parts can be 20-30% lighter than conventional counterparts, which increases fuel efficiency. At the end of a product's life cycle, hemp provides another environmental advantage. In an unalloyed form, hemp will decompose and release the carbon it has sequestered, and will do the same if it is incinerated after use in a composite with fossil fuel-based plastics. In the case of waste-to-energy systems, incineration of hemp composites offers more combustion value than burning up glass-reinforced counterparts.

Hemp In Construction

Since the 1990s, hemp lime composites have been used in France for construction, with other countries following suit in more recent years. Hemp lime composites are often referred to as hemp concrete, or simply "hempcrete". They are building materials made by mixing hemp hurds as aggregate together with lime or magnesium based binders. Construction of walls, floors and roof insulation can incorporate hempcrete.

The European Union's built environment creates approximately 40% of the territory's energy use, and 36% of its CO2 emissions. Roughly half of all extracted materials are used in the construction sector, which is also responsible for just over one-third of the EU's waste generation. Incorporating hemp, a resource that grows above the ground and can be replanted every several months, may therefore reduce the need for mining. In developed countries, maintaining the indoor climate is responsible for a significant slice of energy consumption too. In-building energy consumption accounts for approximately 40% of the whole energy demand in many regions. Of this, space heating and cooling requires almost 60% of the total energy consumed.

When hemp is used in construction to produce concrete, its carbon sequestration benefits grow. One chemical analysis of Lime Hemp Concrete (LHC)[18] found a carbon

[18] https://www.researchgate.net/publication/320058537_Assessment_of_Carbon_Sequestration_of_Hemp_Concrete/link/59cbb45b45851556e982eec5/download

dioxide sequestration rate of 161.31 grams per 7cm^3, or 470.3kg per m^3. Another study found a sequestration rate of 251.67kg per m^3, and the full life cycle assessment showed a net emission of -35.5kg per m^3, making the LHC-timber frame tested a carbon-negative structure. In contrast, conventional cement is responsible for 8% of the world's carbon emissions, including 99 million tonnes emitted in India's production of the material in 2014. Per ton of reinforced concrete, 198 kilograms of carbon dioxide is emitted during production. Making one ton of steel results in an average of 1.46 tons of carbon dioxide.[19] Hempcrete is also resistant to mould and bacteria; non-flammable; and regulates humidity and temperature. For example, when a three-storey building was constructed at Bath University using hempcrete, all heating, cooling, and humidity control could be switched off year-round. Constructing new buildings with hempcrete could therefore provide tremendous emissions savings, and speed the transition to renewable energy via lower generation capacity needs.

[19] https://www.theguardian.com/sustainable-business/2014/sep/25/hemp-wood-fibre-construction-climate-change

Hemp In Agricultural Systems

Industrial hemp can even be cultivated on nutrient poor soils with very small amounts of additional water and no fertilizers. Unlike most forestry projects, hemp can be incorporated into existing agricultural land, and benefit the overall yields of other crops when added into a rotation system. Its rapid growth rate of approximately four metres in 100 days, plus low fertilizer needs and little to no requirement for pesticides or herbicides make hemp an efficient, non-toxic addition to existing farms.

Crop Yields

Hemp can add value to other agricultural commodities, including staple food crops, in a system of crop rotation. For example, hemp can naturally reduce the prevalence of pests such as weeds when planted in a rotation with either organic or conventionally grown crops. Some farmers in China reportedly use hemp as a barrier to repel insect pests from vegetable crops; in Canada, it is planted in rotation with soybeans to reduce cyst nematodes, a parasitic pest[20]. In the Netherlands, hemp is sometimes rotated with potatoes to reduce harmful nematodes. In other rotation experiments, hemp has successfully prevented infestations of the weed *Cyperus esculentus*, as well as increasing yields of winter wheat when alternated in the same field. Practices such as these demonstrate some of the benefits of crop rotation, even showing that vegetable and fibre crops can be alternated between, as opposed to only producing one single crop. Higher crop yields aid the battle against climate change by reducing the need for land clearing. This way, more carbon can be sequestered in the forests and other environments preserved as a result.

[20] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.293&rep=rep1&type=pdf

Many members of the European Industrial Hemp Association (EIHA) report that hemp is an ideal crop for organic production and grows well near surface water. Even other crops included in rotation systems benefit from hemp. For example, wheat yields have been found to be 10 to 20 percent higher after the cultivation of hemp in the same field. The trial from Rodale Institute mentioned above confirmed this, and then found similar results when soybeans were planted afterwards.

Chemical Inputs

Other sustainability advantages of hemp in terms of agriculture are the relatively low inputs required for its cultivation. Generally, herbicides are not used in hemp production. It is seeded at very high densities when grown for fibres, and the plants' rapid growth crowds out most species of weeds that may infiltrate the fields. When hemp is grown at lower densities for seed or flower harvesting, it does not perform as well in terms of controlling weeds.

It is common for industrial hemp to be grown profitably with little or no use of pesticides. However, if industrial hemp was grown under intensive conditions, with irrigation and conventional fertilizers, it is a fair assumption that the crop would develop pests and diseases that require external treatment. Boosting crop genetic diversity and implementing crop rotation are methods of avoiding this situation. *The Author supports the use of Regenerative Agriculture and not farming hemp as a monoculture crop.*

The use of fertilizer in growing hemp ranges widely. At the upper estimates, its fertilizer needs are equal to or less than high-yielding wheat or corn. The rapid growth of these crops requires an external input of nitrogen. In Canada, anywhere between 55 to 80 pounds per acre of nitrogen, and 30 to 40 pounds per acre of phosphate, are used to grow industrial hemp. Much higher rates of nitrogen fertilizer use have been reported in other countries. However, hemp does not require significant fertilization, with very little response of the plant to conventional nitrogen fertilization noted in Southern Europe (Italy). An

internal survey of EIHA members found that half of all respondents use natural alternatives, such as manure or slurry. It is therefore possible that education would reduce the use of conventional fertilizers further.

Why is this important in the fight against climate change? Fossil fuels, namely natural gas, are tied to conventional agriculture production through the use of inorganic fertilizers. Conventional fertilizer production is responsible for roughly 1.2% of global energy use and total emission of greenhouse gases. In the United States, 9% of industrial greenhouse gas emissions in 2005 were the result of nitrogen fertilizer production. It was also responsible for 60% of total nitrous oxide emissions. Fertilizers can cause environmental damage when they leach from soils, contributing to eutrophication. Soil erosion and eutrophication as a result of agricultural runoff are leading causes of poor water quality in the USA.

Hemp and Water Use

Hemp also uses far less water than other fibers. Cotton is one of the most widely-known comparative examples, which uses approximately 10,000 litres per kilogram while the water use of hemp is 2,719 litres per kilogram[21]. This is partly because industrial hemp often does not require irrigation. European research during a hot, dry growing season demonstrated hemp's resiliency in periods of low rainfall[22]. Some cultivars respond by developing earlier and faster, while others take longer to grow but may have higher yields. Overall, it was proven that hemp can be grown in dry conditions without continuous irrigation.

Biodiversity

Another environmental concern in agriculture is biodiversity depletion. One study, assessing 23 crops along 26 biodiversity parameters, found that both oilseed and industrial hemp beat most major crops in terms of preserving overall biodiversity. As hemp generally

[21] http://essay.utwente.nl/68219/1/Averink,%20J.%200198501%20openbaar.pdf
[22] https://www.mdpi.com/2073-4395/10/9/1361/htm

requires little to no pesticides and herbicides, it can improve biodiversity by providing a safer habitat for animals. The flowering period of hemp usually takes place from July to September (Northern Hemisphere), when other common farm crops do not produce pollen. As a dioecious, staminate and wind pollinated plant, hemp makes large amounts of pollen, thus acting as a key food source for bees when other flowers are not blooming. Hemp also supports a wide range of bee species. In northern Colorado plantations, research on the bee populations in hemp fields found 23 different genera. The most common species was *Apis mellifera*, representing 38% of bees, followed by *Melissodes bimaculata* at 25% and *Peponapis pruinosa* at 16%.

Healing The Soil With Hemp

In addition, hemp's carbon-catching benefits can be extended to the soil. As a fast-growing crop with a high leaf turnover rate, hemp grown for its stalk will completely cover the ground in three weeks after germination if grown in ideal conditions. Its dense leaves quickly provide a natural source of soil cover, which helps to reduce water loss and soil erosion. What's more, fallen leaves increase the nutritional value of the soil. In the case of cultivation for fibre, hemp stalks are an important source of soil nutrition during retting. This is the decomposition of the stalk's outer layer, allowing access to the fibres for manufacturing.

The height and shading capacity of hemp leaves the soil in optimum condition by effectively inhibiting weed growth. Early results from research at Rodale Institute in the United States demonstrates that the use of hemp as a summer crop, and its earlier harvest date, prevented weed growth all season long and allowed a wider window for the winter crop to be established. This is another important advantage of growing hemp in crop rotation systems. As it has no natural predator insects, hemp does not need insecticides. It is overall

vulnerable to few serious pests, and is usually cultivated without, or with a minimal use of chemical treatments such as herbicides.

What about land that has already been significantly degraded? Hemp has even demonstrated significant efficiency in land reclamation. It is considered a quality pioneer crop – the first plants reintroduced to damaged land – because of its phytoremediation capacity. This is the ability to remove toxins such as heavy metals from the soil. Hemp is highly cadmium-tolerant, and is resistant to long-term heavy metal exposure. Former mining sites could be rehabilitated by hemp cultivation, with crops supporting production of long-lasting plastic and construction items that will not be broken down again to release the heavy metals back into the environment.

Soil Conservation As Carbon Sequestration

Soil conservation may play an essential role in carbon sequestration. Although it has no beneficial effects in tropical rainforest ecosystems, research in regions such as the Yellow River basin has found that it has its place in arid areas. Intensive soil erosion control, regardless of the intended purpose, has led to a significant drop in carbon mobilisation and release. Conservation practices that prevent soil erosion are a natural way to sequester carbon.

With preventing the increase of carbon dioxide in the atmosphere as a priority, it was shown that around 9.7Tg[23] of carbon was kept out of the air every year by soil conservation practices such as regenerative agriculture[24]. This includes both reduced emissions and the carbon fixated inside restored or protected plants and soils. At a significant scale, it can affect the land to atmosphere carbon exchange within the environment affected. China's average carbon dioxide emissions caused by burning fossil fuels and cement production were 1.42

[23] 1Tg = 1012g of carbon or one million metric tonnes ref: EPA
[24] https://en.wikipedia.org/wiki/Regenerative_agriculture

tonnes per capita from 2000 to 2014. When applied to the Yellow River basin, the total annual carbon emissions from these two sources were 198Tg of carbon. This means that the carbon removed from the atmosphere accounted for 5% of these emissions, and 10.4% of emissions were controlled by soil conservation.

In some areas of the Yellow River basin, carefully chosen trees, shrubs and grasses have been planted on former farmland. These are all adaptable to the local dry climate. As a result, the soil erosion rate and sediment flux have been substantially relieved, and the ecosystem has improved alongside this[25]. The rate of sediment flux into the ocean is only 10% of its level in the 1950s. These significant improvements in soil erosion and loss of sediment have affected carbon cycling processes, which are linked with erosion and sediment movement. Alongside over 10 years of restoring local vegetation, this once severely degraded environment has been significantly repaired, even though more work is still needed to completely reverse the damage.

The Greenwashing Of Petroleum-Based Plastics

In recent years, biodegradable and compostable plastics have gained popularity due to their image as safe, non-polluting alternatives. It is different compositions and manufacturing methods that mainly categorise plastics into two groups: biodegradable and non-biodegradable plastics. Biodegradable plastics contain certain additives which promote a relatively rapid degradation compared to traditional plastics. They

[25] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6089926/

may still be made using petrochemicals, and don't always break down into non-toxic substances. Some of them still leave behind harmful residues, so they are often unsuitable for composting, particularly in home systems where the compost will be spread onto gardens[26].

Biodegradable plastics can be broken down into water, carbon dioxide and some biochemicals with the use of microbes. When they are disposed of in landfills, they emit harmful greenhouse gases when breaking down, making them more toxic than some other conventional plastics. Biodegradable or biocompostable plastics that may include polylactic acid (PLA), polybutyrate (PBAT), polyhydroxalkanoate (PHA) and polycaprolactone (PCL).

Australian biodegradability standards require "compostable" plastics to be 90% broken down within 180 days when disposed of in compost. In 12 weeks, 90% of plastic should be in particles under 2mm in size. There should also be no toxic effects on plants or earthworms; hazardous components such as heavy metals shouldn't be present above legal levels; and plastic materials should contain at least 50% organic materials. The categories of compostable plastics are distinct, and potentially confusing: some are labelled as home compostable, others can only break down rapidly in industrial compost.

If compostable plastic enters landfill, it is just as harmful as conventional plastics and can last years. In a 2019 study, biodegradable and oxo-degradable bags were still able to carry a load of groceries after being buried for three years in a range of environments, including soil and shallow seawater. The compostable bag was not usable, but hadn't entirely broken down either.[27]

Current compostable plastics can compromise the durability of recycled plastic if mixed with recyclables. Even if correctly sorted into industrial composting, it may leave microplastics behind by taking longer to degrade than other materials. Industrial facilities

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[26] How Green Are Compostable Plastics? Sophie Weiner, *Renew Magazine*, Issue 152.

often aim to process materials in two or three months, which may be sufficient for some waste but not enough time for the plastics.

Tea bags and coffee pods, which are already commonly disposed of in home compost, are two suitable uses for compostable plastic. Situations where the seller has control of the item's entire life cycle, such as an events centre where the product is bought, consumed and disposed of, are suitable candidates for compostable plastic too. However, the rapid growth of hemp makes them an even more sustainable alternative for these single-use items. The more we use and incorporate hemp into all forms of plastics, the faster we will improve our carbon use on our planet.

The Health Effects Of Pollution

Pollution is a major cause of disease and mortality. In 2015, one in six deaths worldwide were the result of illnesses triggered by pollution[27]. This was three times higher than those caused by AIDS, malaria and tuberculosis combined, and 15 times more than those from war and violence. Just under half of these deaths – 4.2 million – were from ambient air pollution outdoors. Pollution was responsible for 43% of deaths from lung cancer, 51% of the chronic obstructive pulmonary disease (COPD) mortality, and 21% of cardiovascular disease deaths.

Looking at its economic effects, pollution-related disease reduces gross domestic product (GDP) in low- and middle-income countries by up to 2% every year. Approximately 1.7% of healthcare costs in high-income countries, and 7% in middle-income countries, can be attributed to pollution. These health and financial costs are likely to be underestimated, as additional associations between pollution and disease may be found in the future.

The effects of chemical pollution on human health are "almost certainly underestimated", according to The Lancet Commission on Pollution and Health. Over

[27] https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32345-0/fulltext

140,000 man-made chemicals have been synthesised since 1950, and roughly 5,000 of these are produced in such high volumes that there is near-universal human exposure. However, 85% of air pollution comes from combustion, including burning fossil fuels for energy and waste burning.

Plastic Pollution

Some of these chemical pollutants are released by the slow breakdown of conventional plastics. Currently, microplastics are sadly ubiquitous in the environment. Water samples taken in Europe yielded approximately 24,600 particles per litre, and even ice flow samples in Greenland and Svalbard contained 1,760 microplastic particles per litre. These have made their way into humans, with the average person consuming 50,000 particles of plastic every year[28].

The use of hemp plastics will reduce the toxic burden on the environment and humanity. Fossil fuel-based plastics contain endocrine-disrupting chemicals (EDCs), which can significantly impact health and childhood development. Even low doses of EDCs may increase risk of chronic disease and lead to permanently damaged organ function if children are exposed to them in the womb. In a study of 2,517 children and adults in the United States, bisphenol A (BPA) was found in 92.6% of their urine samples[29]. BPA is commonly found in plastics and synthetic resins, but greater awareness of its effects has led to some phaseouts in recent years. Another chemical used in these products, 4-tertiary-octylphenol (tOP), was found in 57.4% of urine samples.

Toxins such as benzene and toluene, which are linked to multiple diseases in humans, are not found in hemp products despite being prevalent in petrochemical-based plastic. Benzene and toluene are two volatile organic compounds (VOCs). Benzene is a carcinogen

[28] https://cleantechnica.com/2019/08/15/plastics-in-rainwater-plastics-in-snow-plastics-in-our-food-plastics-everywhere/

[29] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2199288/

that also affects the respiratory, reproductive, nervous and circulatory systems[30]. Toluene is toxic to the nervous and reproductive systems. On top of this, benzene has harmful effects on the development of blood cells, which raises the risk of acute myelogenous leukaemia and aplastic anaemia.

Oil Extraction And Pollution

Another way that the use of petroleum harms the global environment is the event of oil spills. Although dispersing agents had been commonly used to assist in cleaning spills, the level of petroleum compounds in water columns can be significantly worsened by their presence. The natural motion of the ocean, along with chemical dispersants' ability to reduce the oil/water interfacial tension, allow oil to be broken down into very fine, more mobile droplets. Surfactants in the water column have molecular properties of opposing solubility tendencies, giving them the ability to interact with the cellular membranes of marine life[31]. This can damage the permeability of their cells and their organelles – "miniature organs" inside cells that carry out vital functions, such as energy production and protein synthesis. Therefore, this may trigger a range of physiological problems, ranging from the cellular to multi-system levels. Fish readily take up and metabolize petroleum hydrocarbons, and may also pass on any unmetabolized substances, or potentially more dangerous intermediate metabolites, onto predators including humans.

The extraction of fossil fuels itself is responsible for a range of toxic effects on the environment. This is amplified by their consumable nature; as they and most of their end-products cannot be recycled or reused, more must be mined or pumped out of the earth, and more reserves must be sought once currently exploited deposits are no longer economically viable. Environmental pollution with carbon-based compounds and heavy metals found in oil

[30] http://www.eeer.ir/article_52149_90bdf6c5d51ae5844111c5105b2a9bc3.pdf
[31] https://link.springer.com/article/10.1007/s002449910009

is a global issue, and a serious one due in part to their toxicity and accessibility. Alkanes, benzene, methylbenzene, and a range of heavy metals commonly contaminate soils near oil extraction sites. These damage the health of all life forms, including humans, with some categorized as known carcinogens. Many cannot be easily removed from the soil, and they will often leach into the groundwater systems that support lakes, vegetation, and drilled wells for human consumption. Research in Romania found high concentrations of lead, cadmium, copper, and chromium, as well as abnormally high zinc levels, in all soil samples near oil extraction sites[32]. In many cases, they exceeded the limits specified in Romanian law.

Conclusion

The use of industrial hemp to at least partially displace petrochemicals in plastics, as well as conventional building materials, could play a significant role in the fight against climate change. The benefits of using hemp in plastics are found in all stages of production, from its cultivation methods and displacement of petroleum to lack of toxic pollutants and long-term carbon sequestration in permanent structures.

[32] https://www.researchgate.net/publication/258218522_Assessment_of_heavy_metals_content_of_crude_oil_contaminated_soil?enrichId=rgreq-1845b56dea6421dc69cad94ec16b03b7-XXX&enrichSource=Y292ZXJQYWdlOzI1ODIxODUyMjtBUzo0NzUwNTk0ODQ2NjM4MTFAMTQ5MDI3NDQxNTk5MQ%3D%3D&el=1_x_2&_esc=publicationCoverPdf