

# Fiber- Based Bioreactor Media for Air Pollution Control

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## ABSTRACT

Polluted air and water treatment by bioconversion/biofiltration is a large, rapidly growing industry that presently does not involve many textile products. Unlike pollution control methods based on regular filter media, bioconversion does not require disposal of contaminated used-up filter media. Moreover, higher environmental costs of current practices drive the pollution control equipment/media suppliers to shift their focus toward the more compact, high surface area fiber-based bioconversion media. Our research on textiles and fiber coated biofiltration surfaces will lead to opening a new applications area for fiber/textile products. The U. S. fiber and electro-fiber coating (flocking) industry will greatly benefit from this basic research of the proposed fiber based bioconversion surfaces by supplying more fiber and flock products to the potential market. Our research will provide opportunities for developing a new generation of water and air biofiltration media with high specific surface area. Our findings shall provide the US fiber, fiber finishes and fabric producers with basic knowledge on how to form textile based biofiltration surfaces using electrostatic principles. This work will also provide direction on how to engineer the fabric with predetermined geometry and hence predetermined bioconversion properties.

## GOAL STATEMENT

A previous NTC sponsored project (F04-MD11) has shown that flocked surfaces have been found to be very effective in water based biofiltration applications. This work involved the bioconversion of ammonia to nitrite and nitrate in trickling water biofiltration systems. Biofiltration of ammonia in water is widely used in aquaculture and municipal water treatment. Our present project aims to extend this work by determining the efficacy of using flocked surfaces as filtration media in air-biofilter applications. Air-biofiltration is widely used in industry as a means of (1) curbing air pollution ( $H_2S$ , Ammonia, CO removal for example) and (2) functioning as an industrial biochemical process such as bioconverting Syn Gas to ethanol.

## OBJECTIVE

Presently, the detoxification of polluted air by biological processes is done primarily on media such as peat moss, wood chips or particles (sand filter), plastic beads or shell-like surfaces (trickle filters). All of these existing systems are bulky, cumbersome, easily contaminated and highly inefficient. Recent studies in the UMD Textile Sciences laboratory have shown that nylon flocked polymer surfaces are at least 10 times more efficient in the bioconversion of ammonia ions in water to nitrite and finally to nitrate than other water based bioconversion (biofiltration) media [Kim and Lewis 2001]. The main objective of this proposed work is to determine if textile flocked surfaces are also effective as biofilter media materials for air biofilter applications.

Based on this background, the specific objectives of this proposal are to:

- (1) Determine the fundamental materials and geometric parameters that will enable the optimization of flock fiber-coated polymeric film and textile fabric surfaces for air bioconversion activity.

- (2) Model and establish the aerodynamic/hydrodynamic flow characteristics of air/water across fiber coated (e.g. flocked) surfaces and bioconversion efficiency of the fiber surface to design compact, efficient bioconversion /biofiltration polluted air remediation devices.
- (3) Establish the chemical and mechano-physical conditions that will enable the fiber coated bioconversion surfaces to be easily regenerated, should they become contaminated or coated with excessive biomass.

## APPROACH

UMD's experience with trickling biofilter operations in biochemically removing ammonia from water has led us to propose the use of flocked surfaces as the bio-removal substrate for odor causing air pollutants such as H<sub>2</sub>S. Here, a challenge lies in selecting the flock fiber material and the flock adhesive. These bioreactor media materials must function durably under strongly acidic conditions. This means that to prepare the media materials we must choose fibers, fabrics and flock adhesives that can withstand low pH and are inert to the chemicals produced. Here it is expected that the choice of flock fiber material and its surface chemistry is very important. It is believed that chemical surface treatments of the flock fibers can provide a key role in the overall project's success. Surface chemical studies will enable one to project the use of flocked fabrics as media for the bio-conversion of other air pollutants, VOCs etc. Compaction of media during the continuous flow of air through the media is very critical to the overall reliability, durability and steady state continued operation of a bioreactor. Therefore airflow through the media studies must be carried out. To this end, the design of an Air Bio-Filter Media Testing (ABMT) apparatus has begun. This designed apparatus will have three functional sections: (1) Air Mixing – where the inlet air is moistened, thermally controlled and injected with the pollutant (H<sub>2</sub>S for example), (2) Bioreactor Media Test Chambers (two stations)- where the media material will be inoculated with bacteria and tested for its ability to biochemically remove the air pollutant, and (3) Scrubber – serves to prevent any stray or excess polluted air from being inadvertently expelled into the laboratory atmosphere. The design calls for two identical media test chambers so that one can evaluate experimental media material and a "control" media material on a side-by-side comparison basis. Our approach is summarized below:

1. Construct the ABMT apparatus for studying the use of flocked media in air-biofiltration/bioconversion (H<sub>2</sub>S remediation for example) applications. Set up the gas-analysis instrumentation.
2. Select some flock adhesives and flock fibers. Determine the pressure drop characteristics through selected experimental flock fabric and "standard" media materials.
3. Using the ABMT, determine the biofiltration/bioconversion effectiveness of a "standard" air biofilter media materials, e.g. Bio-Fill®-PVC straw-like ribbon mesh.
4. Evaluate the bioconversion effectiveness of several prepared flocked fabric, air-biofilter media configurations.
5. Determine and study the nature of the biomass ("slime layer") build-up on the "standard" and flocked air bioreactor media surfaces. Periodically assess as to whether these flocked bio-media systems are in need of regeneration.
6. Use the above results to carry out modeling studies directed toward identifying the key material functional parameters that lead to optimum air biofilter media performance.
7. Propose some optimum air pollution bioreactor designs for VOC and other gaseous pollutants.

## 1. SUMMARY OF WATER BIOFILTRATION STUDIES

### 1.1 Review of Background Work

Bio-filtration in general is a water environmental pollutant remediation technique that utilizes living organisms (i.e. biological microorganisms) to remove bio-degradable impurities from the water by breaking down organic or an inorganic pollutant compounds [Bohn (1975)]. The bio-remediation reaction can be generalized as follows:

Organic / Inorganic Pollutant (in water) + Oxygen + Bacteria → CO<sub>2</sub> + Water+ Heat + Biomass+ Salt

Bio-filters are designed for the purpose of converting water pollutant chemicals such as ammonia, benzene, toluene, xylene, and other chemical contaminants dissolved in water into non- toxic chemical species. Major applications for

bio-filters can be found in Municipal Sewage Treatment Plants, Aquaculture Systems, Pig Farm Drainage Streams, and Water Pollutant Generating Industries such as the paper industry.

The important part of the bio-filtration system is the filter media, which acts as a support for the bacteria to grow. On this support, bacteria grow in the form of bio-film or bio-mass, which comes in contact with water. Hence, the more bacterial film in contact with polluted water the more will be the bioconversion of the pollutants to non-toxic compounds. This results in a conclusion that, to build an effective bio-filtration system, one has to provide maximum support (surface) to the bacteria for their growth. Traditionally, wooden chips, gravels, fine sand particles, fiber mesh pads, structured packing of polymers like polyethylene, polypropylene, polyvinyl chloride have been used as bio-filter media [Ottengraf et al. (1983)]. The problem with these kinds of media is that they are bulky, have a low specific surface area per unit volume, are difficult to reuse, have a low porosity, some media undergo compaction and clogging, high cost and smell badly when used over long time periods [Wu (2005)].

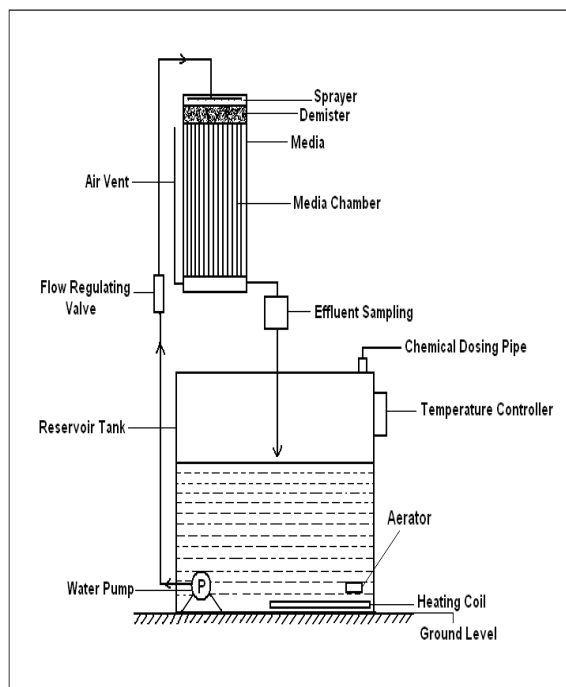
Kim and Lewis (2001) reported that textile flocked surfaces are more effective as media for the bio-conversion of ammonia to nitrate ions than un-flocked surfaces. To optimize the bioconversion efficiency and refine the design, we selected a simple inorganic compound i.e. ammonia, as a water pollutant which is easy to biodegrade. Ammonia is a toxic inorganic compound and has a strong pungent smell. The toxicity of ammonia solutions does not usually cause problems for humans and other mammals, as a specific mechanism exists to prevent its build-up in the bloodstream [Shareedeen et al (2004)]. Ammonia is converted to carbamoyl phosphate by the enzyme carbamoyl phosphate synthase, and then enters the urea cycle to be either incorporated into amino acids or excreted in the urine. However, fish and amphibians lack this mechanism, as they usually eliminate ammonia from their bodies by direct excretion. Therefore ammonia, even at dilute concentrations is highly toxic to aquatic animals.

In the bio-filtration of ammonia in water, nitrifying bacteria such as *nitrosomonas* and *nitrobacter* are used to oxidize ammonium ions to nitrite and then to nitrate. These bacteria are grown on solid support media, which is either made up of natural materials like wood chips, grains of sand etc. or synthetic material like polyethylene or polypropylene formed shapes. The polluted water from an aquaculture fish tank enters in the bio-filtration unit, where it comes in contact with the nitrifying bacterial film, which oxidizes the ammonium ion present into nitrite and further to nitrate. The nitrifying bacteria metabolize or get energy from the ammonium ions present in the polluted water. The water is then continuously re-circulated. In this fashion the aquarium or fish tank can be kept free of excess ammonium ions and thus provide a healthier environment for fish to thrive and grow [Allen (2004)]. In the UMD study, flocked bioconversion media were prepared and tested for their effectiveness by evaluating in two similar bio-filtration systems. We studied effects of various key parameters such as specific surface area, flock density (number of flock fibers /mm<sup>2</sup>), packing density and the flow rate of water trickling through the media on the rate of conversion of ammonium ion to nitrate.

## 1.2 Experimental Procedures For Water Based Bioconversion

Two Biofilter Media Test Modules (BMTM) were constructed to determine the basic materials and geometric parameters that can optimize flock fiber coated polymer and textile surfaces. The first will serve as a control where Bio-balls<sup>®</sup> and Bio-fill<sup>®</sup> (commercial bio-filter media from Aquatic Eco-Systems, Apopka, FL) was used as a “standard” bio-filter media and the second test module was used to test our experimental flocked fabric media. A schematic diagram of one of these constructed recirculating trickling bio-filter test modules is shown in Figure 1.

These BMTMs consist of a 300L reservoir tank and media chamber in which filter media is packed. The size of media chamber is bio-reactor is 11.375” x 11.375” x 14”, which corresponds to a volume of 0.0297 m<sup>3</sup>. The polluted water from the reservoir tank is sprayed on the top of the filter media in the chamber, the polluted water comes in contact with the bio-film growing on the filter media where oxidation of ammonium ion to nitrate occurs, the water then collected at the tank bottom and re-circulated again. Air diffusers are placed in the tank to maintain the required dissolved oxygen level. A temperature controller was installed to keep the water at a constant temperature (25°C). Water flow through the bio-reactor is controlled by a flow controlling valve.



**Figure 1: A Schematic of the Constructed BMTM.**

### 1.3 Water Biofiltration Results and Discussion

#### 1.3.1 Reference Biofiltration Media Efficiency

Baseline experiments were started using *nitrosomonas* and *nitrobacter* microorganisms as the ammonia-in-water biochemical remediation process. A typical “run” consists of starting the concentration of ammonia in both the biofilter tanks at approximately 11 to 12 ppm by the addition of ammonium hydroxide to a fixed volume of de-ionized water (300 liters) in the recirculating tank. The systems are then allowed to stabilize for two days by circulating the ammonia containing water through the biofilter media without inoculating the media.

Then the biomedica is inoculated with *nitrosomonas* and *nitrobacter* bacteria once the pH and ammonia concentration in the tank have stabilized. The inoculation cycle is carried out over an eight-day period. The flow rate of water in both systems is kept constant; typically chosen to be at either 0.5 or 1.5 gallons per minute. During this time, the ammonia concentration, pH, temperature are routinely recorded. The drop in ammonia concentration from its original 11 to 12 ppm value signals the successful inoculation of the media. The ammonia concentration is then continually followed until it reaches a low value of 1 to 2 ppm. This constitutes the end of a “first” cycle. For a “second” cycle, another portion of ammonia (as  $\text{NH}_4\text{OH}$ ) is added so that the reservoir tank ammonia concentration reaches again at the 11 to 12 ppm range. This experiment is continued for several ammonia cycles until several ammonia depletion rate “cycles” are obtained. A summary of results on the standard “commercial” media is presented in Table 1. From these data it is clear that the Bio-Ball<sup>®</sup> media is a better biofilter media than the Bio-Fill<sup>®</sup>. Therefore, the Bio- Ball<sup>®</sup> media was chosen as the “Standard” media material in our study.

**Table 1: Biofiltration efficiency of commercial media.**

Flow Rate (gallons/minute)	Bio-Balls <sup>®</sup> (600 <sup>2</sup> /m <sup>3</sup> )	Bio-Fill <sup>®</sup> (820 m <sup>2</sup> /m <sup>3</sup> )
1.5	1.14 ppm/day	0.98 ppm/day
0.5	1.59 ppm/day	1.24 ppm/day

### 1.3.2 Flocked Media Configuration and Surface Area Effects on Bio-conversion Rate

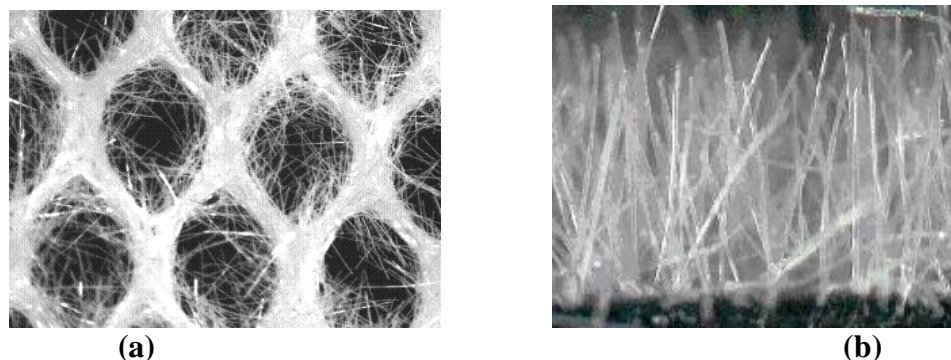
The flocked PET netting used in this study is depicted in Figure 2. The open structure nature of the flocked netting is clearly shown. A series of parametric studies for flocked biofiltration media was carried out, and the results are presented in Table 2.

**Table 2: Surface area effects on bio-conversion rate two water flow rates**

Biofiltration Media (a)	Surface(b) Area (m <sup>2</sup> ) (e)	Bioconversion Rate (ppm/day)/per surface area of media present in the 0.0297m <sup>3</sup> volume chamber	
		@ 0.5gpm	@ 1.5gpm
Bioball®	17.8	1.59//0.0893	1.14//0.0640
Biofill®	24.3	1.24//0.0510	0.98//0.0403
Polyester Netting (8holes/in <sup>2</sup> )			
AdhesiveCoated(c) (partial packed)	9.6	0.7//0.0729	0.6//0.0625
AdhesiveCoated(c) (fully packed)	21.7	1.1//0.0507	0.9//0.0415
18D NF Flocked	47.6	1.8//0.0378	1.65//0.0347
18D NF Flocked	84.2	2.5//0.0297	2.34//0.0278
3D NF Flocked	83.2	2.32//0.0279	2.2//0.0264
3D NF Flocked	126.2	2.95//0.0234	2.68//0.0212
Polyester Netting (20 holes/in <sup>2</sup> )			
18D NF Flocked	35.6	2.15//0.0604	1.92//0.0539
18D NF Flocked	47.6	2.25//0.0473	2.0//0.0420
3D NF Flocked	79.4	2.4//0.0302	2.28//0.0287
Adhesive Coated Base Fabric (f)	43.15	1.20//0.0278	1.05//0.0243
18DNF Flocked(d)	185.3	3.9//0.0211	3.8//0.0205

- (a) NF : Nylon Fiber
- (b) Surface area of media contained in bio-reactor chamber volume (0.0297 m<sup>3</sup>)
- (c) Not flocked, adhesive coated 8 holes/sq. in netting, partial pack 67 layers, and full-pack 151 layers placed in 0.0297 m<sup>3</sup> media sample chamber.
- (d) This is the nylon base fabric flocked with 18d nylon flock.
- (e) To convert to bulk surface area divide by 0.0297
- (f) 210 layers (plies) in the 0.0297 m<sup>3</sup> media chamber.

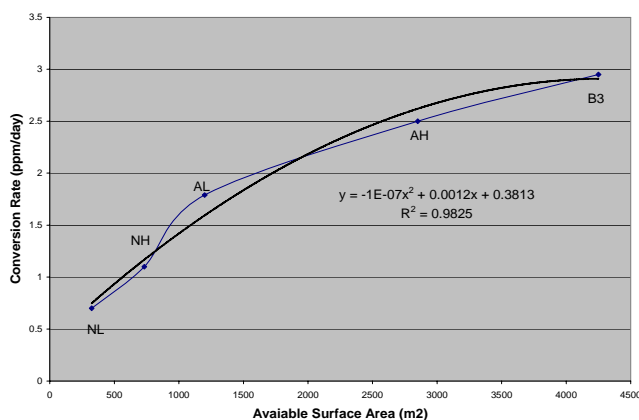
Here, it was learned that: (1) as the media “packing density” increases, the bulk surface area of the media increases and the media bioconversion rate correspondingly increases. (2) When the denier of the nylon flock changes from 18 d to 3d, the bioconversion rate data were inconclusive. What is certain however is that the 3d nylon can be flocked to a higher flock density condition (higher surface area/volume) than the 18d nylon flock, therefore the 3d flocked surfaces could potentially yield higher bioconversion rates for fully boil-covered available surface area, (3) when the hole size of the flocked netting is increased (from 20 holes/in<sup>2</sup> to 8 holes/in<sup>2</sup>) there is a slight decrease in ammonia bioconversion rate. This result led to the testing of a special flocked media configuration namely, (4) A fully flocked (both sides with 18d, 0.180” long nylon) fabric sheets or panels (not netting) was tested. This flocked fabric configuration had the highest bulk surface area of all the experimental flocked media tested. Correspondingly the bioconversion rate of this fully flocked for ammonia in water was the highest registered so far in this research work.



**Figure 2: (a) Photomicrograph of flocked netting (8 holes/in<sup>2</sup> polyester netting flocked with 18d, 4.6mm nylon fibers). (b) Side view of flocks on a fabric substrate (not a netting fabric).**

### 1.3.3 Available Surface Area, Biofilm Formation and Bioconversion Rate

The bio-functional entity characterizing this flocked media is referred to as a “Bio-reactivity Site” or “Unit Cell” based on the netting material and the number of flock fibers that exist in the repeating unit of the polyester netting. From typical flocked netting microscopic examinations, the spacing between two nylon flock fibers is about 1500 $\mu$  and the height of single nylon fiber is about 4600  $\mu$ . Thickness of the bio-film was approximately 30 $\mu$  for a typical biofiltration media installation. [Kim (2003)] With a flocked netting media configuration, the unit cell geometry is such that the bio-mass growth should not cause media “clogging”. Furthermore, a microorganism biofilm can be bioactive up to 150 -200  $\mu$ m thick. This suggests that the durability of flocked netting biofilter media will be very good. This media will be operational for long periods of time without changing or having to be rejuvenated. It is assumed that this bio-film formation on the flock fiber lateral surface will promote a higher microbiologically available surface area (ASA). Figure 3 shows the effect of Available Surface Area in terms of different packing density of media, flock density and flock fiber denier on bioconversion effectiveness. It is clearly observable that conversion rate is not linearly proportional to ASA. This is attributed to the biofilm did not fully cover ASA during the 3-month observation time period. A micrograph of the biofilm formed on the flocked media showed very thin irregular, partially covered flocked media by bacterial colonies. Once the biofilm can form in a thicker, uniform thickness (50-100  $\mu$ m) and covers the whole ASA of the media for a longer period, the conversion rate would be the expected to show a more linear trend.



**Figure 3: Ammonium conversion rate vs. available surface area. (NL= unflocked, 67ply; NH = unflocked, 151 ply, AL = 18D low flock density, 67 ply; AH = 18D high flock density, 67 ply; B3= 3D nylon flock high density, 103 ply)**

## 1.4 Conclusions of Water Biofiltration Media Experiments

1. From trickling biofilter experiments, it is demonstrated that on a volume of media basis, flocked fabric experimental media are superior to Bio-Ball® and Bio-Fill® commercially available biofilter media for the bio-

conversion of ammonia in water. An example calculations, using data existing to date, show that a volume reduction of a trickling biofilter media/chamber apparatus of almost two thirds (2/3) compared to the standard Bio-Balls®, is possible using flocked fabric as the biofilter media.

2. It appears that the overall influencing parameters that control the volume based bio-conversion of media materials are (a) the available-to-the-bacteria surface area of the particular media and (b) the flow rate of ammonia-water that is trickled through the media material.
3. The ammonia bio-remediation effectiveness of flocked fabric surfaces increases as the surface area of the flocked fabric surfaces increases. However, this effect is not exactly proportional. The bioconversion rate value falls to less than 90% of the expected doubling value of bio-reaction rate. The confocal microscopic analysis shows that the bacterial films did not completely cover the available surface area of flocked media after the end of the three-month continuous bioconversion experiment. Moreover, the average bacterial film thickness was less than 50 µm, which is one third of the effective film thickness. Therefore, once the available surface is fully covered and the bacterial film thickness reaches 100 to 150 µm, the bioconversion efficiency should be proportional to the specific surface area of the bioconversion media.

## 2. EVALUATING FLOCKED MEDIA FOR AIR BIOFILTRATION

### 2.1 Background

Air biofiltration is not a new technology. It has been in use for many years [Gostomski (2003), Lucchetti (1988), Westerman et al (1996), Deviny (1999), Kaiser (1983)]. In air bioreactors, moist (polluted) air is passed through a porous (solid) media having been previously inoculated with specific micro-bacteria that metabolizes the pollutant in the gas into useful products or less toxic substances. Just like in water biofiltration, the bio-film/biomass layer that forms on the media serves as a biochemical reaction site where a mass exchange of the gaseous pollutant (via partitioning) is converted into a non-odorous or non-toxic gaseous product. Many air biofiltration operations use media such as soil, peat moss, compost or wood chips. However, while these media are low cost, they are problematic. In the moist-air bioconversion of H<sub>2</sub>S for example, sulfuric acid is formed degrading the media causing the bioreactor media bed to deteriorate, collapse and become plugged. Once this happens, the "spent" bioconversion media must be treated as hazardous waste and be disposed of accordingly. Recently, plastic based air biofilter media has been developed for odor control applications [Deshusses, et al. (2004)]. Many of these plastic, shaped materials have low surface areas resulting in the formation of low bacterial surface populations per unit volume. They are also costly, voluminous and are inefficient in their bioconversion capacity.

Badger (2002) pointed out that cost-effective technologies for producing ethanol-from-cellulose (EFC) in the US have started to emerge: Three basic types of EFC processes—acid hydrolysis, enzymatic hydrolysis, and biochemical, together with variations for each. The most common is acid hydrolysis. However, most versatile EFC based on bioconversion technique from any feedstock from refuse to plant /wood cellulose biomass is a thermochemical and biological hybrid system. An example is a process under development by Bioengineering Resources in Fayetteville, Arkansas. The gasification process does not rely on chemical decomposition of the cellulose chain. The carbon in the raw material is thermochemically gasified and converted into synthesis gas (a mixture of hydrogen and carbon oxides referred to as Syn Gas). The carbon monoxide, carbon dioxide and hydrogen are then being fed into a special kind of fermenter. Instead of sugar fermentation with yeast, this process uses a microorganism named *Clostridium ljungdahlii* (ATCC® Number: 55380™) This microorganism ingests (eat) carbon monoxide, carbon dioxide and hydrogen and produce ethanol and water. This bioreactor needs biofilter media to support the anaerobic bacteria to convert Syn Gas to ethanol/water mixture.

It is expected that the developed flocked netting media will offer advantages like high specific surface area, high porosity, neutral pH, easy to manufacture, light weight, odorless, easy to handle and reusability. The use of flocked media in bio-filtration system should lower system size and therefore the overall operational cost.

## 2.2 Updated Experimental Plan

In this project, initial plans called for determining the efficacy of using flocced textile surfaces for the bioconversion of odor causing air pollutants such as ammonia and H<sub>2</sub>S based on pollutant converting, moist air biofilter/biochemical reactions. Here a polluted air stream would be passed through a porous and moist filter bed in which the pollutant gases are absorbed, stored and degraded by the inhabitant microorganisms. A secondary objective of this proposed research project was to develop criteria based on the use of flocced fiber as air-biofiltration media. The overall purpose was to determine the efficacy of using flocced filter media in promoting the biofiltration of polluted air. Here, we originally focused on the use of flocced media in H<sub>2</sub>S emission control. Plans were carried out to construct a lab scale air biofiltration apparatus. The structural elements of this Air Biofiltration Media Testing Module (ABMT) have now been constructed but the detailed instrumentation for this apparatus have not yet been implemented.

During the course of this work, further thoughts have developed relative to the direction of the project toward the study of H<sub>2</sub>S as the toxic gas to be remediated. After these contemplations, it has been decided that the direction of the project should turn to the need for applying our flocced biomedica technology to more contemporary needs. In view of the nation's search for renewable energy sources, we have decided that our project should be directed to investigating Syn Gas to ethanol bioconversion [Demain, et. al. 2005]. In this regard, a general work plan has been developed for directing our air biofiltration project into studying Syn Gas to ethanol conversion. The plan calls for:

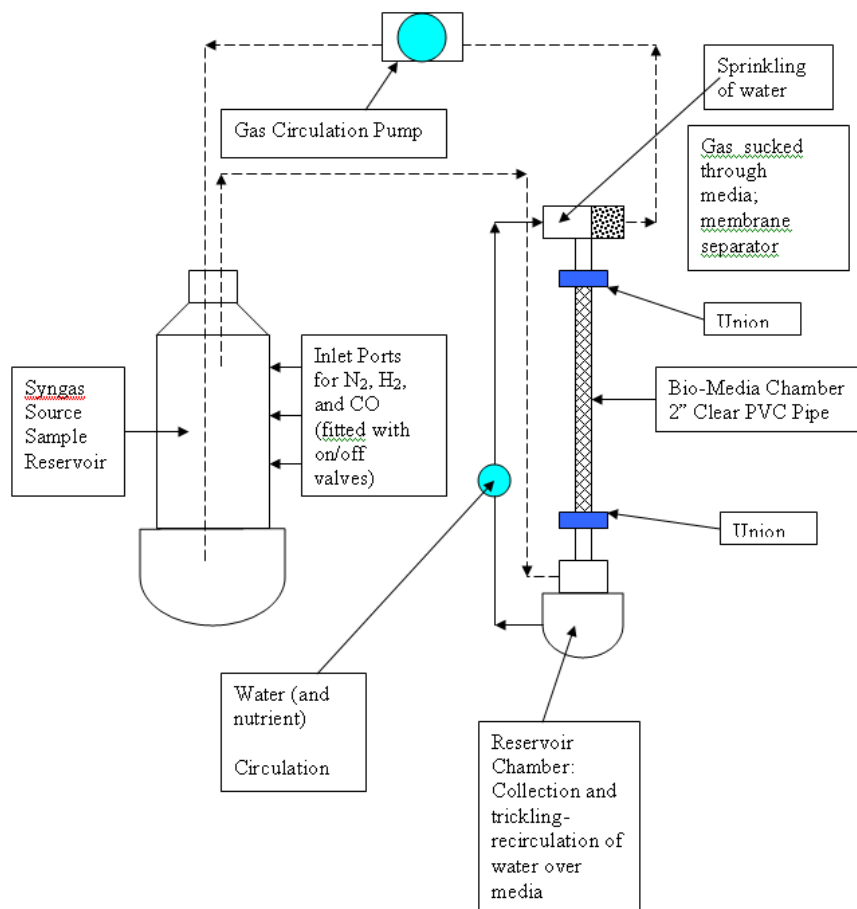
- (1) Constructing a one test cell, small enough to fit into a laboratory fume hood, biomedica test apparatus for studying the conversion of a mixture of CO, H<sub>2</sub> and N<sub>2</sub> (simulated SynGas) into ethanol.
- (2) Carry out studies on the efficiencies of standard biofilter media materials in the conversion of Syn Gas to ethanol. This work will form a base-line for our continued studies on flocced biomedica.
- (3) Determine the configuration of flocced biomedica that will optimize the Syn Gas to Ethanol to bioconversion process effectiveness.

## 2.3 Constructing a Small Size Air Biofiltration Media Testing [SABTM] Apparatus

In designing a laboratory air biofiltration media testing apparatus for studying Syn Gas bioconversion, one must be considerate of the overall flammability of and the toxic nature of the hydrogen and carbon monoxide components of the Syn Gas. Here it was concluded that if the media test apparatus could be of a size that can fit into a chemical laboratory fume hood, the inherent dangers of working with flammable and poisonous Syn Gas would be mitigated. Operating in a fume hood also eliminates the need for a "scrubber" processing feature in the overall apparatus. Therefore, a single sample module media test apparatus has been designed to fit into the 50" x 50" x 20" chemical laboratory fume hood available at our UMD facility. A diagram of this Small Air Biofilter Media Testing (SABMT) apparatus is presented in Figure 4. Construction of this testing module has begun. The plan calls for using a mixture of carbon monoxide (25%), hydrogen (15%) and an inert gas (60%) such as nitrogen (or carbon dioxide) to simulate a Syn Gas composition. These gasses will be fed into the gas reservoir chamber of the apparatus and a set volume of this gas mixture will be circulated *up* (from the bottom) through the media sample tube while a volume of recirculating water (containing nutrient and pH buffer) will be trickling (by spraying) *down* through the media sample. The media material will be inoculated with suitable Syn Gas bio-converting bacteria [e.g. *Clostridium ljungdahlii* (ATCC® Number: 55380™)]. This bioreaction must be carried out under anaerobic conditions. The general biochemical equation for converting this simulated Syn Gas to ethanol is presented:



This overall reaction takes place in the biofilm layer (containing *Clostridium ljungdahlii*) present on the flocced media surface. The optimum pH range for the production of ethanol using this strain of bacteria is 5 to 6. As shown from the above biochemical equation, the production of ethanol is accompanied by the formation of water. Therefore, after the bio-reaction, the ethanol must be separated from the water by a suitable process like distillation.



**Figure 4: Schematic Diagram of Mini-Air Biofilter Media Test Apparatus**

## 2.4 Air Biofilter Media Testing Project Conclusions

The air biofiltration project has been re-directed to a more contemporary topic, namely the study of the bioconversion of Syn Gas to ethanol. In this regard, a small air-biofiltration media testing apparatus is now under construction. It will be assembled to operate in a chemical laboratory fume hood to alleviate any safety problems that might occur while working with toxic and flammable simulated Syn Gas; composed of carbon monoxide and hydrogen gas. This apparatus will be used to determine the efficacy of using flocked netting as media for air biofiltration applications.

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