Abstract

The Global Filters Market Size accounted for USD 33.5 Billion in 2021 and is estimated to achieve a market size of USD 45.2 Billion by 2027 growing at a CAGR of 6.2% from 2022 to 2027 (https://www.marketsandmarkets.com/Market-Reports/industrial-filtration-market-81304454.html). Of these filters, the market only prominently carries one capsule-like filter that allows complete portability of filtration. The fault of this filter is that it fails to capture microplastics (https://twistoflemons.com/wp-content/uploads/2017/03/Go-Pure-Pod-Research.pdf). As microplastics are projected to be apparent in all forms of consumption today, and more than 10 billion tons of plastic waste is assumed to be dispersed in the environment by 2025 (https://orbmedia.org/the-invisibles). Due to their high surface area, microplastics carry harsh chemicals, heavy metals, and cancer inducing molecules.

The goal of this business is to provide its customers with a secure and effective way to remove these microplastics, heavy metals, and cancer inducing chemicals that are now becoming a serious concern to the health of many.

Notes: https://www.sciencedirect.com/science/article/pii/S1385894716311287

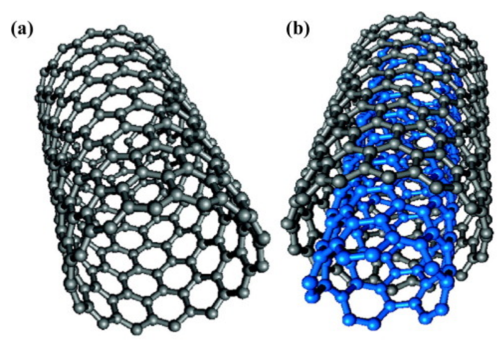
- Heavy metal removal
  - Metals
    - Arsenic
    - Mercury
    - Cadmium
    - Lead

        - Chromium
        - Zinc
        - Copper
        - Antimony
        - Manganese
        - Nickel
        - Cobalt
    - Removal
        - Nanomaterials

          https://www.sciencedirect.com/science/article/pii/S1385894716311287#b0825
            - Adsorption
                - High porosity, small size, and active surface
                - Don’t release its toxic payload in manufacturing
                - Rapid
                - High surface area to volume ratio
                - catalytic potential and high reactivity boosts adsorptivity
            - photocatalytic
            - antibacterial
        - Advanced oxidation
        - Carbon based materials
            - activated carbon
                - Cheaper than carbon nanotubes (CNT)

- Multiwalled carbon nanotubes

  https://pubs.acs.org/doi/full/10.1021/es052208w

- There is no doubt that CNTs possess great potential as **superior adsorbents for removing divalent metal ions, dyes, NOMs and THMs from aqueous solution**, but their relatively **high unit cost** restricts their practical use. In addition to it, **raw CNTs may possess some degree of toxicity** due to the presence of metal catalysts while **chemically functionalized CNTs have not demonstrated any toxicity** so far [72]. As a result, the practical use of CNTs as sorbents in water and wastewater treatment depends on the continuation of research into the development of a cost effective way of CNTs production and the no or low toxicity of CNTs and CNT related materials such as carbon nanocrystals (CNCs).
  - 

  - adsorption **capacity** (maybe later product for higher water effectiveness) depends on nature of the **sorbate** and **surface functional groups**

        https://www.sciencedirect.com/science/article/pii/S1385894710007667

        - **carboxylic, lactonic and phenolic groups** favor adsorption of polar compounds
        - **unfunctionalized CNT surface** favor capacity towards non-polar compounds
    - Both SWCNTs and MWCNTs were examined for their removal efficiencies for NOM parallel to coagulation process in the presence of alum and ferric chloride metal coagulants. **SWCNT's** are better at removing natural organic molecules from synthetic seawater and brackish water and natural river water
- fullerene
- graphene
    - There is a choice of whether to use graphene as a carbon-based nanocomposite will be determined by the cost, process ability, and environmental implications of each material
    - Graphene oxide is favorable due to the higher interactions between metal ions and oxygen groups
    - reduction of GO for the production of graphene is a promising approach to produce low cost graphene on a large scale

- nano metal oxides
    - nanosized ferric, manganese, aluminum, titanium, magnesium, and cerium oxides
    - **Large surface** area and high activities caused by **size quantization effect**
    - **high capacity and selectivity results in a high removal of toxic metals** to **meet increasingly strict regulations**
    - As they go from microsized to nanosized the increased surface energy leads to poor stability
    - Unusable in fixed beds or flow through systems because of pressure drops and poor mechanical strength
        - **To improve the applicability, these metal oxides were impregnated into porous supports of large size to obtain composite adsorbents (Seems to be only practical way to use) 2.2.2**
            - 2.2.2) supports include activated carbon, natural materials, synthetic polymeric hosts, etc.
            - Also bentonite (https://www.sciencedirect.com/science/article/pii/S0304389408014210), sand 9https://www.sciencedirect.com/science/article/pii/S0021979704000451) , and metallic

oxide materials such as Al2O3 membrane (https://www.sciencedirect.com/science/article/pii/S0925838806001800), porous manganese oxide complex 9https://www.sciencedirect.com/science/article/pii/S0896844604000981) , and synthetic polymer hosts such as cross linked ion-exchange resins (https://www.sciencedirect.com/science/article/pii/S004313540900699X)

        - Magnetite nanoparticles
            - . At the same time, loading of the magnetite nanoparticles can avoid or decrease the possibility of serious agglomeration and restacking of the graphene sheets https://pubs.acs.org/doi/full/10.1021/jp208575m
    - Magnetic metal oxides are attractive because they can easily be separated from water under a magnetic field
- pillared clays
- zeolites

            - mesoporous oxides
            - polymers
            - metal organic frameworks
        - Effluents with refractory organic pollutants (semiconductor photocatalysts)
- Plastic
    - Types
        - Microplastics
- Binding Agent
    - Polymer Binders: Various polymer binders, such as polyvinyl alcohol (PVA), polyacrylic acid (PAA), polyethylene glycol (PEG), or polyurethane (PU), can be used to coat and adhere materials together. These polymers can form a stable matrix when applied to both the activated carbon and the bioCap material, effectively binding them together.

    - Crosslinking Agents: Crosslinking agents, such as glutaraldehyde or formaldehyde, can be used to create chemical bonds between the bioCap material and the activated carbon. These agents facilitate the formation of crosslinked networks, enhancing the mechanical strength and stability of the binding interface.
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    - Biopolymer Adhesives: Biopolymer-based adhesives, such as gelatin, chitosan, or starch, offer eco-friendly options for binding materials together. These adhesives

can provide good adhesion and compatibility with both the activated carbon and the bioCap material, promoting strong integration.

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    - Silane Coupling Agents: Silane coupling agents, such as (3-aminopropyl)triethoxysilane (APTES) or (3-glycidyloxypropyl)trimethoxysilane (GPTMS), can be used to functionalize the surfaces of both the activated carbon and the bioCap material, allowing for chemical bonding between them.
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    - Solvent-Based Binders: Solvent-based binders, such as epoxy resins or acrylic adhesives, can be applied as liquid formulations and then cured to form strong bonds between the materials. These binders offer versatility and can be tailored to specific application requirements.
    - Used $FeCl_3$ with tannic acid to promote the binding of tannic acid to earthly building materials? i.e. sawdust
        - Wood is used as a structure that is (hierarchically substrate = multilayered substance) and can use capillary action to attract water. So look if there is another material we can use or combine with the wood to filter heavy metals and maybe carcinogens as well. For the future - maybe bacteria too.
- Analysis
    - Scanning Electron Microscopy (SEM):
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- SEM allows for high-resolution imaging of the composite material's surface morphology.
- By examining the surface, you can visualize the distribution of binding agents and their interaction with the activated carbon and bioCap material.
- SEM can also provide insights into the integrity of the binding interface and the presence of any defects or discontinuities.
- Transmission Electron Microscopy (TEM):
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- TEM offers even higher resolution than SEM and can provide detailed information on the nanoscale structure of the composite material.
- TEM can be used to visualize the distribution of nanoparticles or molecular structures within the composite and assess their dispersion and alignment.
- Atomic Force Microscopy (AFM):
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- AFM allows for imaging and characterization of surfaces with atomic-scale resolution.
- AFM can be used to study the topography, roughness, and mechanical properties of the binding interface between the activated carbon and the bioCap material.
- Additionally, AFM-based techniques such as force spectroscopy can measure the adhesion forces between the materials, providing quantitative data on binding strength.
- X-ray Photoelectron Spectroscopy (XPS):
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    - XPS provides chemical composition information by analyzing the elemental composition and chemical bonding states of the materials' surfaces.
    - XPS can be used to study the chemical interactions between the binding agents and the activated carbon/bioCap material, as well as the presence of any functional groups or contaminants.
    - Fourier Transform Infrared Spectroscopy (FTIR):
    -
    - FTIR spectroscopy can be used to identify chemical bonds and functional groups present in the composite material.
    - FTIR analysis can reveal the presence of specific chemical interactions between the binding agents and the activated carbon/bioCap material, providing insights into the bonding mechanism.
    - Thermogravimetric Analysis (TGA):
    -
    - TGA measures the change in weight of a material as a function of temperature.
    - TGA can be used to study the thermal stability and decomposition behavior of the composite material, providing information on the effectiveness of the binding agents in maintaining structural integrity at elevated temperatures.
- Top two
    - Atomic Force Microscopy (AFM):
    -
    - AFM can provide quantitative data on binding strength by performing force spectroscopy measurements.

    - Force spectroscopy measures the adhesion forces between the binding interface and can quantify the strength of the interaction.
    - Additionally, AFM can assess the topography and roughness of the binding interface, providing insights into the structural characteristics that influence binding ability.
    - AFM can also be used to visualize and quantify the adsorption of microplastics and heavy metals on the surface of the composite material, providing information on adsorption capacity and kinetics.
    - Thermogravimetric Analysis (TGA):
    -
    - TGA can quantify the amount of material adsorbed by measuring the change in weight as a function of temperature.
    - By comparing the weight loss of the composite material before and after adsorption of microplastics or heavy metals, TGA can provide quantitative data on the adsorption capacity.
    - TGA can also assess the thermal stability of the composite material and the desorption behavior of adsorbed species, providing insights into the reversibility of the adsorption process.
    - Additionally, TGA can be used to study the decomposition behavior of the composite material, which can influence its long-term stability and performance.
- Encasing
    - Mesh Screens: Install mesh screens or sieves within the activated carbon encasing to physically trap the bioCap material. These screens can be made of materials

such as stainless steel, nylon, or polyethylene, with pore sizes tailored to prevent the escape of bioCap particles while allowing water to pass through.

- Porous Membranes: Incorporate porous membranes or filters into the design of the activated carbon encasing. These membranes can be made of materials such as polypropylene, cellulose acetate, or polytetrafluoroethylene (PTFE), with pore sizes selected to retain the bioCap material while permitting fluid permeation.

- Microcapsules: Encapsulate the bioCap material within microcapsules or microbeads dispersed throughout the activated carbon matrix. These microcapsules can be made from biocompatible polymers, such as alginate, chitosan, or poly(vinyl alcohol), and designed to release the bioCap material upon contact with fluids while preventing its diffusion out of the encasing.

- Sponges or Foams: Integrate sponge-like or foam-like structures into the activated carbon encasing to absorb and immobilize the bioCap material. These structures can be made from hydrophilic materials, such as cellulose, polyurethane, or silicone, and designed to swell upon exposure to fluids, effectively trapping the bioCap particles.

- Fiber Mats or Felts: Embed fiber mats or felts within the activated carbon matrix to entangle and retain the bioCap material. These mats can be composed of natural or synthetic fibers, such as cotton, polyester, or polypropylene, and engineered to provide a porous yet mechanically stable scaffold for the bioCap material.

    ○

    ○ Nanostructured Templates: Utilize nanostructured templates or scaffolds to confine the bioCap material within the activated carbon encasing at the nanoscale level. These templates can be fabricated using techniques such as electrospinning, nanoparticle templating, or nanofiber weaving, allowing precise control over the distribution and retention of the bioCap particles.

Plan

<u>Problem/Solution</u>

- Our problem is the contamination of microplastics in our commercially available drinks and water supplies. There are numerous studies explaining the dangers of micro and nanoplastics including entry into our vital organs and brains, causing problems on a world wide scale. Adjacent to the uncontrollable presence of plastic, heavy metals are also commonly present on a similarly massive scale that cause many forms of cancers and are linked to degenerative diseases. In order to combat this, our company proposes a simple and versatile filtration device that can be added to any commercially purchased bottle or water source.

<u>Business model</u>

- What’s the idea? Problem/Solution?
    - The idea is a small device that can be put into plastic bottles or other drinking containers and will adsorb any micro, nano, or larger plastics and heavy metals that are present in the liquid. This device will be made out of all natural materials and will take no energy supply to run. It is pure, natural, chemistry that provides

no harmful effects to the user and can be easily recycled alongside the container it is in.

- Who is your customer?
  - Our customer is people in their 20's / teens who are young enough to understand the impact microplastics can have on their life. Mostly focused on the east and west coast specifically. Also, parents with young children.
- Which Category does your idea/customer belong to?
  - Health / Fitness community
  - Consistently on the go workers
  - Maybe restaurants
- What are the typical revenue streams?
  - Subscription packages
  - Ad space on container?
- How much do you expect your customer to pay for your solution?
  - No more than 30 cents per tab
- Do you spot a new or a shift in business model?
  - There could be a shift as a new type of wood can be used or a new crutch/base like clay that might incorporate a more effective treatment solution. Being first to market is very important

<u>Costs</u>

- Enumerate all costs and make estimates for each – Prototype Cost, Overall Product Cost, Sales, Marketing Cost, Engineering Costs, Administration Costs, etc.:
  - Prototype cost

Preparation of bioCap

Wood sawdust (5 g) was rinsed three times with Milli-Q water and suspended in 20 mL of water. Tannic acid (3.5 mL, 24 mmol L^{-1}) and $FeCl_3 \cdot 6H_2O$ solution (3.5 mL, 37 mmol L^{-1}) were added and the dispersion was completely mixed, followed by the adjustment of pH value to 7.4 with buffer (containing 200 mmol L^{-1} of $Na_2HPO_4 \cdot 12H_2O$, 100 mmol L^{-1} of citric acid monohydrate). The as-synthesized bioCap was rinsed with Milli-Q water three times, and polyphenol-mediated nanocoatings were deposited on the surface, in which the TA molecules were first attached and bridged by coordination with Fe^{3+} ions.

        - Bulk
            - Tannic Acid $27.60 (50g)
            - Ferric Cl $44.81 (4L)
            - Wood biochar $0.35
            - buffer $59
                - Disodium Phosphate
                - Citric Acid Monohydrate
        - Per unit (~22) = $21.85
            - Crutch / micron mesh (component supply co) $20??
                - https://componentsupplycompany.com/product-pages/nylon-screening-mesh.php?gad_source=1&gclid=CjwKCAjwp4m0BhBAEiwAsdc4aFdgOBWAgc8OEaQp7-94ME1AcIiYi68Zu8R_swtMaza-iqEVIK7ZpRoCKZEQAvD_BwE
            - Ferric Cl $0.63
            - Tannic Acid $0.41
            - Wood <$0.01
            - Buffer $0.80

- Are there any large capital costs required (e.g. factory/manufacturing, …)
    - Ideation 0-$1000
    - Manufacturing
        - Wood:
- What are typical costs in your industry/category?
- What is typical profitability in your industry/category?
- Can you identify top cost drivers?
- Do you spot a shift in any of these components of the business model?

Market Ecosystem

- What kind of ecosystem is it
- Consider ecosystem forces and analyze how attractive the ecosystem is for your idea
- What is the typical profitability in your industry and how does it affect your profitability
- Who are the main competitors

- Identify top threats and opportunities
- Do you spot any shifts

Market adoption

- What market adoption rate do you expect
- What can you do to change it
- What issues do you see in customer adoption? What can you do to change that

Market research

- Who did you talk to and what was there feedback
- List the key points of information gathered that you are using in your decision making
- What fallshorts can you observe in you data collection

Customer Value Proposition & Critical Success Factors

- Our solution is a durable and easily installed piezoelectric floor mat that generates energy by ‘crowd farming’ the energy exerted by pedestrians along a busy walkway, eliminating a fraction of electricity costs for the consumer. Unlike the limited number of other piezoelectric flooring that has entered the market in the past, this mat allows the client to:
    - (i) install the moveable mat in various locations to identify the optimum location.
    - (ii) allows the client to renovate their flooring without having to reinvest in piezoelectric flooring.
- This latter fact is largely where we derive our value proposition: piezoelectrics themselves are very durable and do not have to be replaced for decades, however the sidewalks or roads that they have been directly installed into in the past may need to be replaced every decade. Our product is the only piezoelectric solution on the market that accounts for this and provides customers with this flexibility that is necessary to make piezoelectrics a viable solution. Since piezoelectrics are an expensive investment, our model utilizes a 4 payment installment plan allowing customers to better experience the money saving benefit of switching from electricity to piezoelectric power. This is another critical success factor since one of the main deterrents to investing in piezoelectrics in the past has been expensive single payment renovations to piezoelectric flooring, where the money spent on the solution cannot be recuperated by the savings on electricity until many decades before which the infrastructure it is built in must be replaced. By making our solution ‘bite size’ for this energy source that is still gaining traction, we significantly reduce these barriers for consumers. This also makes sense given the recent skepticism on

piezoelectric following the Innowattech's controversy. Milgrom and his company, Innowattech, invested in piezoelectric energy technology based on misleading claims presented by Technion scientists. Allegedly, the results were fabricated, with batteries substituted for piezoelectric generators to deceive investors. Despite evidence of fraud, Technion denied responsibility, leading to an ongoing legal battle. The situation resulted in financial losses for Innowattech and a tarnished reputation for piezoelectrics as a viable solution for renewable energy. This makes our piezoelectric floor mat the first piezoelectric solution to address prior issues and provide a format that works both technologically and from a business perspective.

<u>Investors in our Industry: Clean energy, specifically Piezoelectric based</u>

- **Amazon** is currently the world's largest corporate purchaser of renewable energy for the fourth year in a row and has invested in more than 100 new solar and wind energy projects in 2023.
- The **California Energy Commission** has invested $2 million to study the efficiency of piezoelectric crystals to harness energy from vehicles driving on roads.
- **Sunwealth** is a clean energy investment firm that has provided $155M in revenue for local solar developers and installers, and made $0.53 for every dollar invested.

<u>Potential investor for our company</u>

- CalSEED is a potential investor in our company. They focus on funding entrepreneurs to further California's clean energy goal and to bring said entrepreneurs ideas to commercial readiness. In the past they have invested and awarded 116 grants to start ups, but recently they have invested in EarthEn, which is a company that we share many similarities with and are in the same industry as us. The total investment was $4 million and was made in 2023. During this round of fundraising, EarthEn raised a total of two years worth of funding. Their primary product is an alternate way of energy creation/storage. With the money they raised this round of funding they plan on accelerating the commercialization of the product.
    - In the past (CalSEED), has had both successful cases and some companies that seemed to not venture out
        - **Hago Energetics, Inc**. succeeds in aiding farm profitability by transforming agricultural waste into hydrogen and carbons, utilizing anaerobic processes. Their innovative approach promises cost-effective

hydrogen production with a reduced carbon footprint compared to traditional methods.

- Hago energetics was able to expand due to their innovative technology and even receive funding from NASA

- **Biozen Batteries**
    - Biozen is developing a low-cost, carbon-based redox-active electrolyte fluid named "redoxloyte" for redox flow batteries (RFBs), inspired by green plant organic chemistry, aiming to optimize solubility, redox potential, and manufacturing efficiency.
    - Since receiving funding from Calseed, they haven't expanded to working with any notable organizations, nor many organizations at all.