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Patent Number	:	**282257**
Application Number	:	**2892/CHE/2010**
Date of Filing	:	**30/09/2010**
Patentee	:	**INDIAN INSTITUTE OF TECHNOLOGY**

It is hereby certified that a patent has been granted to the patentee for an invention entitled AXIAL FLOW FILTER BLOCK FOR WATER PURIFICATION AND A METHOD FOR PREPARING THE SAME as disclosed in the above mentioned application for the term of 20 years from the 30 day of SEPTEMBER 2010 in accordance with the provisions of the Patents Act, 1970.

Karthiki
Controller of Patents

Controller General of Patents,
Designs & Trademarks

Date of Grant:31/03/2017

Note: The fees for renewal of this patent, if it is to be maintained will fall/has fallen due on 30 day of SEPTEMBER 2012 and on the same day in every year thereafter.

FORM 2

THE PATENTS ACT, 1970

(39 OF 1970)

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The Patents Rules, 2003

COMPLETE SPECIFICATION

(Refer section 10 and rule 13)

TITLE OF THE INVENTION:

AXIAL FLOW FILTER BLOCK FOR WATER PURIFICATION AND A METHOD FOR PREPARING THE SAME

2. APPLICANT:

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3. Preamble to the Description

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which is to be performed.

COMPLETE SPECIFICATION

TITLE OF THE INVENTION

AXIAL FLOW FILTER BLOCK FOR WATER PURIFICATION AND A METHOD FOR PREPARING THE SAME

FIELD OF INVENTION

The present invention relates to the preparation of an axial flow, low pressure drop, porous block filter inside the housing for the purification of drinking water. More particularly, the present invention relates to a cost-effective, gravity-fed filter offering higher contact time for contaminant adsorption and simultaneous removal of a number of toxic contaminants and to an art of making an axial block directly inside a non-porous/porous housing tube. This invention, therefore, details the procedure for fabrication of a ready-to-use water purification cartridge offering highly effective removal of several contaminants.

BACKGROUND OF THE INVENTION

One of the most important ways of removing contaminants from fluids is by adsorption. A cost-effective and universally adopted easy method for purification of drinking water at domestic scale is gravity-fed filtration. Numerous methods of gravity-fed filtration devices and apparatuses are known for removing contaminants from domestic water.

Various modifications and variations have been done in the art of making gravity-fed filtration devices for targeted removal of contaminants from drinking water such as organic (i.e., volatile organics and pesticides), inorganic (i.e., fluoride, arsenic, iron) and biological (i.e., bacteria and virus) species. The design of gravity-fed filtration device explained here focuses on following aspects: efficient removal of contaminants with complete utilization of active filtration media (*axial flow system*), efficient removal of contaminants found in trace as well as high concentration (*multi-layered composite axial block*), acceptable output water flow rate (*low-pressure drop*), continuity of flow rate over a period of time (*flow rate consistency*) and sealing of the porous block with the housing (*in-situ sealing*).

Necessity of axial flow block: Several contaminants in drinking water have been reported to be found in high concentration. A typical example of such contaminants is fluoride. Excess fluoride in drinking water has led to more than 25 million people suffering from fluorosis in our country and approximately 66 million people are at risk. Excess fluoride in groundwater is reported in many countries around the world (more than 25 countries), notably those located in North America, Africa, and Asia. In India, the allowed concentration for fluoride in drinking water is 1 ppm whereas an average concentration of 5 ppm has been reported from fluoride affected areas. In case of high contaminant concentration, the removal using adsorption mechanism requires a significantly higher contact time than offered by radial flow blocks (typical empty bed contact time in radial block is less than 10 seconds).

The most affected population with fluoride is typically concentrated in rural areas of the country, wherein people cannot afford to use costlier reverse osmosis based household units requiring electricity. Activated alumina based adsorption at household level has not been attempted at large scale due to its low fluoride adsorption capacity. As on date, there is no product commercially available in the market as a gravity-fed water purifier for the removal of fluoride from drinking water. A major reason for this is the low fluoride adsorption capacity of activated alumina and high contact time required (Ghorai, S. Pant K.K. Investigations on the column performance of fluoride adsorption by activated alumina in a fixed-bed. *Chem. Eng. J.*, **2004**, *98*(1-2), 165). It is important to know that fluoride removal from drinking water is therefore being attempted only at community scale, using activated alumina based adsorption or reverse osmosis based exclusion. In order to reach a larger population affected by fluorosis and to provide them with a solution, it is imperative to design a gravity-fed household water purifier for fluoride removal. In the light of our recent inventions (1529/CHE/2010, 2082/CHE/2009) wherein the fluoride adsorption capacity of adsorbent is significantly enhanced and design improvement reported in the present application, it is possible to have a household unit for fluoride removal. This is illustrated in the detailed description of the present invention.

Necessity of multi-layered composite axial block: The problem of drinking water contamination in India and elsewhere is often simultaneous presence of several contaminants. Some of the contaminants are geological in origin whereas others are due to pollution-based contamination of the water source. Typically, dust filter, activated carbon and anti-microbial media are essential for a water purifier. The emerging scenario of water contamination in the country requires additional media for specific contaminants such as:

(a) Arsenic: affected areas in India - West Bengal, Chhattisgarh, Bihar, Jharkhand, Uttar Pradesh, Assam, Punjab, Karnataka and Haryana

(b) Iron: affected areas in India - Bihar, West Bengal, Karnataka, and Rajasthan

(c) Fluoride: affected areas in India - Andhra Pradesh, Gujarat, Rajasthan, Tamil Nadu, Uttar Pradesh, Maharashtra, Bihar, Jharkhand, Chhattisgarh, Karnataka, Haryana and Punjab

This has been reiterated in the reports published by Central Ground Water Board, Government of India (Groundwater in 33% of India undrinkable, Times of India, March 13th 2010, accessed from http://timesofindia.indiatimes.com/india/Groundwater-in-33-of-India-undrinkable/articleshow/5673304.cms on May 14th 2010). This clearly necessitates a water purifier addressing multiple water purification needs.

In reality there is no universal single filtration media to remove all types of contaminants such as organic, inorganic, biological, sediments, etc. For different contaminants, different types of filtration media are required. The active filtration media can vary from activated carbon to activated alumina, natural/synthetic metal oxides such as sand, titania, zirconia, zeolite, magnesia, different nanoparticles coated metal oxides, etc. To remove the desired contaminants as per the IS standards, large quantity of adsorbent media is required for each contaminant. Homogenizing all these materials together is not possible in huge volume as they phase separate due to variation in their density. Moreover, homogenized mixture cannot offer required contact time for individual contaminants. Contact time which is determined by adsorption kinetics of adsorbate on the adsorption media is different for different contaminants. Hence, for simultaneous removal of different contaminants, it is necessary to create the capability to fabricate filtration block having multiple filtration media wherein the volume, porosity, dimension, etc. can be varied as per the requirement.

Necessity for low-pressure drop: It has been understood that population lacking access to clean drinking water is largely concentrated in rural areas. Providing clean drinking water to people in rural areas at the household level is a challenging problem due to several reasons: erratic electricity supply, unavailability of online water supply sources and poor economic status. All these reasons have led to the creation of a new water purifier market segment (gravity-fed, zero electric power water purifier). This market segment is growing at a much faster pace due to low cost of product ownership.

A technical challenge with the gravity-fed water purification is that water pressure available for the flow of water through the porous filtration cartridge. Typically, water height pressure in a gravity-fed water purifier is less than 0.5 lbs/sq in (water head of 34 cm). As reported by Bommi et al. in United States Patent 7396461, a typical water flow rate through 15 mm wall thickness radial flow block is 200 ml/min. Reported data shows that the flow rate drops linearly with increasing wall thickness. Upon extrapolating the linear correlation between flow rate and wall thickness, it is expected that flow rate will become negligible at a wall thickness of 30-35 mm. A wall thickness of 30-35 mm is also not sufficient for multi-contaminant removal. Thus, modification in the existing design of gravity-fed water purification cartridge is necessary for improving the pressure drop through the cartridge.

Necessity for the continuity of flow rate: An aspect of the decreasing flow rate upon prolonged use is reported in an earlier patent application WO/2007/059832. The decreasing flow rate is attributed to the entry of air inside the porous block upon prolonged use, wherein air bubbles inside the block prevent the water flow. The patent application WO/2007/059832 reports that presently available filter cartridges based on activated carbon get choked frequently, especially in gravity water filters and provide very low flow rates of water. Due to constant choking, the filter cartridges require frequent backwashing, thereby causing hassles to the consumer. In a block, flow rate chocks due to incomplete displacement of air packets trapped inside the filtration medium and in the block. In in-line or pressurized systems, water pressure is high so as to expel the trapped air packets. When the primed (air free) condition is reached and maintained, chocking of flow rate is prevented. But gravity-fed filtration apparatus cannot exert enough water pressure to displace air packets. Thus flow rate drops frequently.

Therefore, it is necessary to address the issue of flow rate continuity. The problem of flow rate choking is further accentuated in the axial flow cylindrical blocks due to increased path length of the block. This is one of the major reasons which prevent the use of axial flow blocks in gravity-driven domestic water purifiers. We have found that primary reason for the drop in the flow rate upon continued use is related to the hydrophobic character of the block. Gravity-fed water purifiers reported previously are hydrophobic due to the use of binders, which are inherently hydrophobic. The hydrophobic nature of the block increases the difficulty in displacing air with water using gravity pressure. This is further described and addressed in a subsequent section of the application.

Necessity for in-situ sealing: Prior to use, the porous blocks have to be suitably covered with a housing unit. This is also important for axial flow blocks. The way it is sealed to a solid tube determines the reliability of the filtered water and manufacturing cost. Various food grade sealants and cements have been used. Production of axial flow blocks is commercially expensive due to the need of extra manual work, curing time and costly food grade sealants/cements. Moreover, clogging of pores happens due to sinking of organic based sealants inside the block and swelling of media such as activated carbon in the solvents (VOC) used in sealants.

Therefore, a new approach is necessitated for the appropriate sealing of the block with the housing unit.

It is commonly understood that the flow rate through a porous block depends on a number of parameters: path length for the water through the porous block, size of the particles used, packing density, type of binder used, wettability and method of block preparation (*reference prior art*: United States Patent 7396461, United States Patent 20060000763, PCT application WO 2007/109774 A2). While the fully functional axial flow block as reported in this application benefits from the prior art on gravity-fed radial flow block (typical path length: 1-2 cm), gravity-fed axial flow blocks (typical path length: 4-15 cm) can be operated only when critical technical challenges are addressed (high pressure drop, flow rate drop on continued use, housing). The associated prior art for these challenges is reviewed here.

Prior art related to axial flow filtration device

As described earlier, axial flow filtration device is suitable for effective water purification due to increased contact time and consequent higher removal capacity thereby offering complete utilization of media.

Prior art on axial flow blocks: In axial flow cartridges, fluid flow occurs parallel to gravity. For decades, axial flow cartridges such as carbon cartridges are made by packing loose granular activated carbon in a column for low pressure drop applications. Manojlovic et al. in U.S. Patent No. 4,684,471 demonstrates an axial flow granular bed filtration cartridge and the process for carrying out the water purification. Collins et al. in U.S. Patent No. 6,159,363 teaches the importance of primed (air-free) condition of bed for adequate flow rate. However, packed carbon particle bed system results in channeling (flow of fluid without contact with the adsorbent media) where domestic water cannot be treated effectively. Additionally, the use of granular media also affects the performance because the kinetics of adsorption with granular media is slower than powder media.

The axial flow porous blocks have been employed to overcome channeling of untreated water. The axial flow blocks have been used in in-line and mechanically pressurized systems. Example of simple mechanical filtration device is reported by Busch et al. (U.S. Patent No. 5,064,534). Although axial flow cylindrical block shows much high performance, in practice axial flow carbon blocks are not employed in gravity-fed domestic water purifiers due to increased pressure drop and reduced low flow rate.

Prior art on the continuity of flow through gravity-fed blocks: Continuity of flow through a porous block upon prolonged use is a problem associated with the degree of wettability. The ease of wettability is further correlated to the ease of priming (ease of expelling the trapped air and maintaining “air-free” condition) a gravity-fed filtration block. Wettability also influences the flow rate of the porous block. Wettability is determined by the chemical groups present at the surface.

Although filtration medium such as powdered activated carbon has both hydrophilic and hydrophobic surfaces, the final carbon block becomes highly hydrophobic due to hydrophobic nature of binder used. Hydrophobic binder increases the cohesive force and hence wettability becomes poor. Hydrophilicity of the carbon block has been enhanced by using additives such as zeolite materials, surfactants, fiberglass, silica gel and humectants, by sourcing carbon having large amount of acidic surface oxygen, by incorporating hydrophilicity in the binder particle by physical process such as plasma treatment and chemical process such as functionalizing surfactants or hydrophilic molecules, etc. But, incorporating these additives and surface modification of carbon and binder are cost-consuming processes. In conventional blocks, quantity of the binder used has been increased to get the strong block in order to prevent cracking or collapse of block under water pressure over a period of time. As a result of increase in binder quantity, wettability decreased due to hydrophobicity, flow rate decreases due to reduced wetting, removal performance decreases due to surface coverage of active filtration media by binder, and hence priming becomes difficult.

Mistry et al. in Indian patent applications 1452/MUM/2005, 801/MUM/2005 and PCT application WO/2007/059832 teaches an alternative method for preventing the leak of air in a running block by introducing a receptacle for holding the water that exits from the block. A similar approach of holding the water at the exit from the filtration bed is also described by Collins et al. in US patent no. 6,159,363. A challenge with this approach is that introduction of receptacle containing several turns/bends in the path of water introduces additional pressure drop, which further leads to lowering of the flow rate.

Prior art on the in-situ sealing of the block with housing: Taylor et al. in U.S. Pat. No. 5,817,263 teaches an alternative method for sealing an axial block with non-porous sleeve by heat. A method of making an axial block inside a non-porous thermoplastic sleeve which is kept inside a mold is disclosed.

Therefore, the object of the present invention is the art of making gravity-fed axial flow cylindrical block having a height/diameter aspect ratio significantly greater than conventional block filters for water flow, so as to have sufficient contact time for complete removal of various contaminants.

The another object of the present invention is the art of making a filter block that does not suffer from low flow rate and frequent choking problems as gravity-fed purifiers.

The another object of the present invention is the art of easy and fast making of cost-effective, axial flow cylindrical block avoiding extra manual work, curing time and costly food grade sealants/cements.

The another object of the present invention is the art of making an axial flow block having many active filtration media stacked in multi-layered fashion for the removal of various contaminants such as organic, inorganic and biological species at desired flow rate.

SUMMARY OF THE INVENTION

The present invention describes the art of making gravity-fed axial flow porous composite block for the removal of various contaminants at desired flow rate. More particularly, the present invention demonstrates an axial flow block having end-to-end flow prepared directly inside a non-porous/porous filter housing tube.

The present invention discloses the unique axial block which operates with the gravity pressure (up to 0.5 psi) and has the height/diameter ratio 0.2 to 3.75; preferably, an aspect ratio of 2-3. Height is the length of the adsorbent media in the axial flow cartridge through which contaminated water passes. The art of making the block as explained here is such that the water experiences low pressure drop and the flow rate doesn’t decay with prolonged use. The longer path length introduced in the porous block is meant to deliver improved performance for a given contaminant and also handle multiple contaminants when different filtration media are stacked as layers in the block. The need to address multiple contaminants in drinking water has to be looked at in the context of published reports for the presence of various contaminants in water. Addressing multiple contaminants with various filtration media has become feasible in the light of our recent inventions for novel materials removing specific contaminants (Indian patent 200767, Indian patent 20070608, Indian patent applications

2052/CHE/2009, 2082/CHE/2009, 169/CHE/2009, 1529/CHE/2010, 2433/CHE/2010, 2563/CHE/2010).

In this invention, an axial flow cylindrical block fully functional at gravity-fed conditions is obtained when the quantity of binder used is reduced from the conventional quantity to a defined value. The present invention is contrary to the knowledge gained from the art of making conventional radial flow blocks. When the quantity of binder used in conventional block is used in axial flow blocks, flow rate decays very fast. A dramatic increase in flow rate and continuity in flow rate is seen as the quantity of binder used is reduced.

According to the method of present invention, the hydrophilicity of the block is increased by reducing the quantity of binder used to form the porous block. The axial flow block is properly housed inside a solid tube. The circumferential surface of cylindrical axial block is supported by solid tube. As axial flow block is properly housed and supported inside a solid tube, the strength of the block is enhanced. Hence, cracking or collapse of block under water pressure over a prolonged time is not possible. As housing tube enhances the strength of the block, the quantity of binder required is reduced significantly. Hence, the filtration medium to binder weight ratio defined for conventional blocks need not be followed for the making of axial flow cylindrical blocks. Accordingly, strong axial block is made using lesser quantity of binder.

The embodiment of the present invention includes the procedure for making porous block of various filtration media. Various modifications and variations are done to the known art of making porous blocks. Most of the filtration media such as activated carbon, activated charcoal, activated alumina and the like have unwanted moisture content. Active filtration media tend to absorb moisture over a period of time. The moisture content in the filtration media depends on number of parameters: the method of synthesis, nature of the material, material storage, etc. Moisture content increases the weight of the raw active filtration materials. If moisture is not completely removed before blending with desired binder, the actual active filtration media to binder weight ratio increases post production. Hence, after the sintering process, the weight ratio of binder in porous block is higher than the desired/calculated weight. This further increases the hydrophobicity of the block. Moreover, when filtration media containing high moisture content is blended with the binder, sintering time has to be increased to evaporate the moisture and then to melt the binder. The filtration media to binder weight ratio differs enormously from media to media based on their density, surface roughness, shape and size. Accordingly, in the present invention, all the active filtration media and binder are dried to remove moisture, weighed as per desired ratio and used for making the block.

In view of the above, the present invention describes the art of making of moldless axial flow porous composite block. A non-porous/porous filter housing tube is itself used as in-situ mold, wherein the block is sealed inside the housing tube by coating a layer of the thermoplastic binder in the inner diameter of the housing tube. Use of ex-situ metal molds is avoided. The composite block is made by using any suitable binder with any active filtration media such as activated carbon, activated charcoal, activated alumina, sand, metal oxide nanoparticles loaded activated alumina/carbon, metal nanoparticles loaded activated alumina/carbon, ion exchange resin beads, any composition of micron size metal oxides such as silica, titania, manganese oxides, zeolite and the like. In addition, the composite block is also made by using single active filtration media or multiple layers of different filtration media or homogenized mixture of all filtration media.

Taking into account of the present invention, a non-porous/porous filter housing tube is used as in-situ mold. The housing tube is porous or non-porous depending upon the requirement. A non-porous/porous tube has multiple layers of different filtration media or homogenized mixture of required active filtration media and suitable binder. The whole mixture is sintered at a temperature near to the melting point of the binder used. Inner wall of the housing tube is coated with the thermoplastic binder. Upon heating during the process of block making, thermoplastic binder melts and develops a strong contact between the circumferential surface of the block and inner wall of the housing tube. The thermoplastic binder used to blend the active filtration media also binds with the housing tube. The non-porous/porous housing tube is thermally and mechanically stable under molding.

DESCRIPTION

DETAILED DESCRIPTION OF THE INVENTION

When the axial flow cylindrical block was made by following the parameters defined for making conventional radial flow blocks (method of making radial flow blocks are highlighted in a number of patents and patent applications, e.g., U.S. Pat. No. 4,664,683, U.S. Pat. No. 6,368,504 B1, U.S. Pat. No. 5,024,764, U.S. Pat. No. 5,922,803, U.S. Pat. No. 3,538,020, U.S. Pat. No. 5,328,609, U.S. Pat. Pub. No. 2006/0000763 A1, U.S. Pat. No. 7,429,326 B2, U.S. Pat. No. 7396461, U.S. Pat. No. 4,753,728 and 5,017,318), an axial flow block fully functional under gravity-fed device was not obtained. Without wishing to be bound by theory, the poor functionality such as low flow rate, decaying of flow rate, frequent chocking, etc., are attributed to the high quantity of the binder, inherently hydrophobic in nature, used in the cartridge.

When an axial flow cylindrical block was made with filtration media to binder ratio of 80:20 and sealed inside a solid housing tube using sealants, its flow rate decayed very fast and number of litres filtered at consistent flow rate was very small (called the reference value). Contradictorily when the similar cylindrical block was run in in-line or mechanically pressurized condition or gravity-fed radial flow mode (bored at the core), the flow rate was consistent for a long duration. It was then found that when the binder weight to filtration media ratio is greater than 20:80 (like 25:75, 30:70, 40:60, etc.,), the functionality of the axial cylindrical block further worsens as compared to the one having a ratio of 15:85. This finding was common for all axial flow cylindrical blocks made using any filtration medium such as activated carbon, activated alumina, metal oxide, etc., blended with any binder such as UHMWPE, HDPE, etc.

An important parameter to remember is that the binder to filtration media ratio can’t be reduced to extremely low values which affect the strength/stability of the block while the block is used for water purification.

Although the relation between functionality of axial flow cylindrical block and binder weight percentage is new and not fully known, following observations were seen.

Observation A

Higher the binder weight percentage, faster is the choking of the axial flow blocks. It was found that the typical requirement of higher binder weight percentage is necessary due to the presence of moisture content in the active filtration media and the need for higher strength in the block. Most of the filtration media such as activated carbon, activated charcoal, activated alumina and the like were found to have 1-10% moisture content. Active filtration media are liable to absorb moisture over a period of time as they are highly porous and have hydrophilic group at their surfaces. When active filtration media were produced by wet chemical methods or surface modified by wet chemical methods or surface loaded with another material by wet chemical methods, the amount of moisture in the filtration media will be higher. Moisture content increases the weight of the active filtration raw materials. Moisture content in media differs from one medium to another medium. After the block production, there is a change in the actual active filtration medium to binder weight ratio because of the incomplete removal of moisture before blending with desired binder. Consequently, after the sintering process, the weight ratio of binder in porous block is higher than the desired/calculated weight. This in turns increases the hydrophobicity of the block. In view of the above, in the present invention, all the active filtration media and binder are dried to remove moisture, weighed as per desired ratio and sintered.

Example A1

80 g of raw powdered active filtration medium and 20 g of suitable binder were taken in the ratio of 20:80 and homogenized. An axial block was molded at a temperature higher than melting point of the binder used, maintained for 1 and 1/2 hrs and then air-cooled. Made block was weighed again and 10% decrease in theoretical weight was observed. Therefore the binder to media weight ratio changed from 20:80 to 22.22:77.78. The binder percentage increased from 20:80 to 22.22:78.78, that is 11%.

Example A2

As learnt from example A1, blocks were made by the following method:

Powdered active filtration medium was dried at 100 ^{0}C for an hour. Filtration medium can be any material, for example, carbon is taken here. Filtration medium to binder weight ratio of 10:90 was measured, homogenized and block was made. Then block was molded. Made block was weighed again and negligible difference in theoretical weight was observed.

Observation B

As learnt from observation A, blocks were prepared by first removing moisture from active filtration media to get the right weight ratio. As the binder weight percentage was increased, the frequency of chocking was found to be higher when the block was sealed inside a solid tube. It was observed that the displacement of air by water became difficult in axial block. The depth is maximum in axial flow cylindrical block, compared to the depth in the conventional blocks. In an axial block, air moves upward and water moves downward. The increase in the depth of the axial block reduces the complete displacement of trapped air from the block. On increasing the binder quantity, the block becomes hydrophobic as most binders are hydrophobic in nature. The insufficient displacement of trapped air in the block and the force exerted by inefficient flow of water through the hydrophobic block could be the reasons for the frequent chocking and less flow rate. If this is to be assumed, an axial block having height to diameter aspect ratio between 2 and 3 cannot offer the desired flow rate and continuity of the flow rate. Additionally, it was found that the method by which the block was sealed decided the performance.

Generally, an axial flow block was molded and sealed in a tube using suitable sealants. Various food grade sealants (such as epoxy resins, silicone sealants, cements, etc.) were used. It was found that the same dimension of the blocks prepared under same condition showed different flow rate with different sealants. The expected flow rate was not obtained from none of the above sealants. It was found that the used sealants sink inside the block depending upon their viscosity and solvent used to cure them. Hence, there was the loss of quantity of material used, reduction in actual diameter and likely closure of pores.

Example B1

As learnt from the example A1 and A2, powdered activated carbon was dried and taken. Carbon to binder weight ratio of 20:80 was measured and homogenized. Totally, three blocks were made. Two blocks were made inside a metal mold at a temperature above the melting point of the binder and maintained for 1 and 1/2 hour. It was then air-cooled. One was sealed inside a non-porous solid tube using epoxy resins and another was sealed using a silicone sealant. Both the blocks were run in axial flow mode. And third block was prepared directly inside the silicone extrusion tube. The block sealed inside a non-porous solid tube using epoxy resin chocked earlier than the one sealed using silicone sealant which chocked earlier than the one prepared directly inside the tube.

Observation C

As understood from observation B, the two necessary factors for operating an axial block under gravity are the continuous flow of water through porous block with ease and complete ejection of air from the block. The process of expelling the trapped air from an axial block and maintaining "air-free" condition in gravity-fed filtration block depends on the ease of wetting. Apart from pore size, the flow rate through the carbon block depends on wettability. Wettability is determined by the chemical groups present at the surface. Hydrophilic groups enhance the adhesion force by reducing the surface tension which arises due to the cohesive force. Despite the fact that active filtration media have hydrophilic surfaces, the final axial block becomes highly hydrophobic as binder used are hydrophobic in nature. Hydrophobic binder increases the cohesive force and hence wettability decreases. When the binder weight percentage is high in the block, hydrophobicity of the block increases. As a result of the increase in binder quantity, wettability decreased as a result of hydrophobicity, flow rate decreases due to worsening of wetting, and hence priming becomes difficult. Quantity of binder determines the strength in the block. The axial flow block is properly housed inside a solid tube. The circumferential surface of cylindrical axial block is supported by the solid tube. The structural integrity/strength of the axial block is based on the solid tube. Hence, cracking or collapse of block under severe water pressure over a period is not possible. The quantity of binder required is reduced as covering the tube enhances the strength of the block. For this reason, the media/binder ratio defined for conventional blocks need not be followed for the making of axial flow cylindrical blocks. Consequently, a strong axial block is made using lesser quantity of binder.

Example C1

Dried powdered medium and hydrophobic binder were taken. Binder to medium weight ratio of 10:90, 20:80 and 60:40 were measured and homogenized. Three blocks were made inside a metal mold at a temperature above the melting point of the binder was used and maintained for 1 and 1/2 hour. It was then air-cooled. All the blocks were sealed inside a non-porous solid tube. For simplicity, blocks were cut into 50 mm diameter and 70 mm height (height/diameter ratio 1.4). All the blocks were run in axial flow mode. All the blocks were continued to run without any maintenance (periodic backwashing) till the flow rate dropped drastically. The block having the weight ratio of 10:90, 20:80 and 60:40 showed the highest flow rate of 296 mL/min, 240 mL/min and 80 mL/min, respectively. The average flow rate is shown in Figure 1. It is evident that increasing the hydrophobic binder percentage decreases the flow rate and the continuity of the flow.

Example C2

Dried powdered medium and hydrophilic binder were taken. Binder to medium weight ratio of 10:90, 20:80, 30:70 and 60:40 were measured and homogenized. All blocks were made inside a metal mold. It was then air-cooled. All the blocks were sealed inside a non-porous solid tube. For simplicity, blocks were cut into 50 mm diameter and 70 mm height. All the blocks were run in axial flow mode. All the blocks were continued to run without any maintenance (periodic backwashing) till the flow rate dropped drastically. The blocks having the weight ratio of 10:90, 20:80, 30:70 and 60:40 showed the highest flow rate of 320 mL/min, 440 mL/min, 530 mL/min and 570 mL/min, respectively. The average flow rate is shown in Figure 2. It is evident that increasing the hydrophilic binder percentage increases the flow rate due to affinity towards water.

It should be noted that an axial flow block having the binder to media weight ratio equal to/below 5:95 can be made if the molding temperature is significantly higher than the melting temperature of the binder. It should also be noted that binder to media weight ratio and the molding temperature is determined by the melt flow index of the binder used. In the present embodiment, the molding temperature, binder to media weight ratio, molding duration and compression level are not fixed universal. All these parameters vary from binder to binder, media to media and binder to media. But all these parameters were optimized for each binder for enhanced priming.

In the present embodiment, gravity-fed axial flow cylindrical block can be positioned vertically or horizontally; preferably, under vertical mode. In the vertical mode, axial block can have downward water flow (in the direction of gravity) or upward water flow (in the opposite direction of gravity). In the horizontal mode, axial block has water flow perpendicular to gravity and block can be kept in perfect horizontal position or in slightly tilted position.

In the present embodiment, a cost-effective, easy and fast making of an axial flow cylindrical block is demonstrated. Instead of first making the axial block using a metal mold and sealing it subsequently inside a non-porous solid tube using non-toxic sealants/cement, a method for uniting both the molding steps and sealing step in a single embodiment was performed. A non-porous/porous solid filter housing tube was used as in-situ mold and in-situ sealed by heat. The used non-porous/porous tube does not melt under the molding temperature. Inner wall of the tube is bound to the circumferential surface of the block by thermoplastic binders. The thermoplastic binder used to blend the active filtration media also binds with the housing tube. If needed, the binder particles can be first spray coated on the inner surface of the tube before filling the homogenized media. The so-called non-porous tube can have a closure at one end like a cylindrical container.

The non-porous/porous housing tube defined, can be made up of earthenware, stoneware, porcelain, ceramic filter tube, nylon, teflon, fibre reinforced plastic, high density polyethylene (HDPE), ultra high molecular weight polyethylene (UHMWPE), polypropylene (PP), polyvinyl chloride (PVC), ultra polyvinyl chloride (UPVC), and the like depending upon the requirement and the sintering temperature. When binder such as UHMWPE is taken, tubes such as earthenware, stoneware, porcelain, ceramic filter tube, nylon, teflon, fibre reinforced plastic and the like can be used.

The composite block can be made by using any suitable thermoplastic binder with any active filtration media such as activated carbon, activated charcoal, activated alumina, sand, metal oxide/hydroxide nanoparticles loaded activated alumina/carbon, metal nanoparticles loaded activated alumina/carbon, ion exchange resin beads, any composition of micron size metal oxides such as silica, titania, manganese oxides, zeolite and metal hydroxides such as boehmite, iron oxide-hydroxide.

The embodiment of the present invention has the design flexibility to target particular contaminant for the effective and complete removal and to target more than one type of contaminant in domestic water such as organic, inorganic and biological depending upon the filtration media used.

In one embodiment of the invention, activated carbon is the filtration medium. Activated carbon manufactured from any source such as bituminous coal, nut shell, coconut shell, corn husk, polymers, wood, and the like can be used in the present embodiment. Activated carbon used here can be of any carbonaceous material activated by physical treatment, chemical treatment, and the like. The surface area of the powdered activated carbon is preferably greater than 700 m^2/g and more preferably exceeds 1000 m^2/g.

In the present invention, the mesh size of any filtration medium is approximately U.S. mesh 20x325. Preferably media having particles not more than 5% medium passes through a sieve of U.S. mesh 200, not more than 60% passes through a sieve of U.S. mesh 100 and not more than 5% is retained on a sieve of U.S. mesh 50.

In one embodiment of the invention, an axial flow cylindrical activated carbon block showed complete removal of chlorine from domestic water using lesser media than the conventional block.

Example D

30 g powdered activated carbon was dried at 100 ^{0}C for an hour. UHMWPE was used as binder. Carbon to binder weight ratio, preferably in the range of 92:8 to 86:14, was measured and homogenized. A non-porous cylindrical housing tube such as nylon tube having an end closed was taken. The inner surface was pre-coated with binder particle and was filled with homogenized mixture of carbon and binder. It was heated to a temperature so that at the core of the housing tube filled with mixture was above the melting point of the binder used and maintained for 1 and 1/2 hour. It was then cooled to room temperature. Bottom closure of the housing tube is sliced off to have an end-to-end axial flow. An axial carbon block having 50 mm diameter and 35 mm height (height/diameter ratio 0.7) was obtained and was run in vertical mode. Minimum 3000 L of 2 ppm

chlorine solution was passed through carbon block. The percentage of removal is shown in Figure 3. It showed the removal performance of more than 99.9% constantly.

In one embodiment, when powdered activated carbon was used, the binder content was in the range of approximately 5-20%, by weight. Preferably, 8-12% by weight. In another embodiment, when activated alumina/nanoparticle loaded alumina was used, the binder content was in the range of approximately 3-10% by weight. Preferably, 4-6% by weight. The binder particles were in the range of approximately 20-200 µm, preferably, matching the media size.

The axial cylindrical block can be of single active filtration medium or multiple layers of different filtration media or homogenized mixture of all filtration media. Different binder ratio was used for different filtration media.

Example E1

Powdered activated carbon, activated alumina, silver nanoparticle loaded metal oxides were dried at 100 ^{0}C for an hour. A common binder was used for all media. Carbon to binder weight ratio preferably between 92:8 to 86:14, alumina to binder weight ratio preferably between 97:3 to 90:10, silver nanoparticle loaded metal oxides to binder weight ratio preferably between 97:3 to 90:10, were measured and homogenized separately. A non-porous solid tube, inner surface pre-coated with/without binder particle was taken. Homogenized filtration media were packed inside the tube one over the other. It was heated to a temperature above the melting point of the binder used and maintained for 1 and 1/2 hrs. It was then cooled to room temperature. An axial composite block having 75 mm diameter and 110 mm height (height/diameter ratio 1.46) was obtained and was run in vertical mode. Prepared block was tested for anti-bacterial capability. E. coli was used as a model system. The performance data is given in Table 1.

Sr.No.	SAMPLES	CFU/mL	% OF REMOVAL
1	Raw water	$5X10^8$	-
2	After 1.5 L	0	100.0
3	After 3.2 L	200	99.9999
4	After 5.0 L	12 000	99.997

Example E2

Powdered activated carbon, silver nanoparticle loaded metal oxides and fluoride removal media were dried at 100 ^{0}C for an hour. A common binder was used for all the media. Carbon to binder weight ratio preferably between 92:8 to 86:14, silver nanoparticle loaded metal oxides to binder weight ratio preferably between 97:3 to 90:10, fluoride media to binder weight ratio preferably between 95:5 to 85:15, were measured and homogenized separately. A non-porous solid tube, inner surface pre-coated with/without binder particle was taken. Homogenized filtration media were packed inside the tube one over the other. It was heated to a temperature above the melting point of the binder used and maintained for 1 and 1/2 hrs. It was then cooled to room temperature. An axial composite block having 46 mm diameter and 150 mm height (height/diameter ratio 3.2) was obtained and was run in vertical mode. Prepared composite axial block was tested for fluoride removal capacity. 10 ppm fluoride solution was filtered through the block. The performance data are given in Figure 4.

In this present invention, axial block as well as radial block can also be made directly inside a porous solid tube. Although the present disclosure only focuses on the axial flow block, a radial flow block can also be made in the above described method.

Example F

Powdered activated carbon was dried at 100 ^{0}C for an hour. Carbon to binder weight ratio can be anywhere between 92:8 to 60:40, but more preferably 80:20 was measured and homogenized. A porous dome shaped commercial ceramic filter candle was taken. Homogenized filtration media was packed inside the tube and heated so that the temperature at the core of tube was above the melting point of the binder used and maintained for 1 and 1/2 hrs. It was cooled to room temperature. Ceramic candle filled with carbon block was bored at the core to make a hollow cylindrical core.

The present invention also has a proficiency to solve the well-known wall effect often seen in granular media filter devices by a simple method. To arrest the wall effect (easy channeling of water at the junction of media and inner wall of media container), the sealing method above described (Example D, E1 & E2) are done. The granular media used for filtration purpose was pre-coated at the surface of the housing tube using suitable binder. This method was common for any type of filter devices having loosely packed filter media.

Example G

A desired housing tube in a desired dimension was taken. Thermoplastic binder of U.S. mesh 50x150 having high melt-flow index was coated on the inner surface of the housing tube. The granular media to be used was filled inside the pre-coated housing tube densely and heated above the melting point of the binder used to stick the granular media to the housing tube.

DETAILED DESCRIPTION OF THE DRAWINGS

TAB. 1 is performance data of an axial silver block filter for bacteria removal (prepared as explained in example E1).

FIG. 1is performance data of an axial block filter made using hydrophobic thermoplastic binder (prepared as explained in example C1).

FIG. 2 is continuity of flow rate data of axial composite block filters made using hydrophilic thermoplastic binder (prepared as explained in example C2).

FIG. 3 is performance data of an axial carbon block filter for chlorine removal (prepared as explained in example D).

FIG. 4 is performance data of an axial block filter for fluoride removal (prepared as explained in example E2).

FIG. 5 is a view of an axial composite block filter made in agreement with a preferred embodiment of the present invention.

FIG. 6 is a cross sectional view of an axial, vertical composite block filter made in agreement with a preferred embodiment of the present invention.

FIG. 7 is a three dimensional view of an axial block filter manufacturing system made in agreement with a preferred embodiment of the present invention.

FIG. 8 is a pictorial view of an axial/radial block filter manufactured inside a dome shaped ceramic block made in agreement with a preferred embodiment of the present invention.

The object of the present invention is described in detail by explaining the preferred embodiments illustrated in the drawings. Referring now to drawings, FIG. 5 shows a full vertical view of the preferred embodiment of the axial flow cylindrical block. The cylindrical block 24 shown is the sintered material made by mixing active filtration media and binder. An axial flow cylindrical block 18 is supported inside a non-porous/porous housing tube 25. In the preferred embodiment contaminated water enters through end 18, passes through cylindrical block 18 and the filtered water is collected at the end 19. The entire cross-sectional area of opening end 18 is exposed to water and the collector end 19 can be exposed to air or can be closed with a small opening for water collection.

The present embodiment describes the non-porous/porous housing tube 25 having uniform diameter along its length 55 (FIG. 5). Composite block 24 can be made inside the porous/non-porous housing tube 25 and the maximum height of the axial block 24 can be the height 55 of housing tube or can be less than 55 depending upon the requirement. The composite block 24 can be of single active filtration medium or multiple layers of different filtration media or homogenized mixture of all filtration media. The non-porous/porous filter housing tube 25 is used as in-situ mold. The housing tube 25 can be porous or non-porous depending upon the necessity. The homogenized mixture of required active filtration media and suitable binder is filled inside the housing tube 25, sintered to make a porous composite block 24 and sealed with housing tube 25. The non-porous/porous housing tube 25 is thermally and mechanically stable under molding.

The filter block illustrated in FIG. 6, shows the cross-sectional view of an axial flow cylindrical block consisting of composite block 24 having the diameter 10 and a porous or non-porous housing tube 25 having an inner diameter 40 and the tube wall thickness 8. The diameter 10 of the composite block 24 is determined by the inner diameter 40 of the housing tube 25. The thickness 8 of the housing tube 25 determines the thermal conductivity and mechanical strength of the tube.

Referring to FIG. 7, the non-porous/porous housing tube 25 can be of any shape such as rectangular tube, square tube, triangular tube, oval tube, hemi-spherical tube etc. For demonstration of art of block making, cylindrical tube is used as an example. The tube 25 is itself used as in-situ mold where ex-situ metal mold is not required for the present embodiment of the invention. The non-porous housing tube is having inner diameter 40 is taken. The tube 25 is placed on the metal disc 31. The active filtration media and binder required for the making of composite block is first oven dried to evaporate all the moisture content, weighed at required ratio, mixed to get a homogenized mixture and packed compactly inside the housing tube. The metal disc 31 fits inside the tube so that material can be easily transported for sintering and other successive processes. The packed mixture takes the dimension of the housing tube used. A movable metal disc 30 is placed on the packed material and inside the housing tube. The diameter of the movable metal disc 30 is lesser than the inner diameter 40 of the tube. The whole element is sintered at a temperature beyond the melting point of binder used. Inner wall 40 of the tube is bound to circumferential surface 12 of the block 24 by thermoplastic binders. The thermoplastic binder used to blend the active filtration media also binds with housing tube.

The housing tube 25 can have a bottom closed enclosure. In this case use, of the metal disc 31 is not required. Materials to be blended can be taken inside this cylindrical container. A movable disc 30 is placed on the material. After the sintering process, block is compressed by applying pressure on movable metal disc 30. Composite block can be air cooled or water cooled. Finally, the bottom closure is removed.

The embodiment of the present invention also includes the art of making of composite block 24 in a porous housing tube 25. Without wishing to be bound by theory, during the sintering process, certain binder cannot bind with certain active filtration media if (a) homogenized mixture is directly exposed to air, (b) huge volume of air is there due to loose packing of homogenized mixture, (c) air enters into mixture by any means. When porous housing tube 25 is used, air enters into mixture and hence, block

24 cannot be formed well due to presence of air during the sintering process. In the present embodiment, a non-porous thermal conducting container 26 is used if porous housing tube 25 is required. The porous housing tube 25 having an outer diameter 14 fits inside a non-porous thermal conducting container 26 having an inner diameter 42. The outer diameter 14 of porous tube 25 is a little less than the inner diameter 42 of non-porous container 26. There is no maximum and minimum thickness classified for the non-porous container 26 as far as mechanical strength is there. Preferably, the thickness can be 500 μm and the container can be of aluminium, iron, brass, stainless steel, or any other alloys. Unlike non-porous tube based block preparation, porous tubes are covered well inside a non-porous container for better binding.

Referring to FIG. 8, the present invention includes the manufacturing of composite block 24 inside any porous ceramic filter 52. Ceramic filter 52 having a cylindrical shape with a circumferentially extending sidewall 83 of uniform thickness 85 and a central hollow core 80 which has a closed top end and an open bottom end is used as tube. Inner wall of the ceramic filter 52 is bound to circumferential surface 12 of the ceramic filter 24 by thermoplastic binders. Diameter 80 of the central hollow core can vary from min. 30 mm to max. 100 mm. Thickness 85 of the circumferentially extending sidewall 83 can vary from min. 5 mm to max. 20 mm. Height of the circumferentially extending sidewall 83 can vary from 5 cm to 20 cm. The porosity of the ceramic filter can vary from 0.1 μm to 50 μm based on requirements. Composite block 24 can be manufactured in any shape depending upon the shape of the ceramic block filter 52. Ceramic block filter 52 used here can be of any shape and size. It can be porous open ended radial flow, dome shaped radial flow, cone shaped, hemisphere shaped. In case of porous ceramic filter 52, carbon block is manufactured in closed environment, like keeping the ceramic filter 52 which is filled with active filtration media/binder mixture inside a thermal conducting container 26. The composite block 24 prepared in a ceramic filter 52 can also be bored at the center to create a hollow central core 75 to make it a radial flow block. This radial flow block appears like a dome-shaped, radial flow, composite block having a porous ceramic outer layer. The diameter of the hollow cylindrical core 88 determines the thickness of the composite block 24.

The described embodiments are illustrative of the invention and not restrictive. It is therefore obvious that any modifications described in this invention, employing the principles of this invention without departing from its spirit or essential characteristics, still fall within the scope of the invention. Consequently, modifications of design, methods, structure, sequence, materials and the like would be apparent to those skilled in the art, yet still fall within the scope of the invention.

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WE CLAIM:

1. A gravity fed water purification system comprising;-

   a housing tube;

   an axial flow composite block; wherein;

   a. the axial flow composite block is directly made inside a housing tube without the use of any external mold;
   b. the axial flow composite block is prepared by sintering a mixture of active filtration media and a binder inside a housing tube;
   c. active filtration media are stacked in multi-layered fashion;
   d. the required binder quantity is reduced in the range of 5-20% by weight to enhance the hydrophilicity;
   e. the binder is also heat bound to the inner surface of the housing tube and thus increases the strength of axial flow composite block.;
   f. an axial flow composite block prepared with a height/diameter of ratio 0.2 to 3.75 and preferably, an aspect ratio of 2-3
   g. an axial flow composite block operates at gravity and preferably with any head pressure supplied above 0.5 psi.
2. A gravity fed water purification system as claimed in claim 1, wherein the active filtration media is activated carbon, activated charcoal, activated alumina, sand, metal oxide/hydroxide nanoparticles loaded activated alumina/carbon, metal nanoparticles loaded activated alumina/carbon, ion exchange resin beads, any composition of micron size metal oxides such as silica, titania, magnesia, ceria, manganese oxide, zeolites and metal hydroxides such as boehmite, iron oxide-hydroxide or a combination thereof.
3. A gravity fed water purification system as claimed in claim 1, wherein the active filtration media used as single layer of filtration medium or double or multiple layers of different filtration media for removing different contaminants.
4. A gravity fed water purification system as claimed in claim 1,wherein the active filtration media are dried at least at 100 °C before weighing.

5. A gravity fed water purification system as claimed in claim 1, wherein the active filtration media and binder are dried to remove moisture, weighed as per desired ratio and sintered.
6. A gravity fed water purification system as claimed in claim 1, wherein the housing tube is porous or non-porous used as an in-situ mold.
7. A gravity fed water purification system as claimed in claim 1, wherein the porous housing tube comprises at least one of earthenware or ceramic/polymeric filter candle.
8. A gravity fed water purification system as claimed in claim 1, wherein the non-porous housing tube comprises at least one of earthenware, stoneware, porcelain, nylon, teflon, fibre reinforced plastic, HDPE, UHMWPE, PP, PVC, UPVC, metal and silicone tube.
9. A gravity fed water purification system as claimed in claim 1, wherein the shape of the housing tube is one of an open ended cylinder, a dome, a cone, or a hemisphere.
10. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block is positioned vertically or horizontally.
11. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block is positioned vertically has downward or upward water flow direction.
12. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block is positioned horizontally means either in perfect horizontal position or in slightly tilted position and the tilted position has downward or upward water flow direction.
13. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block prepared using a single binder as common binder for all active filtration media.
14. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block prepared using different binders for different active filtration media.
15. A gravity fed water purification system as claimed in claim 1, wherein the inner wall of the housing tube is pre-coated with binder by heat application.
16. A gravity fed water purification system as claimed in claim 1, wherein the surface of housing tube is pre-coated with granular media using suitable binders upon heating for granular filtration.

17. A gravity fed water purification system as claimed in claim 1, wherein the binder can be hydrophobic and hydrophilic binder.
18. A gravity fed water purification system as claimed in claim 1, wherein the axial flow composite block is used for any pressure driven water purification devices.

Dated at Chennai this March 30, 2017

Signature:

D. Moses Jeyakaran
Advocate & Patent Agent
IN/PA — 369

TITLE OF THE INVENTION:

AXIAL FLOW FILTER BLOCK FOR WATER PURIFICATION AND A METHOD FOR PREPARING THE SAME

ABSTRACT

A method of preparation of gravity-fed axial flow sintered block for use in household water purifier is described. The system consists of a porous composite axial block made by blending powdered active filtration media with suitable thermoplastic binders. The constituents of the block are pre-heated separately so that the moisture content in them is removed. The porous block is made without mold and it is sealed to the housing tube. The filtration unit is an assembly having a porous composite block manufactured directly inside a non-porous/porous tube. The junction between the block and the tube is sealed in-situ by the binder used to produce the composite block.

Name of the applicant:
Indian Institute of Technology Madras
Application No.

No. of sheets:
Sheet No.

Sr.No.	SAMPLES	CFU/mL	% OF REMOVAL
1	Raw water	$5X10^8$	-
2	After 1.5 L	0	100.0
3	After 3.2 L	200	99.9999
4	After 5.0 L	12 000	99.997

Table 1

Date: 22\9\10

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Name of the applicant: No. of sheets:

Indian Institute of Technology Madras Sheet No.

Application No.

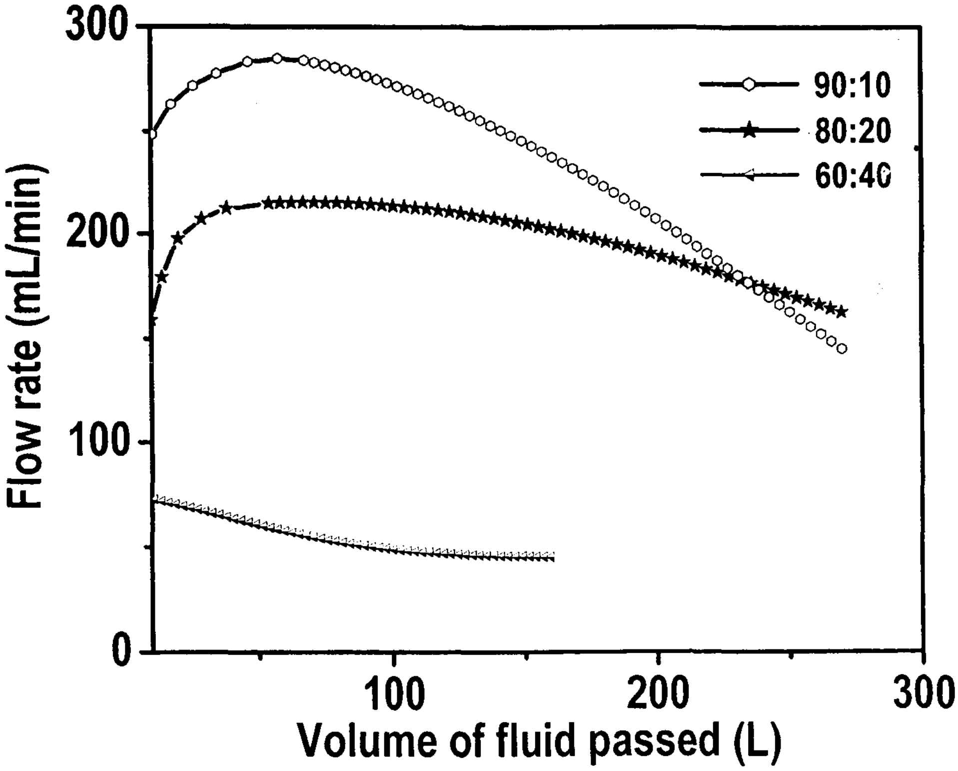

Figure 1

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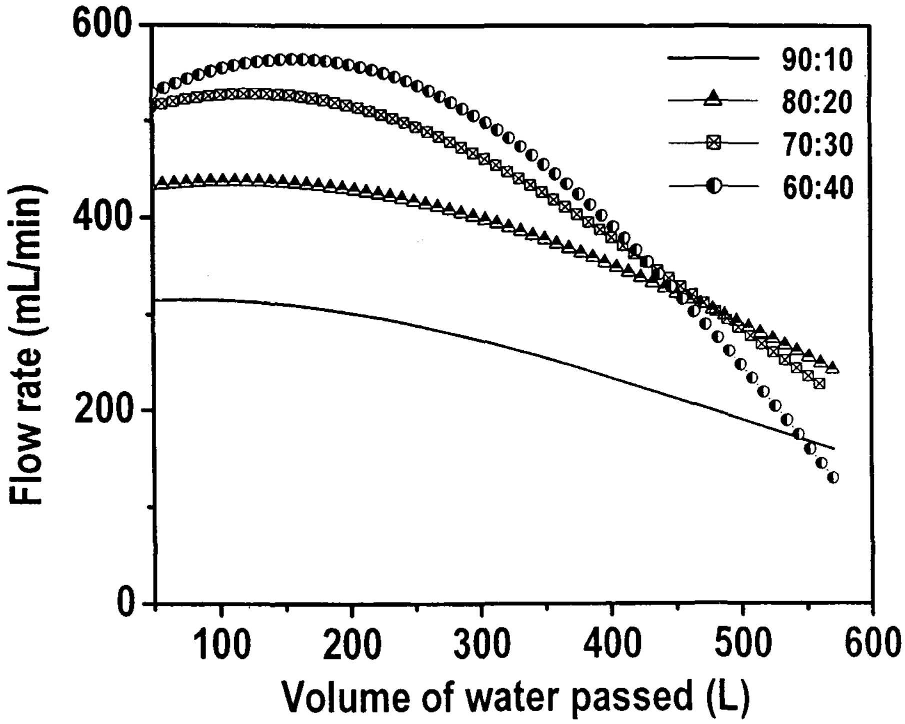

Figure 2

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Application No.

No. of sheets:

Sheet No.

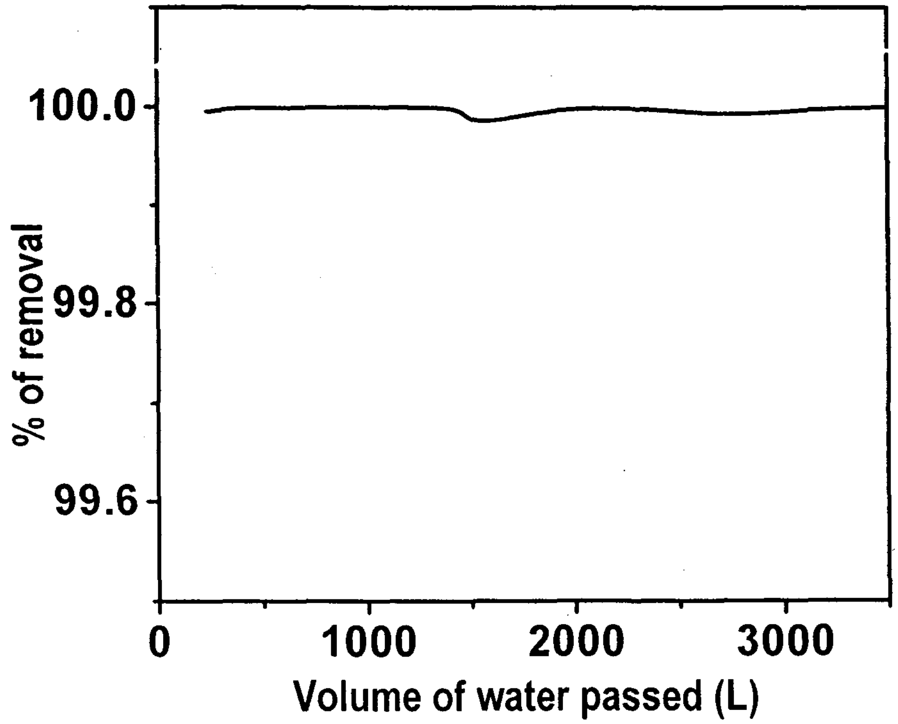

Figure 3

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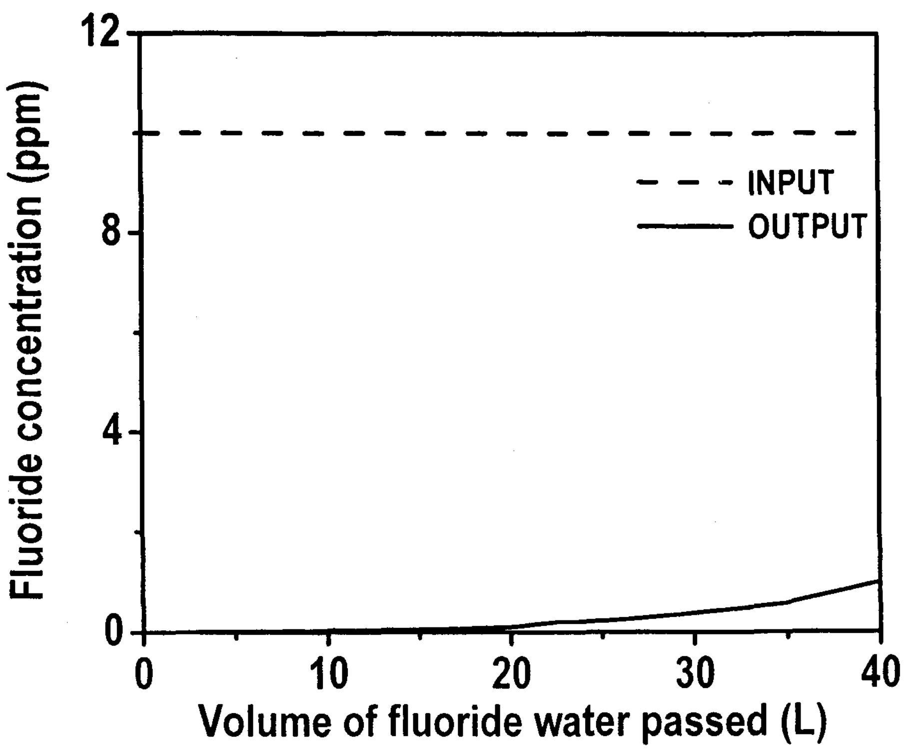

Figure 4

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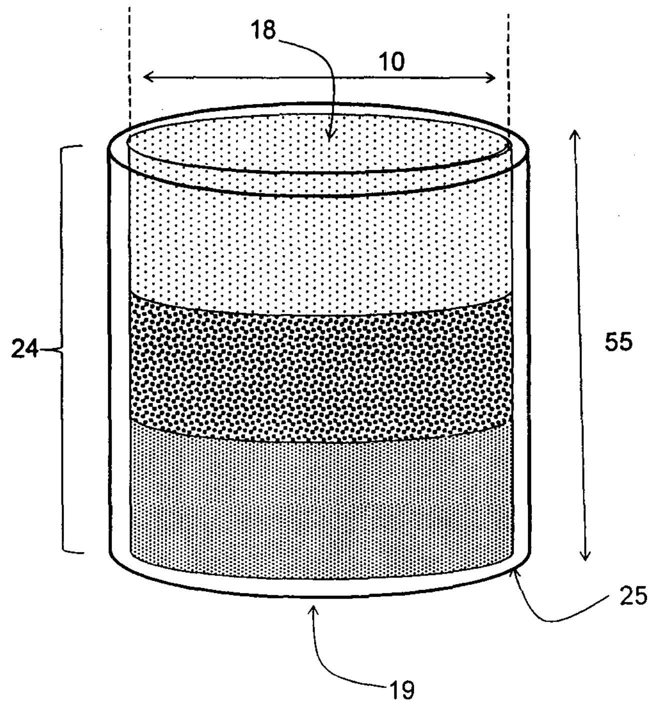

Figure 5

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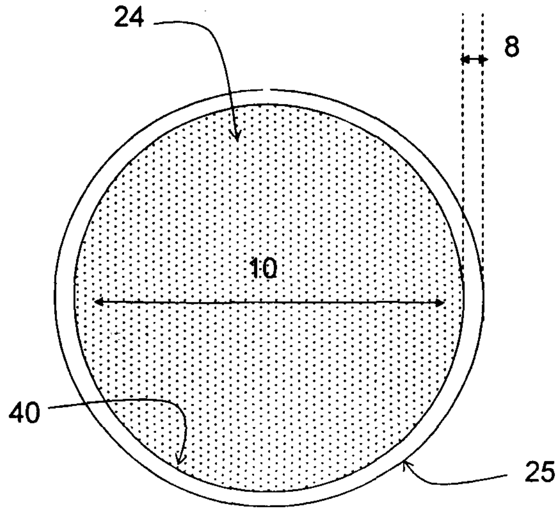

Figure 6

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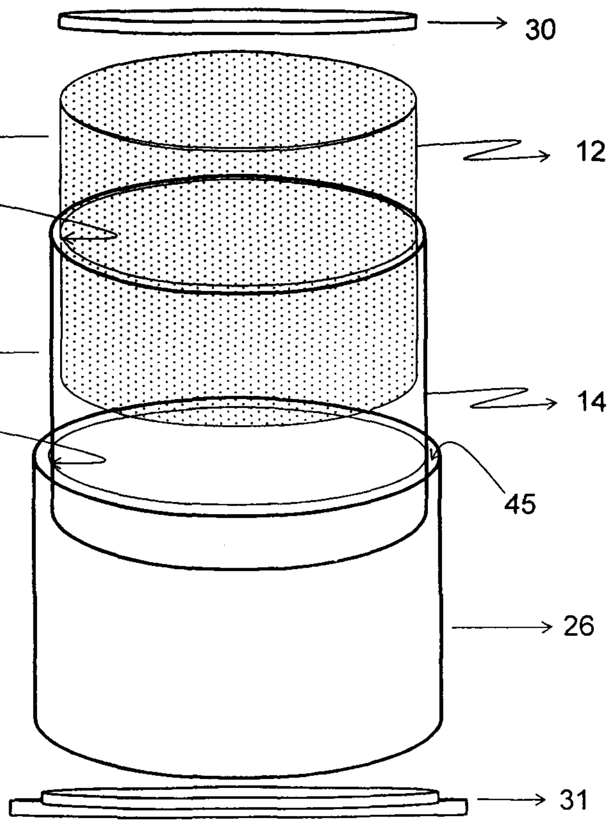

Figure 7

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Application No.

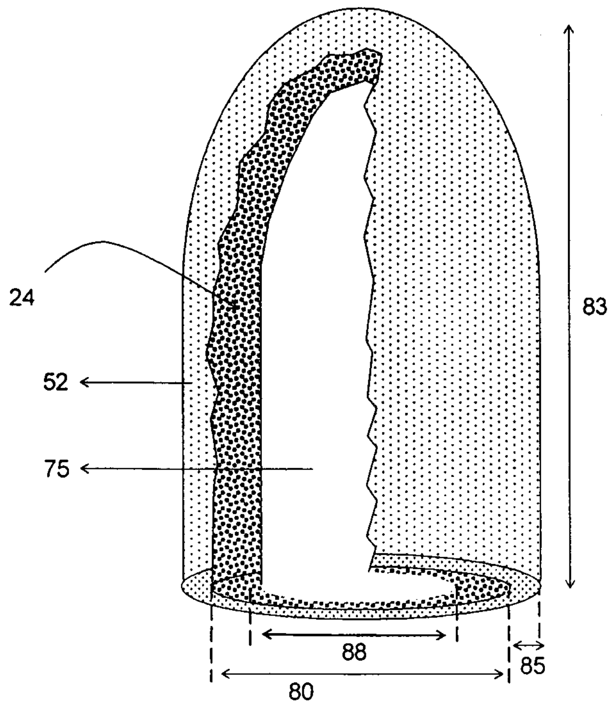

Figure 8

Date: 22\09\10

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