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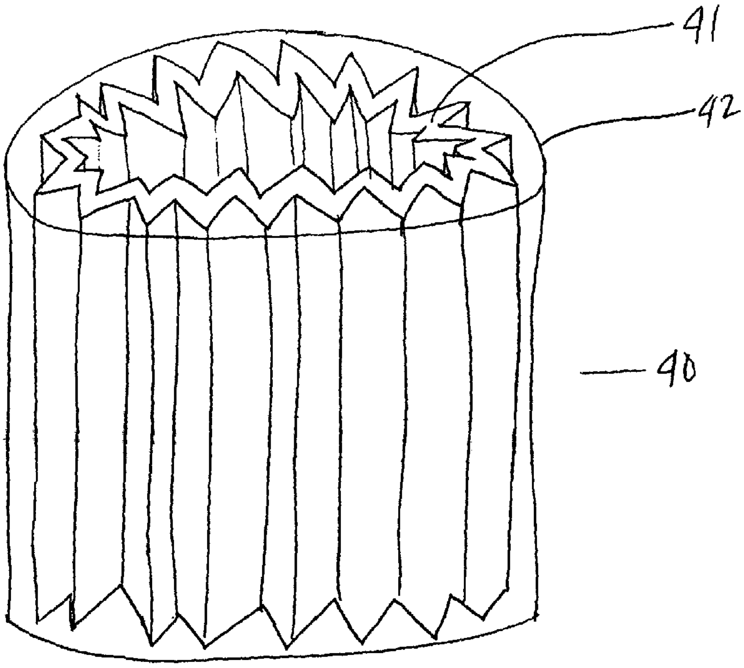
(54) Title: POLYVINYL ALCOHOL FILTER MEDIA



(57) Abstract: Filters comprising water-soluble polyvinyl alcohol material are disclosed. Methods of making and using filters formed from water-soluble polyvinyl alcohol material are also disclosed.

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POLYVINYL ALCOHOL FILTER MEDIA

This application is being filed as a PCT International Patent Application in the name of MICROTEK MEDICAL HOLDINGS, INC., a U.S. national corporation and resident, on 24 December 2003, designating all countries except US, and claiming priority to U.S. Serial No. 60/436,318 filed on 24 December 2002.

FIELD OF THE INVENTION

The present invention relates generally to filter media produced from polyvinyl alcohol material.

BACKGROUND OF THE INVENTION

Over the course of the past 60 years, international treaties, congressional acts, and executive orders have resulted in a number of regulations and standards controlling all aspects of environmental protection and health and safety practices in the workplace. In particular, the disposal of industrial waste has become heavily regulated and monitored. Landfills nationwide have been closed and industry has been forced to turn to using alternatives such as conservation, recycling, fuel blending, deep-well injection and incineration. Under such conditions, industry in general has increased efforts to decrease hazardous and toxic waste emissions in the face of increasing treatment and disposal costs, while providing increased worker safety and exposure control. The “cradle to grave responsibility” that industry must now bear has greatly increased the importance of waste minimization, just as workplace safety regulations have created a focus on exposure control to hazardous and toxic wastes that are generated. It is just such “waste minimization” that has become the focus of many industries as a means to managing their hazardous waste disposal issues while maintaining high levels of workplace safety and exposure control.

A representative example is the medical industry, which generates millions of pounds of waste each year. Much of that waste is related to the use of disposable materials, such as personal protective clothing, equipment, and accessories necessary for patient care that become contaminated with body fluids, human waste, and/or chemicals that render them unsafe for reuse. To prevent the spread of disease, it is imperative, and required by law, that these materials be discarded and not reused, without consideration to the level of contamination of said article.

In addition, the nuclear industry also generates millions of pounds of waste each year. In the nuclear industry, much of the waste is similarly related to the use of disposable materials such as personal protective clothing, bags, mop heads, rags, and other accessories that become contaminated by even low levels of radioactive material, and are therefore unsafe or impractical for reuse. The waste disposal and landfilling practices of the nuclear industry are highly regulated, and nuclear burial ground space is becoming increasingly scarce and more expensive.

Various other industries also generate waste streams with similar characteristics. In seeking alternatives to landfilling and incineration, water-soluble products have been developed. In some cases, water-soluble products may be disposed of in a conventional water treatment facility or the like. Accordingly, in some cases, water-soluble products present a convenient and cost effective alternative to conventional waste disposal means. Such articles provide a means to separate the contamination, and conveniently and cheaply dispose of the larger uncontaminated portion into municipal or regular waste streams, thus vastly decreasing the total volume of hazardous waste that must be dealt with by special regulated (and expensive) disposal methods.

Polyvinyl alcohol (PVA) is a commonly used material for making disposable personal equipment, such as garments, apparel, linens, drapes, towels, sponges, gauze, utensils, rags, mops and other useful articles commonly used in industrial settings. These articles are often produced from non-woven, woven, knitted or otherwise formed thermoplastic polyvinyl alcohol polymer films, fabrics, and fibers that are water-soluble, giving these articles the disposal benefits described above.

Conventional filter media used by industry, particularly in filtering hazardous or toxic waste, are made of water-insoluble materials, and do not provide the benefits of water-soluble products as described above. Due to increased disposal costs and regulations, many nuclear utilities have implemented filter storage programs, opting to use long-term onsite storage as an alternative to burial. While this serves to combat the immediate problem of filter disposal in the ever-shrinking nuclear burial space, it has long-term disadvantages. Conventional filter media tends to degrade over time. After years of storage, these filters will eventually have to be handled and dealt with. The likelihood of a radioactive release due to unstable filter media increases with storage length.

Another concern related to the use of conventional filter media is the overhead costs associated with long-term storage of conventional filter media. Special facilities have to be constructed, maintained and monitored. Increased insurance premiums result from such a procedure.

What is needed in the art is a filter media that (1) eliminates one or more problems associated with conventional filter media, and (2) provides one or more possible benefits, such as (a) decreased hazardous and toxic waste generation, (b) decreased expense of waste treatment, (c) regulatory compliance for waste minimization, and (d) increased work place and personnel safety and exposure control.

SUMMARY OF THE INVENTION

The present invention addresses some of the difficulties and problems discussed above by the discovery of a new filter media comprising polyvinyl alcohol (PVA) material. The filter media of the present invention provides one or more benefits including, but not limited to, (a) decreased hazardous and toxic waste generation, (b) decreased expense of waste treatment, (c) regulatory compliance for waste minimization, and (d) increased work place and personnel safety and exposure control. The filter media may have a variety of filter configurations, and may comprise additional materials other than PVA. In one desired embodiment of the present invention, the filter media comprises as much as 90 percent by weight or greater of water-soluble PVA.

The present invention is also directed to methods of making and using the filter media comprising PVA material. In one exemplary method, the filter media is used in a process for treating nuclear waste. In this embodiment, the filter media may be used to perform a particular purpose (i.e., filtering), and then disposed of by solubilizing the filter media. Radioactive waste may be separated from the water-soluble components of the filter media, substantially reducing the amount of radioactive waste and volume of waste.

The present invention is further directed to a method of reducing an amount of radioactive waste generated by a contaminated filter, wherein the method comprises disposing of the filter by placing the filter in an aqueous bath under condition such that at least a portion of the filter becomes soluble. Desirably, the water-soluble component of the filter comprises PVA. The method may further comprise one or more additional steps including, but not limited to, separating radioactive material from the solubilized portions of the filter in the aqueous bath.

The present invention is even further directed to a method of reducing an amount of radioactive waste generated by at least one contaminated product, wherein the method comprises (i) disposing of the at least one contaminated product by placing the at least one contaminated product in an aqueous bath under condition such that at least a portion of the product becomes soluble; and (ii) filtering any non-solubilized material from the aqueous bath using at least one filter comprising water-soluble polyvinyl alcohol material. In a subsequent operation or method step, the at least one filter comprising water-soluble polyvinyl alcohol material may be disposed of by solubilizing the water-soluble components of the at least one filter, further reducing the amount of radioactive waste in the process.

The present invention is further directed to a process for treating a material comprising at least one polymer, comprising the steps (i) introducing at least one oxidizing agent and a material comprising at least one polymer into an aqueous environment, wherein said at least one polymer is a polymer capable of being reacted, degraded or broken down into at least one degradation product; (ii) reacting, degrading or breaking down at least a portion of the at least one polymer under conditions effective to provide at least one degradation product; and (iii) filtering the aqueous environment using a filter comprising water-soluble polyvinyl alcohol material. In a subsequent operation or method step, the filter comprising water-soluble polyvinyl alcohol material may be disposed of by solubilizing the water-soluble components of the filter, further reducing the amount of radioactive waste generated in the process.

These and other features and advantages of the present invention will become apparent after a review of the following detailed description of the disclosed embodiments and the appended claims.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 depicts an exemplary filter media of the present invention having a wound-type cartridge design;

FIG. **2** depicts an end view of the exemplary filter media of FIG. **1** as viewed along line **A-A**;

FIG. **3** depicts a cut-away view of the exemplary filter media of FIG. **1**, wherein a portion of the wound fibrous material has been removed from the core;

FIG. **4** depicts an exemplary filter media of the present invention having a pleated filter design; and

FIG. **5** is a schematic of an exemplary processing system for treating waste streams using one or more filter media of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to filter media comprising polyvinyl alcohol (PVA) material. The present invention is also directed to methods of making and using the filter media comprising PVA material. Polyvinyl alcohol exhibits several unique and positive physical and chemical characteristics for making filter media. The excellent resistance of polyvinyl alcohol to chemicals, acid and base, solvent and oil and grease makes PVA an excellent material for applications in nuclear, industrial and other environments.

For example, the following table compares the impact of common oils and solvents on fully hydrolyzed PVA resin. As the table describes, PVA resins are substantially unaffected by most ester, ethers, ketones, aliphatic, aromatic hydrocarbons and the higher monohydric alcohols. The lower monohydric alcohols have cause some swelling action on the resin, but the effect is negligible. Conventional grades of PVA are unaffected by animal and vegetable oils, greases, and petroleum hydrocarbons. In the table below, the percent gain in weight of molded and un-plasticized PVA resin was measured when they were immersed in a solvent for 10 days at 25-35°C. The lower the number, the better the resistance of PVA resin to the chemicals.

Category	Solvents	PVA Resin, Fully Hydrolyzed
Alcohols	- Methanol - Ethanol 95% - N-Butanol	0.4 < 0.1 < 0.1
Esters	Ethyl acetate Amyl acetate	< 0.1 < 0.1
Ethers	Ethyl ether	< 0.1
Ketones	Acetone	< 0.1
Hydrocarbons	Heptane Kerosene Toluene Turpentine	< 0.1 < 0.1 < 0.1 < 0.1
Chlorinated Hydrocarbons	Carbon tetrachloride Tetrachloroethane Ethylene dichloride Trichloroethylene	< 0.1 < 0.1 < 0.1 < 0.1
Oil	Sea #10 oil Lard oil Cottonseed oil Raw linseed oil	<0.1 < 0.1 < 0.1 < 0.1
Miscellaneous	Oleic acid	0.9

Resources: DuPont ELVANOL^{TM} brochure, * Percent gain in weight of molded unplasticized PVA immersed for 10 days at 25-35°C.

PVA fiber for use in the present invention is desirably produced from fully hydrolyzed PVA resin. In addition to chemical resistance of the PVA resin, the properties of the resulting fiber may be further enhanced by physical treatments such as heat and fiber orientation. The chemical resistance of PVA fiber is even better that the PVA resin.

PVA fiber is unaffected by the levels of ionizing radiation normally seen in nuclear filtering operations, making it useful in both highly radioactive and low level nuclear filtering operations.

I. PVA Filter - Manufacturing and Application

A PVA-based filter may be produced, used, and disposed of in the same manner as current filters. However, PVA filter media has the distinct advantage of being able to change its form and be volume reduced using a chemical oxidation process or simply dissolving it. In both cases, the components would cease to exist in filter form; rather the filter media would be liquefied and discharged or filtered to remove the radioactivity or other contaminants. In nuclear and other industrial applications, this puts the filtered radioactive or hazardous contamination into a much more stable and desired waste form. The user would realize significant economic advantages since regulations governing the disposal of highly radioactive or filters containing hazardous materials would no longer apply. Facilities would no longer pay for the disposal of these filters in conventional form, saving a substantial amount of money in handling, packaging, shipping and disposal.

PVA filters may be produced to cover a wide range of filtering capabilities, for example, from about 0.1 to about 2500 microns. PVA exhibits great efficiency in particle removal and retention. For example, when PVA yarn is used on cord wound filters in lieu of conventional media (e.g., polypropylene, cotton, and/or polyester) and wound to the same specifications for a particular micron rating, PVA typically exceeds the design performance parameters that would be expected of the original media. This is due to the slight expansion of the PVA media when exposed to water, creating a tighter, more tortuous path for filterable particles, and therefore improved filtration efficiency.

The strength of PVA fiber makes it very resistant to failure from pressure surges or high differential pressure under high flow conditions. The dissolution temperature of PVA may also be configured during the manufacturing process to ensure media integrity throughout the range of temperatures seen during filter operations. Capacity and throughput of PVA filters of the present invention may be identical to or very consistent with conventional filter media.

PVA filters of the present invention may be used in any water or air filtration application, including nuclear applications. Other applications for the water filters of the present invention include, but are not limited to, electronic component production, medical, wastewater treatment, drinking water, industrial cooling water systems, and home use. Air filters of the present invention include fibers used in applications including, but are not limited to, industrial gas filtration, respirators, building/home ventilation, and automotive. Other applications of industrial use include the water or air filtration of asbestos or fiberglass.

PVA-containing filters of the present invention may be manufactured in an array of configurations and designs, suitable for both liquid and gas applications. In one embodiment of the present invention, the filter has a wound-type cartridge design. Such a design is shown in FIGS. **1-3**. In this filter media **10**, PVA fiber is spun into roving/yarn **11**, which is then wound around a central support core **12**. The core **12** can be metal, plastic, or another material. As shown in FIG. **3**, core **12** has perforations **13** therein to provide flow channels through filter **10**. This filter type is common to many types of existing water filter designs, such as home use. These same filters are used extensively in low-activity filtering applications at Boiling Water Reactors (BWR) throughout the nuclear industry. Cord wound filters can be made in any length to accommodate any existing filter housing. The filtering capability (micron rating) can be varied over a very wide range depending on manufacturing settings, such as yarn density and winding tension and winding pattern. Filtration ratings of about 0.1 microns and lower are achievable. When dissolved, only the central support core will remain from the original filter assembly.

In some embodiments of the present invention, the central support core **12** may be prepared from a water-soluble, water-degradable or water-dispersible material. Suitable water-soluble materials include, but are not limited to, polyvinyl alcohols used to make the filtration component (e.g., roving/yarn **11** of filter media **10** shown in FIGS. **1-3**) of the filters of the present invention. In such an embodiment, the central support core **12** may be injection molded using a PVA material alone or in combination with one or more water-degradable or water-dispersible materials. Suitable water-degradable or water-dispersible materials include, but are not limited to, polymers disclosed in U.S. Patent No. 6,162,852 assigned to Microtek Medical Holdings, Inc., the entirety of which is hereby incorporated by reference. In this embodiment, the central support core **12** also solubilizes and/or disperses when exposed to alkaline having a water temperature above about 37°C further reducing the amount of waste resulting from the filter media.

It should be noted that although filter **10** of FIGS. **1-3** has a cylindrical wound-type cartridge design, filter **10** may have any volumetric shape other than a cylindrical shape (e.g., a circular cross-sectional configuration).

Suitable cross-sectional configurations other than a circular cross-sectional configuration for the wound-type cartridge design include, but are not limited to, triangular, square, rectangular, oblong, oval, star, parallelogram, rhombus, hexagonal, and octagonal cross-sectional configurations. Further, the cross-sectional area through the wound-type cartridge design filter may be substantially constant along a length of the filter or may vary along a length of the filter.

In a further embodiment of the present invention, the filter comprising PVA material is a pleated filter for use in both air and water applications. Such a design is shown in FIG. **4**. Pleated filter **40** comprises a filter media **41** within housing **42**. These filters **40** may have a cage-type housing **42**, wherein the filter media **41** is fully supported from all sides (or combinations of more than one side) to ensure filter integrity. The housing **42** may be metal, plastic or another material. The filter media **41** exists as a woven, knitted or nonwoven sheet, either single or multi-layered, which is pleated to enhance support and maximize filtering surface area. The filter media **41** may also exist as an extruded, monofilament design. Variations of this filter are used in High Efficiency Particulate Air (HEPA) filters when venting radioactive systems, use in radioactive vacuum cleaners, or other applications where radioactive airborne contamination is a concern. Another variation of the pleated filter is used in water applications, such as purification systems in reactors, spent fuel pool clean up, and make-up water filtering. Pleated filters are commonly used in home and industrial applications as listed above.

In some embodiments of the present invention, the housing **42** may be prepared from a water-soluble, water-degradable or water-dispersible material similar to the central support core **12** described above. As discussed above, suitable water-soluble materials include, but are not limited to, polyvinyl alcohols used to make the filtration component (e.g., filter media **41** of pleated filter **40** shown in FIG. **4**) of the filters of the present invention. Suitable water-degradable or water-dispersible materials include, but are not limited to, polymers disclosed in U.S. Patent No. 6,162,852 assigned to Microtek Medical Holdings, Inc., the entirety of which is hereby incorporated by reference.

In this embodiment, the housing **42** also solubilizes and/or disperses when exposed to alkaline having a water temperature above about 37°C further reducing the amount of waste resulting from the filter media.

It should be noted that although filter **40** of FIG. **4** has a cylindrical housing design, filter **40** may have any volumetric shape other than a cylindrical shape (e.g., a circular cross-sectional configuration). Suitable cross-sectional configurations other than a circular cross-sectional configuration for the pleated design include, but are not limited to, triangular, square, rectangular, oblong, oval, star, parallelogram, rhombus, hexagonal, and octagonal cross-sectional configurations. Further, the cross-sectional area through the pleated design filter may be substantially constant along a length of the filter or may vary along a length of the filter.

In a further embodiment, the filter may be a flat or pleated filter having any of the above-mentioned areal configurations. In other words, the filter may have a circular, triangular, square, rectangular, oblong, oval, star, parallelogram, rhombus, hexagonal, or octagonal shape. The filter may have a structural support in contact with the filter or may be self-supporting (i.e., the filter does not require a supporting structure). Such filters are particularly useful for air filtration, wherein air passes through the filter by entering a first major surface and exiting a second major surface. A non-limiting example of such a filter is a rectangular, pleated filter having a length of 60 cm, a height of 30 cm, and a thickness of about 3 cm.

Other configurations might be made as well using techniques common to one skilled in the art of filter manufacturing. Monolithic filter structures, membrane filters, and various other common forms of filters may be constructed using PVA as the filter material instead of conventional, water-insoluble materials.

In any of the above-described filters, the filter may comprise as much as 90 percent by weight (pbw) or more of water-soluble material, such as PVA. In one embodiment of the present invention, the filter comprises at least about 50 pbw of water-soluble material, such as PVA, based on a total weight of the filter. In other embodiments of the present invention, the filter comprises more than 60 pbw (desirably, at least about 70 pbw; more desirably, at least about 80 pbw; even more desirably, at least about 90 pbw; even more desirably, at least about 95 pbw; and even more desirably, 100 pbw) of water-soluble material, such as PVA, based on a total weight of the filter.

The PVA filters of the present invention may comprise PVA alone or in combination with other water-soluble, water-degradable or water-dispersible materials as described above. Suitable materials that may be used in combination with PVA include, but are not limited to, polyacrylic acid; polymethacrylic acid; polyacrylamide; water-soluble cellulose derivatives comprising methyl celluloses, ethyl celluloses, hydroxymethyl celluloses, hydroxypropyl methyl celluloses, and carboxymethyl celluloses; carboxymethylchitin; polyvinyl pyrrolidone; ester gum; water-soluble derivatives of starch comprising hydroxypropyl starch and carboxymethyl starch; water-soluble polyethylene oxides; alkali water-soluble materials comprising ethylene copolymers of acrylic acid (EAA) and methacrylic acid (EMAA), and salts thereof; and ionomers containing acrylic acid and/or methacrylic acid.

In one embodiment of the present invention, the filter media of the filters comprises PVA material. Desirably, the PVA material comprises polyvinyl alcohol with or without acetyl groups, cross-linked or uncross-linked. In other embodiments of the present invention, the filter media of the filters consists essentially of or consists of PVA material. In yet other embodiments of the present invention, all of the components of the filter, including the filter media, consist essentially of or consist of PVA material.

II. Disposal of Filter Media Containing PVA

The hot water solubility and chemical degradability of PVA enable the filters of the present invention to degrade under desired conditions, minimizing the total waste volume and weight. Exemplary disposal methods for the filters of the present invention and exemplary uses for the filters of the present invention are described in U.S. Patent No. 6,623,643; International Publication No. WO03/074432 A1; U.S. Patents Nos. 5,181,967; 5,207,837; 5,650,219; and 5,885,907, the subject matter of all of which is hereby incorporated in its entirety by reference.

Processors for disposing of the filter media can be any desired size. As described below, some methods of disposal may include an oxidation step, wherein an oxidizer is used to degrade polymers within a treated waste stream. In the process steps describe below, oxidizer concentration may vary, effluents may be filtered or not, etc. Processing can be done at a users facility or taken to a remote location. Effluents may also be ion exchanged or not.

Hot water solubility:

In this exemplary scenario, the filter of the present invention is placed into a small processor (60 gallon, nominal). The processor may be located on top of a container housing used radioactive ion exchange resin that is being prepared for disposal. The filter processor is filled with water and heated to a solubilizing temperature for the filter. The solubilizing temperature may be (i) greater than about 37°C, (ii) greater than about 50°C, (iii) greater than about 75°C, (iv) greater than about 90°C, or (v) near boiling conditions depending on the water-solubility of the materials used. The filter media will completely dissolve, leaving at most only the filter housing and/or support structures, although in some embodiments of the present invention, the filter housing and/or support structures may also dissolve. The liquid mixture containing the dilute liquid PVA will be allowed to cool as appropriate then discharged. In one application, the effluent may be directed to a vessel containing ion exchange resin. The PVA and radioactive isotopes will be deposited in the resin matrix, attaching itself mechanically throughout the torturous path as well as adhering to ion exchange sites. The filter housing and support structure will then be removed and disposed of as low-level radioactive, compactable waste.

Chemical degradation:

In this exemplary scenario, the filter of the present invention is placed into a small processor (60 gallon, nominal). The processor may be located on top of a container housing used radioactive resin that is being prepared for disposal. The filter processor is filled with water, and any of the following components are added to the processor: a polymer degradation-enhancing reactant, a precursor to a polymer degradation-enhancing reactant, an oxidizer, ozone, or a combination thereof. Desirably, a chemical oxidizer (e.g., hydrogen peroxide), and an optional catalyst (e.g., ferrous sulfate or a Fenton reagent) are added to the filter processor. The aqueous bath may be heated to near boiling conditions as described above.

The filter media completely dissolves, and its chemical form altered into a dilute aqueous mixture of organic acids, leaving at most only the filter housing and support structures, although in some embodiments of the present invention, the filter housing and/or support structures may also dissolve. The resulting liquid mixture containing organic acids will be allowed to cool as appropriate, then drained to the resin container. The organic acids will be deposited in the resin matrix, where the radioactivity and the acids will attach to the ion exchange sites. The filter housing and support structure will then be removed, when applicable, and disposed of as low-level radioactive, compactable waste.

In both of the above-described scenarios, it should be noted that the filter housing and/or core component may also comprise water-soluble and/or water-degradable polymeric material as described above. In this case, there may not be a filter housing and/or support structure remaining for disposal.

Pleated cartridge filters are commonly used in nuclear utilities to maintain water purity in Refueling Pools and Spent Fuel Pools. These filters are housed in a filter housing and submersed in the appropriate pool. Water is pumped through the filter (by an integrally attached pump) to maintain the radioactivity concentration at an acceptable level. When the filter is taken out of service, it is moved out of the housing remotely and placed in an underwater disposal container. This container is removed from the pool and the filter transferred to a High Integrity Container (HIC) for storage until it can be processed for its final disposition. Due to stringent regulations, only a small number of filters can be packaged in a HIC, a number based on total radioactivity, radioactive dose rates and physical geometry. This leaves large amounts of unused space in a filter disposal vessel, space that the utility will pay for regardless. Because of these stringent regulations, filters are taken out of service based on radioactive dose rates, not useful life, with the burial of the filters being the ultimate consideration. The filter media of the present invention eliminate many of the problems associated with conventional filters and methods of handling conventional filters.

The filter media of the present invention possess other advantages in that the filters may be utilized to take much higher dose rates. Since the filter media of the present invention do not need to be buried in filter form, a cap on dose rate is not necessary. This allows the utility to use less filters to do the same job, saving the cost of extra filters and more importantly, saving the downtime and labor of changing, handling and disposing of more filters.

III. Specific Use in the Nuclear Industry

The filter media of the present invention may be used in a number of applications including, but not limited to, the treatment of polymer(s), as well as, degradation-enhancing reactant(s) or precursors thereof, which may be present in an aqueous environment. This type of process is described in U.S. Patent No. 6,623,643 and International Publication No. WO03/074432 A1, the subject matter of both of which is hereby incorporated in its entirety by reference.

In U.S. Patent No. 6,623,643 and WO03/074432 A1, processes are described, wherein a polymer is not completely solubilized in the aqueous environment. The unsolubilized polymer can optionally be removed from the environment by a suitable means, such as filtration and then recycled or reused. The filter media of the present invention may be used in this filtration step. Further, U.S. Patent No. 6,623,643 and WO03/074432 A1 disclose embodiments, wherein polymer is solubilized prior to the introduction of a degradation-enhancing reactant or precursor thereof. In these embodiments, it may be desirable to filter non-solubilized material from the aqueous solution prior to introduction of the degradation-enhancing reactant or a precursor thereof using the filter media of the present invention.

Similarly, the processes disclosed in U.S. Patent No. 6,623,643 and WO03/074432 A1 may also include "post-treatment" of the aqueous environment. The precise type of post-treatment can depend on the nature of the aqueous environment. In general, where the polymer is degraded to a product including one or more organic acids, the acids can then be depleted through biodegrading the organic acids.

If the aqueous environment is to be biodegraded, the pH should be adjusted to a value within the approximate range of about 3.0 to about 10.0 or, more preferably, within the approximate range of about 5.0 to about 8.0 or, even most preferably, within the approximate range of about 6.0 to about 7.0 It is desired to pass the aqueous waste stream through a reverse osmosis unit after the biodegradation.

Biodegradation may include inoculating the aqueous waste stream with microorganisms such as aerobic, heterotrophic bacteria or anaerobic bacteria. The inoculated aqueous environment or waste stream may be exposed to an aerated, fluidized bed in a bioreactor which contains support materials such as pulverized, activated carbon or plastic bio beads. The inoculated aqueous waste stream may also be exposed to a fixed media reactor or an activated sludge process. Conventional extended aeration, step aeration, sequential batch reactions and contact stabilization may also be used to reduce the organic carbon content of the inoculated aqueous waste stream.

The biological activity of the microorganisms may be enhanced by injecting a nutrient containing nitrogen, phosphorus, potassium or a trace mineral, into the bioreactor. The final resultant waste stream includes neutralized water depleted of organic carbon, which is suitable for delivery to a waste treatment facility or for reuse or recycling.

In an alternative embodiment disclosed in U.S. Patent No. 6,623,643 and WO03/074432 A1 involving treatment of waste generated from nuclear facilities, a filtration and/or ion exchange process may be used to remove radioactive material from the solution. For example, the step of removing radioactive material may be accomplished by filtering the solution through a micron filter, which has a nominal pore size ranging between about 10 and about 100 microns to remove radioactive elements. Optionally, a second particulate filter having a nominal pore size between about 0.1 micron and about 1.0 micron, a reverse osmosis unit or an ion exchange unit consisting of an anion bed, a cation bed or an anion/cation combination bed that reduces depleted radioisotopes at an elemental level may also be used. In either of these filtration steps, the filter media of the present invention may be used.

Desirably, the waste stream may also be adjusted to a higher pH. More desirably, the pH adjusted waste stream can also be biodegraded to eliminate the organic acids. If the waste stream is to be biodegraded, it is desirable to neutralize the waste stream by adding sodium hydroxide until the pH is adjusted to within the approximate range of about 3.0 to about 10.0, preferably from about 5.0 to about 8.0 or, even more preferably from about 6.0 to about 7.0.

In an embodiment disclosed in U.S. Patent No. 6,623,643 and WO03/074432 A1 for treating materials that come from a source that may have been exposed to radioactivity, the potentially radioactive materials may be filtered using the filter media of the present invention. The filtering step may occur at any point in the process, e.g., prior to adding the degradation-enhancing reactant (e.g., an oxidizing agent) to the aqueous waste stream, after producing the degradation products (e.g., organic acids) from the polymer, or after treatment of the degradation products, e.g., biodegrading the organic acids. Contaminated products (i.e., products exposed to radioactivity) may include, but are not limited to, at least one garment, protective clothing, coveralls, booties, face masks, gloves, apparel, linens, drapes, towels, fabrics, films, laminates containing at least one fabric or film, sponges, mop heads, webs, bags, gauze, pads, wipes, pillows, bandages, filters of the present invention, or combinations thereof.

Filters for removing potentially radioactive material (e.g., a transuranic element, a fission product, a natural radioactive element, an activation product from a nuclear process, a medical isotope, or a combination thereof) include particulate filters of the present invention having a nominal pore size of about 10 microns to about 100 microns and optionally a second particulate filter of the present invention having a nominal pore size of from about 0.1 micron to about 1.0 micron through which the waste stream is circulated. Filtering may also comprise circulating the aqueous waste stream through an ion exchange bed. For example, in one embodiment, the process includes: (a) filtering potentially radioactive material from the aqueous waste stream; (b) neutralizing the pH of the aqueous waste stream after producing organic acids; and (c) depleting organic acids from the aqueous waste stream after neutralizing the pH. In any of the above-described process steps requiring filtration, the filter media of the present invention may be used.

One exemplary process disclosed in U.S. Patent No. 6,623,643 and WO03/074432 A1 comprises the steps of:

(1) if required, introducing a polymer or polymer-containing material into an aqueous solution;

(2) if required, adding a degradation-enhancing reactant, or a precursor thereof, to the solution;

(3) heating the aqueous environment so as to react the precursor to form the degradation-enhancing reactant, if necessary, and reacting the polymer to form degradation products;

(4) optionally, filtering non-solubilized material from the aqueous environment;

(5) optionally, measuring a parameter indicator of the concentration of polymer material in the aqueous environment;

(6) optionally, filtering material, e.g., radioactive material from the aqueous environment;

(7) optionally, altering, e.g., neutralizing, the pH of the aqueous environment;

(8) optionally, biodegrading the resulting degradation products in the aqueous environment, e.g., organic acids form CO_2, H_2O and biomass; and

(9) removing any insoluble components from the reactor.

In step (4), the aqueous environment is desirably filtered through strainers to remove any undissolved polymer material and non-water-soluble polymer constituents in the solution. Alternatively, the strainer may be prepared using the above-described PVA material for forming filter media of the present invention. In a desired embodiment, the strainers will have a mesh size in an approximate range of between about 20 and about 50 mesh. In a more desired embodiment, the strainers will have a mesh size of approximately about 30 mesh. Undissolved polymer material trapped in the strainers can be recirculated for final solubilization. In a desired embodiment, polymer material will constitute an approximate range of greater than 0% to about 10.0% by weight in the solution. In a more desired embodiment, polymer material will constitute an approximate range of between about 4.0% to about 6.0% by weight in the solution. In still a more desired embodiment, polymer material will be present in an amount of about 5.0% by weight in the solution. Additionally, in a more desired embodiment, the temperature of the solution during the filtration process step is maintained at or above about 150°F to prevent precipitation of the PVA out of solution prior to its destruction.

In step (6), a filter media of the present invention may be used to filter and deplete radioactivity in solution. This process step is optional and only applicable when the water-soluble polymer material contains potentially radioactive waste. This step may or may not be required, for example, at a nuclear facility. If the polymer material was exposed to radioactivity that affects the disposability of the solution, then this process step should be added. With the addition of this process step, a low-level radioactive waste management system is created. This waste management system can be used as an alternative approach to current dry active radioactive waste treatment methods. The process step of removal of radioactivity typically occurs prior to biological degradation. A more detailed desired embodiment of this process step includes the basic steps of:

(a) filtration of the solution, and

(b) ion exchange of the solution.

At nuclear facilities, radioactivity may be present in process fluids in both elemental and particulate form. Filtration of the solution removes radioactive particulates. In a desired embodiment, the solution is passed through a particulate filter having a nominal pore size ranging approximately between about 10 and about 100 microns. In a more desired embodiment, the solution is then passed through a second particulate filter having a nominal pore size ranging approximately between about 0.1 micron and about 1.0 micron. As described above, a filter media of the present invention may be used in these filtration steps.

In another exemplary process disclosed in U.S. Patent No. 6,623,643 and WO03/074432 A1, the process comprises the steps of:

(1) if required, solubilizing water-soluble polymer material in an aqueous environment;

(2) filtering non-solubilized material from the aqueous environment;

(3) adding a degradation-enhancing reactant, or a precursor thereof, to the filtered environment;

(4) where a precursor of the degradation-enhancing reactant is employed, reacting the precursor to form the degradation-enhancing reactant, and reacting the polymer;

(5) optionally, measuring a parameter indicator of the concentration of polymer material in the aqueous environment;

(6) optionally, filtering material, e.g., radioactive material, from the aqueous environment;

(7) optionally, altering, e.g., neutralizing, the pH of the solution;

(8) optionally, biodegrading the degradation products, e.g., organic acids in the solution to form CO_2, H_2O and biomass; and

(9) removing any insoluble components from the reactor.

This process differs from the previously discussed process in connection with steps (1)-(5), which involve solubilization of the polymer prior to introduction of the degradation-enhancing reactant/precursor and formation of the degradation-enhancing reactant from the precursor. Formation of the degradation-enhancing reactant from the precursor may comprise irradiation of the solution with electromagnetic radiation, heat, or a combination thereof as explained in U.S. Patent No. 6,623,643 and WO03/074432 A1. As with the above-described process, filter media of the present invention may be used in steps (2) and (6) of this particular process.

A suitable system for performing the second process discussed above is illustrated by FIG. **5**, where the reference numeral **100** refers generally to a solution vessel. In a desired embodiment, solution vessel **100** is an autoclave.

Solution vessel **100** is desirably made of stainless steel or similarly corrosively resistant material. Solution vessel **100** is connected by a plumbing line **102** to a filter system **104**. Filter system **104** is connected by plumbing line **106** to a pump **108**. In a desired embodiment, a plumbing line **112** intersects and connects plumbing line **110** to a heat exchanger **114**. Heat exchanger **114** is connected by a plumbing line **116** back to solution vessel **100** to form a recirculating communication.

Pump **108** is connected by a plumbing line **110** to a photochemical reaction vessel **200**. Reaction vessel **200** is desirably made of stainless steel or similarly corrosively resistant material. In one embodiment, photochemical reaction vessel **200** is comprised of a bank of individual photochemical reactors (not shown) arranged in an array within the reaction vessel. In this embodiment, a mechanical mixer (not shown) is located within reaction vessel **200** to provide circulation of the contents. Each of the reactors comprising at least one high-intensity ultraviolet lighting element. In a more desired embodiment, the photochemical reactors within reaction vessel **200** generate ultraviolet radiation in the wavelengths between about 185 and about 250 nanometers.

An oxidative agent injection system **300** is connected by a plumbing line **302** to reaction vessel **200**. In a desired embodiment, oxidative agent injection system **300** comprising a programmable logic controller, sensor, recorder, and dispensing mechanism, such as is well known in industrial chemistry. Photochemical reaction vessel **200** is connected by a plumbing line **202** to a pump **204**. Pump **204** is connected by a plumbing line **206** to a neutralization vessel **400**. In an optional embodiment, a plumbing line 208 intersects plumbing line **206** and is connected to reaction vessel **200** to permit pump operated re-circulating photochemical treatment of the solution.

A pH neutralizing system **402** is connected by a plumbing line **404** to neutralization vessel **400**. In a more desired embodiment, pH neutralizing system **402** comprising an automatic pH controller. Neutralization vessel **400** is connected by a plumbing line **406** to a pump **408**. Pump **408** is connected by a plumbing line **410** back to neutralization vessel **400** to form a recirculating communication. Neutralization vessel **400** is connected by a plumbing line **412** to bio cells **500**. Bio cells **500** are desirably of the fixed media aerobic type or activated sludge processes. Entrance accommodations are made for administration of air, microbes and nutrients to the bio cells by any means well known in the industry. Bio cells **500** are connected by a plumbing line **502** to a pump **504**. Pump **504** is connected by a plumbing line **506** back to bio cells **500** to form a recirculating communication. Bio cells **500** are connected by a plumbing line **508** for discharge.

In an alternative desired embodiment, a plumbing line **602** intersects and connects plumbing line **206** to a radioactive material filtration system **600**. Radioactive material filtration system **600** is connected by a plumbing line **604** back to plumbing line **206** to form a circulating communication. Optionally, radioactive material filtration system **600** is connected by a plumbing line **606** back to reaction vessel **200** to form a recirculating communication by which depletion of radioactivity in solution can be performed coincident with oxidation-reduction of the solution. Radioactive material filtration system **600** may alternatively be connected within the disclosed system at any position between solution vessel **100** and neutralization vessel **400**.

While the specification has been described in detail with respect to specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. Accordingly, the scope of the present invention should be assessed as that of the appended claims and any equivalents thereto.

WHAT IS CLAIMED IS:

1. A filter comprising polyvinyl alcohol.

2. The filter of claim 1, wherein the filter comprises:

(a) a filtration media of fibrous material formed from polyvinyl alcohol; and

(b) a support for the fibrous material.

3. The filter of claim 2, wherein the filtration media comprises polyvinyl alcohol yarn or roving, and the support comprises a core; wherein the yarn or roving is wound onto the core.

4. The filter of claim 3, wherein the core comprises a water-soluble or water-degradable polymer.

5. The filter of claim 2, wherein the filtration media comprises a woven, nonwoven or knitted fabric of polyvinyl alcohol fibers, and the support comprises a structural support in contact with the fibrous material.

6. The filter of claim 5, wherein the structural support comprises a water-soluble or water-degradable polymer.

7. The filter of claim 1, wherein the filter has a nominal pore size ranging from about 0.1 microns (μm) to about 2500 μm.

8. The filter of claim 1, wherein the filter has a nominal pore size ranging from about 0.1 μm to about 1.0 μm.

9. The filter of claim 1, wherein the filter has a nominal pore size ranging from about 10.0 μm to about 100 μm.

10. The filter of claim 2, wherein the filtration media consists essentially of fibrous material formed from polyvinyl alcohol.

11. The filter of claim 2, wherein the filtration media consists of fibrous material formed from polyvinyl alcohol.

12. The filter of claim 2, wherein the filtration media and the support comprise polyvinyl alcohol.

13. The filter of claim 2, wherein the filtration media and the support consists essentially of polyvinyl alcohol.

14. A method of reducing an amount of radioactive waste generated by a contaminated filter, wherein the method comprises:

(a) disposing of the filter by placing the filter in an aqueous bath under condition such that at least a portion of the filter becomes soluble.

15. The method of claim 14, wherein the aqueous bath has a bath temperature of greater than about 37°C.

16. The method of claim 14, wherein the aqueous bath has a bath temperature of greater than about 50°C.

17. The method of claim 14, wherein the aqueous bath has a bath temperature of greater than about 75°C.

18. The method of claim 14, wherein the aqueous bath has a bath temperature of greater than about 90°C.

19. The method of claim 14, wherein the aqueous bath contains a polymer degradation-enhancing reactant, a precursor to a polymer degradation-enhancing reactant, an oxidizer, ozone, or a combination thereof.

20. The method of claim 14, wherein the filter comprises a fiber, a fabric, a film, or a combination thereof containing water-soluble polyvinyl alcohol material.

21. The method of claim 14, wherein the filter comprises a nonwoven fabric containing water-soluble polyvinyl alcohol material.

22. The method of claim 14, wherein the filter comprises a woven fabric containing water-soluble polyvinyl alcohol material.

23. The method of claim 14, wherein the filter comprises a knitted fabric containing water-soluble polyvinyl alcohol material.

24. The method of claim 14, wherein the filter comprises water-soluble polyvinyl alcohol material.

25. The method of claim 24, wherein the filter further comprises one or more additional materials selected from the group consisting of polyacrylic acid; polymethacrylic acid; polyacrylamide; water-soluble cellulose derivatives comprising methyl celluloses, ethyl celluloses, hydroxymethyl celluloses, hydroxypropyl methyl celluloses, and carboxymethyl celluloses; carboxymethylchitin; polyvinyl pyrrolidone; ester gum; water-soluble derivatives of starch comprising hydroxypropyl starch and carboxymethyl starch; water-soluble polyethylene oxides; alkali water-soluble materials comprising ethylene copolymers of acrylic acid (EAA) and methacrylic acid (EMAA), and salts thereof; and ionomers containing acrylic acid and/or methacrylic acid.

26. The method of claim 24, wherein the water-soluble material comprises polyvinyl alcohol with or without acetyl groups, cross-linked or uncross-linked.

27. The method of claim 14, wherein the filter is contaminated due to exposure to radioactive material, wherein the radioactive material comprises a transuranic element, a fission product, a natural radioactive element, an activation product from a nuclear process, a medical isotope, or a combination thereof.

28. The method of claim 14, further comprising one or more of the following steps:

(i) placing the filter into a disposal reactor;

(ii) introducing water into the reactor to form an aqueous solution;

(iii) adding one or more components to the disposal vessel, wherein the one or more components comprise a polymer degradation-enhancing reactant, a precursor to a polymer degradation-enhancing reactant, an oxidizer, ozone, or a combination thereof;

(iv) heating the aqueous solution to (a) optionally convert the precursor, when present, to a degradation-enhancing reactant, and (b) reacting the degradation-enhancing reactant with the water-soluble polymer to form one or more degradation products;

(v) filtering non-solubilized material from the second aqueous solution;

(vi) optionally, measuring a parameter to indicate a concentration of polymer material in the aqueous solution;

(vii) separating radioactive material from the aqueous solution by a separation technique;

(viii) collecting the radioactive material for proper disposal;

(ix) optionally, altering or neutralizing a pH of the aqueous solution substantially free of radioactive material;

(x) biodegrading the one or more degradation products in the aqueous solution substantially free of radioactive material to form CO_2, water and biomass; and

(xi) removing any insoluble components from the reactor.

29. A method of reducing an amount of radioactive waste generated by at least one contaminated product, wherein the method comprises:

disposing of the at least one contaminated product by placing the at least one contaminated product in an aqueous bath under condition such that at least a portion of the product becomes soluble; and

filtering any non-solubilized material from the aqueous bath using at least one filter comprising water-soluble polyvinyl alcohol material.

30. The method of claim 29, wherein the aqueous bath has a bath temperature of greater than about 37°C during the disposal step.

31. The method of claim 29, wherein the aqueous bath has a bath temperature of greater than about 50°C during the disposal step.

32. The method of claim 29, wherein the aqueous bath has a bath temperature of greater than about 75°C during the disposal step.

33. The method of claim 29, wherein the aqueous bath has a bath temperature of greater than about 90°C during the disposal step.

34. The method of claim 29, wherein the aqueous bath in the disposal step contains a polymer degradation-enhancing reactant, a precursor to a polymer degradation-enhancing reactant, an oxidizer, ozone, or a combination thereof.

35. The method of claim 29, wherein the at least one contaminated product is a fiber, a fabric, a film, or a combination thereof.

36. The method of claim 29, wherein the at least one contaminated product is a nonwoven fabric.

37. The method of claim 29, wherein the at least one contaminated product is a woven fabric.

38. The method of claim 29, wherein the at least one contaminated product is a knitted fabric.

39. The method of claim 29, wherein the at least one contaminated product comprises at least one garment, protective clothing, coverall, bootie, face mask, glove, apparel, linen, drape, towel, fabric, film, laminate

containing at least one fabric or film, sponge, mop head, web, bag, gauze, pad, wipe, pillow, bandage, or combination thereof.

40. The method of claim 29, wherein the at least one contaminated product comprises coveralls.

41. The method of claim 29, wherein the at least one contaminated product comprises water-soluble material selected from the group consisting of polyvinyl alcohol; polyacrylic acid; polymethacrylic acid; polyacrylamide; water-soluble cellulose derivatives comprising methyl celluloses, ethyl celluloses, hydroxymethyl celluloses, hydroxypropyl methyl celluloses, and carboxymethyl celluloses; carboxymethylchitin; polyvinyl pyrrolidone; ester gum; water-soluble derivatives of starch comprising hydroxypropyl starch and carboxymethyl starch; water-soluble polyethylene oxides; alkali water-soluble materials comprising ethylene copolymers of acrylic acid (EAA) and methacrylic acid (EMAA), and salts thereof; and ionomers containing acrylic acid and/or methacrylic acid.

42. The method of claim 41, wherein the water-soluble material comprises polyvinyl alcohol with or without acetyl groups, cross-linked or uncross-linked.

43. The method of claim 29, wherein the at least one contaminated product is contaminated due to exposure to radioactive material, wherein the radioactive material comprises a transuranic element, a fission product, a natural radioactive element, an activation product from a nuclear process, a medical isotope, or a combination thereof.

44. The method of claim 29, further comprising one or more of the following steps:

(i) placing the at least one contaminated product into a disposal reactor;

(ii) introducing water into the reactor to form an aqueous solution;

(iii) adding one or more components to the disposal vessel, wherein the one or more components comprise a polymer degradation-enhancing reactant, a precursor to a polymer degradation-enhancing reactant, an oxidizer, ozone, or a combination thereof;

(iv) heating the aqueous solution to (a) optionally convert the precursor, when present, to a degradation-enhancing reactant, and (b) reacting the degradation-enhancing reactant with the water-soluble polymer to form one or more degradation products;

(v) optionally, measuring a parameter to indicate a concentration of polymer material in the aqueous solution;

(vi) separating radioactive material from the aqueous solution by a separation technique;

(vii) collecting the radioactive material for proper disposal;

(viii) optionally, altering or neutralizing a pH of the aqueous solution substantially free of radioactive material;

(ix) biodegrading the one or more degradation products in the aqueous solution substantially free of radioactive material to form CO_2, water and biomass; and

(x) removing any insoluble components from the reactor.

45. The method of claim 44, wherein the filtration step comprises passing the aqueous solution through a particulate filter having a nominal pore size of about 10 microns to about 100 microns, wherein the filter comprises water-soluble polyvinyl alcohol material.

46. The method of claim 44, wherein the separation step (vi) comprises passing the aqueous solution through a second particulate filter having a nominal pore size of from about 0.1 microns to about 1.0 microns and then circulating the aqueous solution through an ion exchange bed, wherein the second particulate filter comprises water-soluble polyvinyl alcohol material.

47. A process for treating a material comprising at least one polymer, comprising the steps:

introducing at least one oxidizing agent and a material comprising at least one polymer into an aqueous environment, wherein said at least one polymer is a polymer capable of being reacted, degraded or broken down into at least one degradation product;

reacting, degrading or breaking down at least a portion of the at least one polymer under conditions effective to provide at least one degradation product; and

filtering the aqueous environment using a filter comprising water-soluble polyvinyl alcohol material.

48. The process of claim 47, wherein the at least one polymer is a polyvinyl alcohol.

49. The process of claim 47, wherein the introducing step further comprises dissolving at least a portion of the at least one polymer in the aqueous environment.

50. The process of claim 47, wherein the introducing step further comprises the addition of heat to the aqueous environment.

51. The process of claim 50, wherein the aqueous environment is heated to a temperature between approximately 180°F and 250°F.

52. The process of claim 47, wherein the introducing step comprises increasing the surface area of the material comprising at least one polymer after being introduced into the aqueous environment.

53. The process of claim 47, further comprising the step of increasing the surface area of the material comprising at least one polymer prior to the introducing step.

54. The process of claim 47, wherein the introducing step comprises forming an emulsion, a dispersion, or a solution comprising the at least one polymer.

55. The process of claim 47, wherein the reacting step comprises treating the aqueous environment with heat, electromagnetic radiation, metallic catalysts, ozone, or any combination thereof.

56. The process of claim 55, wherein the reacting step comprises heating the aqueous environment to a temperature between approximately 180°F and 250°F.

57. The process of claim 47, further comprising step:

biodegrading at least a portion of the at least one degradation product.

58. The process of claim 47, wherein the at least one oxidizing agent comprises hydrogen peroxide.

59. The process of claim 58, wherein the ratio of milliliters of hydrogen peroxide to grams of the at least one polymer is at least 0.5.

60. The process of claim 47, wherein the process further comprises reacting the at least one oxidizing agent to produce hydroxyl radicals, molecular oxygen, or a combination thereof.

61. The process of claim 47, wherein the reacting step comprises contacting the at least one polymer with hydroxyl radicals, molecular oxygen, or a combination thereof.

62. A process for treating an aqueous environment containing an at least partially solubilized, potentially radioactive material comprised of at least one water-soluble polymer, comprising the steps of:

providing an aqueous environment containing at least partially solubilized potentially radioactive material comprised of at least one water soluble polymer;

filtering at least a portion of non-solubilizing material from the aqueous environment using at least one filter comprising water-soluble polyvinyl alcohol material;

adding a rate-enhancing amount of at least one oxidizing agent to the aqueous environment;

heating the aqueous environment for a sufficient amount of time to form at least one organic acid;

measuring the concentration of the water soluble polymer in the aqueous environment;

filtering at least a portion of radioactive material from the aqueous environment using at least one filter comprising water-soluble polyvinyl alcohol material;

neutralizing the pH of the aqueous environment; and

biodegrading at least a portion of the at least one organic acid in the aqueous environment, to form CO_2, water and biomass.

63. The process of claim 62, wherein the aqueous environment containing at least partially solubilized potentially radioactive material is processed and the first filtration step is accomplished by a particulate filter having a nominal pore size of about 10 microns to about 100 microns, wherein the particulate filter comprises water-soluble polyvinyl alcohol material.

64. The process of claim 62, wherein the aqueous environment is circulated through a second particulate filter having a nominal pore size of from about 0.1 microns to about 1.0 microns and then circulated through an ion exchange bed, wherein the second particulate filter comprises water-soluble polyvinyl alcohol material.

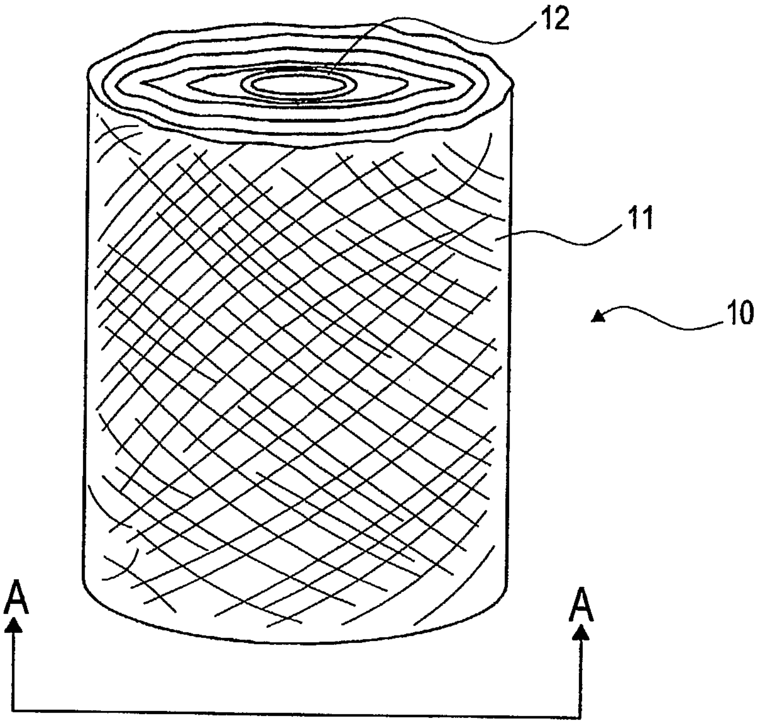

FIG.1

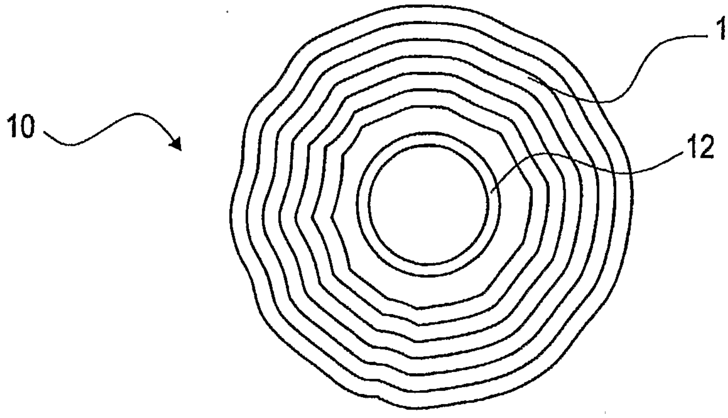

FIG.2

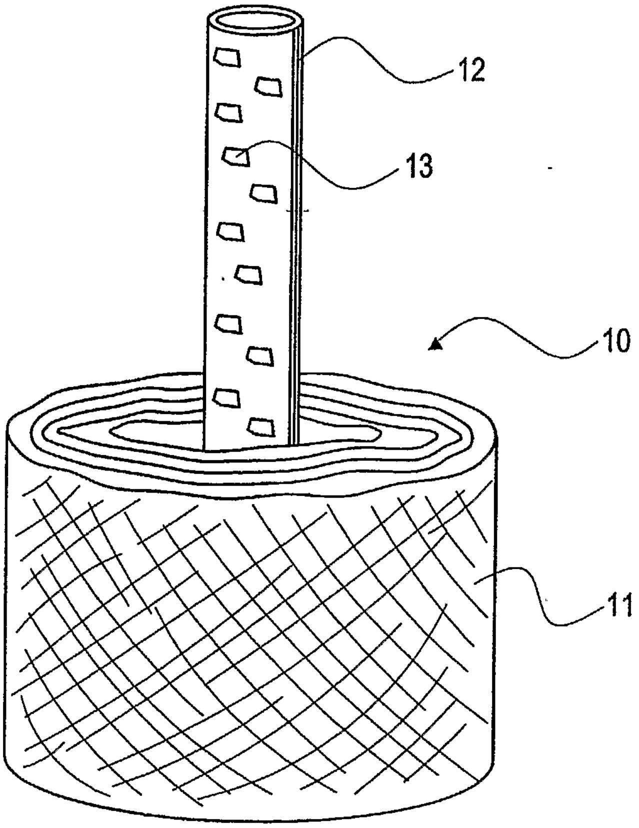

FIG.3

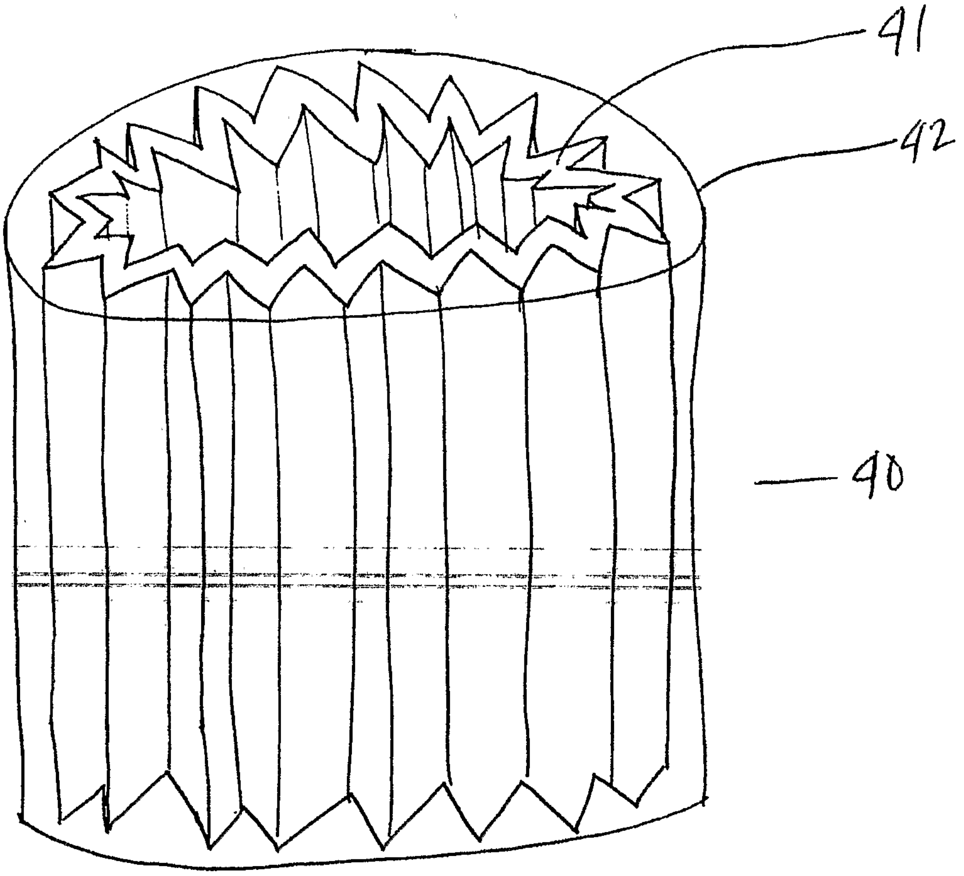

FIG. 4

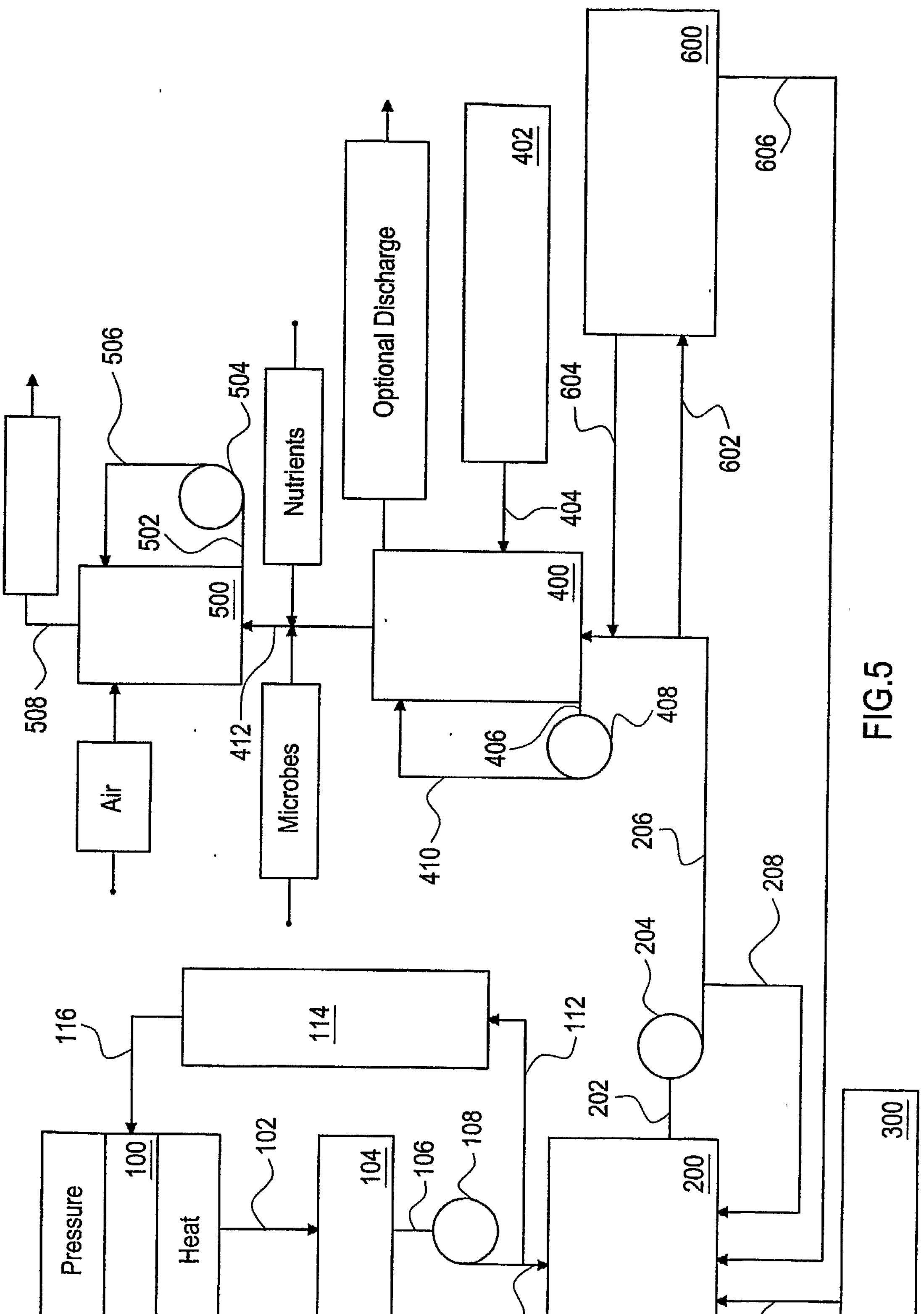
Pressure
100
Heat
102
104
106
108
110
112
114
116
200
202
204
206
208
300
302
400
402
404
406
408
410
412
Optional Discharge
Nutrients
Microbes
Air
500
502
504
506
508
600
602
604
606

FIG.5