Abstract

As the Earth becomes more populated, the need for eco-friendly diapers becomes more urgent. The current disposable diapers used cause harm to the environment in the majority of its existence, from production to the end of its 500 year lifespan. We propose that we use carbon capture as a way to fuel the creation of more eco-friendly diapers. Doing this reduces climate change and pollution, both large concerns for the habitants of Earth. To create these diapers, we need to connect smokestacks into a factory packed with mycelia which traps carbon as it grows. Once the mycelium is grown, we can use it to create absorbent material. The process of making the absorbent material for our 'Shiitake Diapers' captures carbon dioxide, preventing the greenhouse gas from causing further damage, while the biodegradability and decomposition of our diapers also eliminates pollution and methane from landfills that disposable diapers currently contribute to.

Manufacturing eco-friendly diapers using CO_2 emissions from smokestacks

Present Technology

Diapers are critical to a baby's health and well-being. The amount of waste disposable diapers produce is enormous. Today, disposable diapers are primarily made of cellulose, polypropylene, polyethylene and a super absorbent polymer, as well as minor amounts of tapes, elastics and adhesive materials.

The diaper can be broken down into three main parts: the inner layer, the absorbent core and the waterproof outer shell. The inner layer is the part that goes against the baby's skin and is typically made of polypropylene nonwovens. Polypropylene nonwovens take around 30 years to degrade, but it is not the worst material in modern disposable diapers. There are no fully biodegradable diapers currently and one of the most popular eco-friendly diapers is only 87% biodegradable and is made by the company Andy Pandy. They make their top layer out of nonwoven bamboo.

In most disposable diapers, the absorbent core is made up of cellulose fluff pulp (wood pulp fluff), polypropylene and super absorbent polymer (SAP). Fluff pulp primarily comes from wood and a popular diaper company, Pampers, bought 650K acres in North Florida and started harvesting the forest to produce pulp for the pampers diapers. On its own, cellulose pulp fluff is biodegradable but together, the entire core of the diaper can take decades to decompose. The absorbent material in most eco-friendly diapers still contains SAP and TCF (Totally Chlorine Free) Fluff Pulp.

Petroleum-based plastic and nonwoven materials make up the waterproof outer layer of the basic disposable diaper and these materials take the longest to degrade. Nonwoven means that the fabric was created by bonding fibres with a chemical, heat, mechanical or solvent

solution. Most of the time, the petroleum-based plastic in disposable diapers is polyethylene and it can take centuries for it to decompose in landfills. While decomposing, plastic releases toxic chemicals that seep into the Earth's soil causing more of a negative environmental impact. In eco-friendly diapers, nonwoven bamboo (viscose) or a combination of a natural material and polyethylene is used.

For the rest of the diaper chassis, there are no biodegradable or compostable substitutes for the fastening systems and leg/waist gatherers. Nest Baby Diapers uses a naturally derived biodegradable synthetic rubber for adhesive and Bambo Nature uses a basic synthetic rubber adhesive. Eco-friendly diaper brands still have not figured out a natural product to replace the spandex, elastin and other chemically related products inside their diapers. In the near future, we hope that there will be fully compostable natural substitutes.

Altogether, one diaper takes over 500 years to decompose and damages the surrounding earth while doing so. Most diaper companies have made improvements in functionality at the cost of environmental health. In North America alone, we are throwing away 30 to 40 billion diapers a year, which leaves massive amounts of slowly degrading plastic in our landfills. Our product will not include any plastic and will be made of compostable materials that will nurture the soil.

History

Carbon Capture

Carbon capture and storage is the process where waste carbon dioxide is taken and then deposited in a place where it cannot re-enter the atmosphere. Carbon capture occurs in nature and is being mimicked by man-made products as well. Using CO_2 Capture and Storage (CCS) in order to prevent climate change was an idea first mentioned in 1977. At that point in time there

was already carbon capture technology, but it was used for other purposes. The pre-existing carbon capture tech dating from the 1920s was intended for separating natural gases and carbon, in order to be able to put the gas for sale. The carbon captured would then be injected into oil fields to enrich them, in a process called Enhanced Oil Recovery (EOR). By the end of 2012, there were 5 major CCS projects that were progressing and 23 others developing.

Fungi paired with plants, has been found to carbon capture extremely well, allowing the soil to contain up to 70% more carbon dioxide, indefinitely. Mycelium, the vegetative part of the mushroom/fungi, is responsible for a large part of this process. Fossils prove that mycelium has been around for over a billion years but they were only discovered by Beatrix Potter over a century ago. Mycelium has been said to possibly be the solution to climate change, and is being tested for use in a few mediums, including in packaging for shipping products.

The idea for using mycelium to carbon capture originated from two mycologists in 2002. The company “HiveMind” later conducted an experiment where they tested the fungi’s carbon sequestering abilities. The results were surprising, the mycelium allowed the capture of over 100 tons of carbon and N_2O from a 500 square feet space, while also improving the health and lifespan of the plant itself. Mycelium can also survive a forest fire, even if the tree it is attached to cannot. In 2016, engine manufacturing company “Cummins Diesel” reached out to HiveMind to help in reducing their carbon emissions to 16.5 million tons by 2025, oil company Shell closely following, working to reduce emissions by 230 million tons by 2030 with HiveMind in 2019. HiveMind has also created a smaller company named NetZero that works to help everyday people use carbon capture to help the planet. NetZero has found that mycelium doubles the carbon capture rate while also being cheaper than using mechanics.

Smokestacks

Smokestacks are vertical exhaustion or venting pipes that are used to disperse pollutants and gases from buildings over a larger area, in order to make the gases less concentrated. They were first made in 1836 during the Industrial Revolution. Pollutants released into the atmosphere by these pipes are nitrogen oxides, sulfur oxides, carbon dioxide, carbon monoxide, and particulate matter. Polluted air from power plant smokestacks prematurely killed around 52,000 people in the U.S., according to a study MIT did in 2013. Since smokestacks do create a lot of pollution and greenhouse gases, there are on-going projects that are trying to scrub the CO2 and harmful gases out, in an attempt to reduce harm caused to the environment.

Diapers

Around 4000BC, in Central Asia, swaddling was used to contain the waste of infants. This swaddling was not the most sanitary and resulted in crying, skin ulcerations and disease. In Ancient times, mothers would use natural resources such as Milkweed leaves, and animal skin to create a diaper for her baby. Natives often used seal skin or rabbit skin as an outer layer, and used moss or grass as an absorbent material inside. Mothers in warmer, more tropical climates, would use elimination communication. In the late 1800s, pieces of cotton or linen were used for a diaper, using a safety pin to secure it. As the world became more aware of bacteria and its harmful effects in the early 1900s, mothers learned to boil the pieces of fabric before reusing them. In 1942, a Swedish man came up with the first disposable absorbent pad in a diaper, made of unbleached creped cellulose tissue. Four years later in the U.S., Marion Donovan, a mother of three, patented waterproof coating for cloth diapers and clips that were safer than the pins being used. In the 1950s, “Curity" created the first pre-folded diaper, and at the same time, the popular diaper brand “Pampers" came out with their all-in-one system. Newer diaper styles also came out, pre-formed with plastic clips. In the 1960s, after the invention of pulp mills, disposable

diapers began to be made of cellulose fibers instead of paper. Disposable diapers started growing in popularity in the 1970s and is predominantly the type of underwear that parents opt to use to this day. However, debates concerning the environmental consequences of using disposable diapers spurred in the 1990s, and the discussion still continues. In the U.S. in 2016, around 20 billion disposable diapers ended up in landfills annually, which secrete methane gas, another greenhouse gas. Disposable diapers accounted for almost 3.5 million tons of annual waste.

Future Technology

The future of diapers can be a green one. Our technology offers fully compostable diapers that will effectively eliminate diapers from rotting in landfills for centuries. The eco-friendly process will start with the creation of the diapers. Carbon emissions from factories will be captured then absorbed by our naturally grown mycelium, which will in turn transfer the carbon into the soil. Alongside storing carbon, the mycelium will serve as being the primary ingredient in our non-toxic eco-friendly diapers.

The diaper can be broken down into three main parts: the top layer, the absorbent core and the bottom layer. The most important part of the diaper is the absorbent core, which is where most of the waste resides. For the absorbent core of our diapers, we will be using mycelium and a small amount of cellulose fluff pulp. Mycelium is the vegetative part of a fungus, made up of a network of white filaments (hyphae). It is an incredibly absorbent material that can retain liquids for long periods of time. Being a natural fungus, it will easily compost and nourish the surrounding soil. Mycelium is also excellent for carbon sequestration and will transfer carbon to the soil before it makes its way into our diaper products. Current diapers use biodegradable cellulose pulp, which is fully sourced from wood. Our product will replace a majority of the cellulose fluff with mycelium to act as the absorbent factor, thereby reducing the need for

wood-sourced cellulose fluff. However, some wood fluff pulp will be needed to keep diapers light, comfortable and soft.

Alternative solutions for the adhesive, velcro tape and elastic trim for the waistband and legs still remain a challenge. In 20 years, we imagine that there will be significantly better compostable plastic-alternative products. Since biodegradable plastic development is still underway, we are also hoping for completely plastic-free adhesives, elastics and velcro tape and we would prefer that they were derived fully from non-chemical ingredients.

Currently, there is no waterproof plastic film that is made from entirely biodegradable or compostable ingredients that can be used for our bottom layer. Although most bioplastic is made from renewable biomass sources such as sugarcane, starch, corn and yeast microbes, it is also made with petroleum-based plastic. In order for our product to be fully compostable and have no chemicals seep into the soil during decomposition, the product must be 100% petroleum-free.

For the top layer of our diaper, we will be using non-woven mycelium fibres. The fibres will quickly transfer the liquid to the absorbent core and will keep the baby dry and happy. The mycelium will be grown without any use of pesticides, chemicals or toxins. Instead of bonding the mycelium fibres with chemicals, heat will be used to create the fabric. Additionally, the top sheet will have a coat of aloe to nurture and moisturize the skin. The aloe will come from the aloe barbadensis miller (aloe vera) plant The aloe contains antioxidants, enzymes, Vitamins A and C which can help treat inflammations, burns and dry skin.

Our environmentally friendly diapers will significantly diminish the number of hazardous materials in our environment. It will provide the same features as popular diapers of today while promoting sustainability for our environment. The promise of better plastic alternatives for adhesives and elastics will further allow our diapers to be fully biodegradable and safe. Our goal

is to have a product that will have zero negative impacts on our natural world. Our environment does not tolerate plastic, so why should we.

Breakthroughs

The breakthroughs need to happen in three principle areas: 1. factory design, 2. mycelium optimization and 3. product design.

Factory Design

Important elements of factory design will be carbon supply, the ventilation system and mycelium growing surfaces. The carbon supply will be through underground piping, which is well known, but has to be combined with ventilation and environmental controls to ensure optimal growing conditions for the mycelium (e.g. humidity, carbon concentration) and to keep out contaminants such as bacteria and outside fungal spores . The breakthroughs would have to be in the design of the carbon supply (e.g. safely transporting emissions from the partnering factory to our building), the ventilation; separating the carbon dioxide from the other gases that are being sent to our factory, and regulating the carbon dioxide being spread around the growing rooms. Since we're growing the mycelium on boards stacked in columns, we have to make sure that there are multiple entrance points for carbon dioxide to enter from so that all the mycelia have access to proper amounts of carbon.

Mycelium Optimization

Fungi have one of the highest bio masses in the world and since using mushrooms to build things, instead of breaking them down, is a relatively new idea, there's limited information on what type of mycelium would be best for our purposes. There are around 75,000 species of fungi that are scientifically identified and scientists believe that there may be millions of species still left unidentified. For our technology to work, we need to find a fungus with a mycelium that

is non toxic and non irritating to humans, all while being very absorbent to it can do the job a regular diaper would. The ideal mycelium will also be fast growing and will absorb a lot of carbon relative to its weight.

Mycelium are categorized into three basic groups based on how they acquire nutrients; mycorrhizal, saprophytic and parasitic . Mycorrhizal mycelium obtains nutrients from living plants such as trees in a symbiotic relationship; saprophytic mycelium absorbs nutrients from dead organic matter (e.g. rotting logs) and parasitic mycelium feeds off a living host. For our technology, the parasitic option is not the way to go because a living host is needed to grow it and it would be hard to sell baby diapers based on a parasitic organism. So our choice will be between mycorrhizal and saprophytic mycelia. We believe that saprophytic will be the easiest to grow because we would just grow the mycelium on boards that have dead organic matter on them - even cardboard!

To discover which species of saprophytic mycelium is the best for our purposes we would perform a research project. We would take a variety of non-toxic saprophytic mycelium and test for all the necessary characteristics: effectiveness at carbon capture, growth rates (higher growth means we can produce more diapers in a fixed time period) and absorbency. The project would entail having each species grow in a sealed environment for a fixed duration such as 10 days with the same amount of carbon inputted into each growing container. The carbon level would be measured using a carbon meter at the beginning of the 10 days, as well as at the end. The mycelium with the biggest difference is the best at carbon capture. During these 10 days, the growth rate of each mycelium would be monitored (perhaps by weighing) and by the end we will also know which type of mycelium grows the quickest. To measure the absorbance of each species, we would need to dry out the mycelium and then add a known quantity of

water. The species that can hold the most water without leaking is the most absorbent. After all these tests, we will have the best mycelium for the job.

Product Design

For our diapers to be effective at reducing negative substances in the atmosphere, all parts of our diapers have to be eco friendly. One component that doesn't have an eco friendly substitute is the elastic band to make sure the diaper is not too big or too small for the baby. Obviously it's very important for our diapers to fit babies, so making an elastic that is biodegradable would be an important breakthrough to make our technology come to life.

Design Process

The ideas that our team rejected for our mycelium carbon capture factory are as follows; a plastic used in the applications of our technology (e.g. diapers), the placement of our factory and growing all parts of the fungi. We moved on from these ideas through research and lots of group discussions.

Originally, we were just thinking about substituting the absorbent material used in baby diapers with our carbon capturing mycelium, thinking this would help solve the issue of all these diapers ending up in landfills. Just switching out the absorbent material meant that the plastic shell that gives a diaper its structure is still present. This plastic shell isn't decomposable and counteracts the environmentally responsible product we're trying to develop. Instead, we found that we could substitute the plastic for biodegradable plastic. Biodegradable plastics don't use fossil fuels to be produced, decompose much faster and don't release harmful substances into the atmosphere, like methane, when they do. Using biodegradable plastics allow our product to reduce carbon and greenhouse gas emissions by a substantial amount, compared to regular diapers.

Where our factory would be situated was another design issue that the group needed to work through. Originally, we thought that we should place our factory close to a city because there would be a lot of economic activity going on and therefore lots of carbon emissions. While this was an okay idea, we realized that carbon production in cities is widely distributed (in homes, businesses, cars on the road and public transportation) making carbon capture difficult. Without lots of carbon capture our factory design would not work. We then thought of the industries that produce the most carbon and arrived at energy production by burning fossil fuels, for example natural gas or coal fired electricity generation plants (we note that there are no longer any coal fired plants in Ontario but there are in lots of other places). Situating our factory close to an energy generation plant would put us close to a large source of carbon , but we still need to ensure our mycelia would have access to it. This led to our final idea, to transport the electricity generation plant's carbon to our factory through pipes, instead of having the generation plant use a smokestack to release carbon dioxide into the atmosphere. By doing this, we are making sure that the mycelium have access to lots of carbon, and we are helping reduce the carbon footprint of the factory we are working alongside.

Our final design that we rejected was the process for growing our carbon capturing material. Originally, we thought that we should grow the whole fungi (spores, mycelia, hyphae, mushroom…), but this would lead to us having to have a large growing space that included soil. This didn't seem very efficient to us, so we researched the other options we have. We arrived at just growing the mycelia. The mycelium is the equivalent of the root systems for a fungus; they obtain nutrients and capture carbon dioxide. The mycelium is very adaptive in terms of where it can grow and it grows very quickly. Growing just the mycelia would take up less space because we could grow them on big sheets that are stacked on top of eachother; kind of like baking trays.

Consequences

Every technology has its pros and cons, the goal is to find a technology where the pros outweigh the cons, and we believe that our diapers made with carbon capturing mycelium meets this goal. Of course, it still has its own cons.

Our technology is still in the early stages of development and we're not sure if it's the most effective up and coming technology for carbon capture/sequestration. Our research project (see Breakthroughs), would take a significant amount of money, money that may be better used on other developing carbon sequestration technologies more effective than ours.

On the other hand, the positive consequences for our technology could help with the fight against climate change. Growing the mycelium using emissions from a nearby factory will greatly reduce the carbon footprint of that factory and will reduce the amount of carbon dioxide going into the atmosphere.

Our diapers will also help replace waste made by disposable diapers. Lots of trees and fuel oil goes into the production of diapers, and on top of that they can take over 500 years to decompose. The Environmental Protection Agency reported around 20 billion diapers are thrown out each year in the U.S and other sources say that around 1.5 billion diapers are thrown away each year in Canada. If we can obtain just 0.5% of that market for Canada, we'll be able to replace 7.5 million disposable diapers with our own more environmentally friendly diapers each year.

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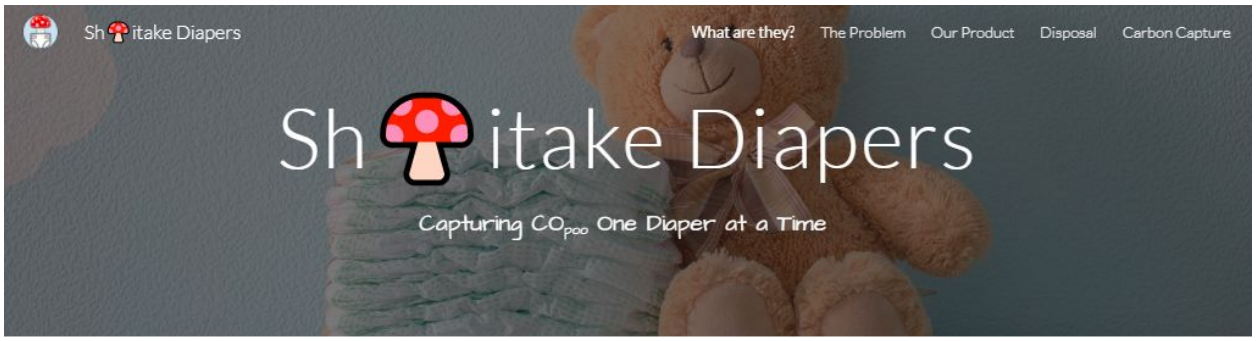


What they do?

Not only are Shiitake Diapers amazing diapers for your young ones, but they are even more amazing for the environment. We use completely compostable materials to eliminate diaper waste from landfills. The main ingredient is mycelium which is the absorbent part of the fungus that is usually underground. Mycelium is composed of hyphae and it is a safe material.

Environmental Benefits

- Shiitake Diapers reduce the burden of landfills.
- They reduce carbon emissions.
- Their production is less harmful to the environment.
- Our mycelium is organically grown with no use of pesticides or other toxins.

Product Benefits

- Our diapers are comfortable and healthy for babies of all shapes and sizes.
- We have a thin aloe layer on the top that keeps the skin rash-free and soft.
- Our natural waterproof bottom layer is completely leak-proof and ensures that there are no blow-outs.

Why choose us over other brands?

- Not only is our diaper eco-friendly but it is also an amazing diaper for your child.

The evolution from cloth diapers to disposable diapers benefit humans in the short term, allowing babies to stay cleaner and healthier, while also loosening the workload on the mother. However, this "improvement" does not help the environment, in fact it harms it. We have been benefitting from many products that harms the environment for too long, and are on a path that is leading to extinction, unless we change.

The life of a disposable diaper, and its effects

Production

Factories that make disposable diapers emit a lot of carbon, a greenhouse gas, into the air. These factories contribute to climate change.

Use

Bought from the store, disposable diapers are ready to be worn by a cute little baby! This portion of a diapers life is why we produce them in the first place. However, a lot of diapers have to be used per day to keep the baby clean and tidy.

Disposal

After being used and thrown out, the diaper ends up in a landfill. Living the rest of its 500 year life to secrete methane gas, yet another greenhouse gas. This contributes to climate change as well.

The amount of air pollution that disposable diapers cause outweighs the actual period of time where the diaper is in use. The average baby goes through 8-12 disposable diapers a day, 1,800 diapers a year. Now imagine that number, multiplied by all babies on Earth. In 2016, in the United States, it was estimated that 20 billion diapers were ending up in landfills annually, accounting for almost 3.5 million tons of waste. Waste which will decompose over the course of 500 years.

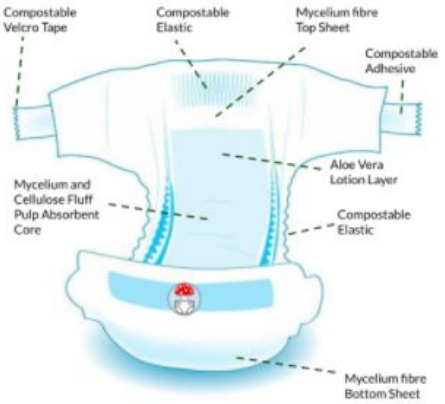
Climate Change

Climate change is caused by many factors, pollution being a main factor. Certain man-made chemicals eat away at the ozone layer, a protective layer surrounding our atmosphere which prevents too many of the Sun's harmful rays from reaching us on Earth. The abundance of greenhouse gases being produced by burning fossil fuels also contributes to climate change. These gases trap the Sun's heat, and since there are too many being produced, they are trapping too much heat.

What is it made of?

- **Top layer:** The top layer of our diaper is made of non-woven mycelium fibres. The liquid will be quickly transferred to the absorbent core, keeping your baby dry and happy.
- **Absorbent Core:** The absorbent core will be made of mycelium and a small amount of cellulose fluff pulp. The mycelium is grown 100% pesticide and chemically free.
- **Bottom Layer:** The bottom layer will be made with a base of mycelium fibres and fully compostable bioplastic. It is fully waterproof keeping your baby's clothes clean.
- **Elastic:** For the elastics that go around the waist and legs, we will be using chemical-free compostable plastic.
- **Adhesive and Velcro Tape:** The adhesive and velcro tape will be used to keep the diaper fitting comfortable and snug around the waist. We will be using compostable plastic that is completely petroleum free.

Our Prototype



Note: a landfill is not the same as a composting facility. A landfill does not allow for the diapers to break down properly.

Through a Service: you can also subscribe to a compostable diaper service. The service picks up your dirty diapers and brings them to a industrial composting facility for you.

Through the City: make sure to check that your city allows biodegradable diapers in the city's compost system, because not all do.

At Home: make sure only to compost pee-filled diapers, because home composters can't kill pathogens (microorganisms that can cause disease). To break down pee-filled diapers, add browns (e.g. dried leaves) and greens (e.g. fresh cut grass).

Smokestacks

What is carbon capture?

Carbon capture is the process of taking carbon out of the atmosphere, and storing it in a place where it cannot return. Carbon capture is a method used to reduce climate change since carbon dioxide is the most potent and abundant greenhouse gas. Carbon capture occurs naturally but there are also man-made machines/devices that can carbon capture as well.

Our use of carbon capture

To make our diapers while help the environment, we use carbon capture technology. We connect a smokestack which emits CO_2 to our factory which grows mycelium. The mycelium traps the CO_2 in order to grow. Once the mycelium is grown, we use it as an absorbent material in our diapers. This way, we reduce carbon dioxide emissions. Since it is biodegradable, it also reduces methane emissions which would usually happen in the landfill.

Mycelium