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(54) Title: WATER PURIFICATION DEVICE

(57) Abstract: The present invention relates to a water purification device for effective removal of particulates, organics, micro-organisms and dissolved salts by a water purification device that has a filtration unit including a carbon block enveloped with a spirally wound layer of non-pleated fabric which in turn is enveloped with spirally wound layer of pleated fabric, encased in a housing having an inlet and an outlet and a filtration membrane in series and in fluid communication with the filtration unit whereby the water exiting the filtration unit flows through the filtration membrane. The water purification device of the invention is capable of filtration of 15000 litres of water without the requirement of any intervention at the membrane level.



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Water Purification Device**Technical field**

The present invention relates to an inline or online water
5 purification device for making water suitable for human
consumption. The present invention relates to a water
purification device for effective removal of particulates,
organics, micro-organisms and dissolved salts. The invention
has been developed primarily for use in drinking water
10 application and will be described hereinafter with reference to
this application. However, it will be appreciated that the
invention is not limited to this particular field of use.

Background and prior art

15 Any discussion of the prior art throughout the specification
should in no way be considered as an admission that such prior
art is widely known or forms part of the common general
knowledge in the field.

20 For water to be microbially safe, WHO recommends 6 log removal
of bacteria, 4 log removal of viruses and 3 log removal of
cysts. By chemical disinfection (e.g. by contacting with
halogen/chlorine) it is possible to achieve the required
removal but these disinfection methods do not achieve 3 log
25 removal of cysts. It is possible to achieve 3 log removal of
cysts by radiation-based disinfection (e.g. by exposure to
ultraviolet radiation) which also requires electricity.

Both inline and gravity fed devices are available where it is
30 possible to achieve 6 log removal of bacteria, 4 log removal of
viruses and 3 log removal of cysts using filtration in
combination with biocide action. Gravity fed devices function
in the absence of electricity and running water. However, in

using the gravity fed filters the user has to physically fill in water to be purified. All the online water purification systems have the advantage where the flow of water to be purified is directly from the tap and no manual filling is required but they require electricity and pressurized chambers for efficient functioning and this makes the use of online systems expensive.

One way of achieving 6 log removal of bacteria, 4 log removal of viruses and 3 log removal of cysts by a single process is by membrane filtration. Membranes are effective in removing suspended particles from water as well as microorganisms such as bacteria, viruses and cysts.

Generally there are two types of membranes used for the purpose of effective removal of suspended particles as well as microorganisms such as bacteria, viruses and cysts from water viz. ultrafiltration (UF) membrane and reverse osmosis (RO) membrane. Both the membranes are capable of effective removal of microorganisms from water. However RO membranes require more inlet pressure than UF membranes. RO membranes are also capable of reducing total dissolved solids (TDS) of water, which makes it a suitable process for water purification where water has high TDS. High TDS water can have a detrimental effect on health.

Gravity based ultrafiltration systems are known. These systems use ultrafiltration membranes for purification of water for domestic purposes but the rate of filtration is relatively low. The other problem is that current systems do not remove viruses effectively. Large scale industrial systems based on ultrafiltration are also known. These systems are too complex to be operated by a consumer for domestic purpose and also

these are relatively expensive. So there is a need for a method and apparatus for removing microorganisms including bacteria, viruses and cysts that is convenient to use with an efficient rate of filtration.

5

Fouling of ultrafiltration membranes is one of the key issues associated with using the technology for water purification. Fouling results in reduced flow of water through the membrane. Fouling of an ultrafiltration membrane is primarily due to

10 suspended particles and dissolved organic matter. A prefilter is generally used before the filtration through an ultrafiltration membrane and if the prefilter is not very efficient in removing suspended particles there will be fouling of the ultrafiltration membrane and thus the number of

15 interventions will be high. On the other hand, a prefilter, which is highly efficient in removing suspended particles, reduces the fouling of the ultrafiltration membrane and also the number of interventions but the prefilter itself gets clogged resulting in the reduction of flow rate and ultimately
20 the choking of the prefilter.

Water purification using RO membranes is also quite well known. Filtration methods and apparatus based on RO membranes need an efficient method for removing suspended particulates, organics etc. so that there will be less load on the RO membrane thereby
25 increasing the life of the membrane. One of the problems associated with currently available water filtration devices using the RO process is that either the life of the membrane is too low or it uses a number of different stages to reduce the load on the RO membrane.

30

US2009008318, (PRISMEDICAL CORPORATION, 2009), discloses a modular filter system which is provided with one or more modules that can be interchangeable, depending upon the

specific application or specific health or environmental issue presented. Disclosed combinations can include one or more of any of the following modules in any relative position to one another: (a) a microbiological contaminant mitigation module, 5 preferably in the form of an inverted u-shaped hollow fiber filter module wherein the fibers have ends potted on the downstream side and that consists essentially of hydrophilic fibers for water filtration with a small amount of hydrophobic fibers for venting of entrapped air; (b) a first chemical 10 mitigation module, preferably in the form of an adsorption module comprising carbon or the combination of carbon and a deionization resin; and (c) a second chemical mitigation module, preferably in the form of a deionization resin module. Modules including a carbon bed or a resin bed may be equipped 15 with a pair of hydrophobic foam bed restraints that apply opposing axial pressure to the bed in all operating conditions.

However this prior art uses at least three modules with one of the modules as a supported carbon bed. This device is 20 cumbersome due to its construction. Another limitation associated with this prior art is the number of interventions will be high due to its mesh type prefilter which is not efficient in filtering small sized particles which will eventually get deposited on the ultrafiltration membrane. 25 Though in one of the preferred embodiment it uses a bed of carbon or resin or a mixed one after the prefilter but the interventions will still be high because of the use of the supported carbon bed which is also incapable of removing small sized particles.

30

WO2008/028734, (HomeFlow Switzerland Distribution, 2005), discloses reliable filtration of particulate solids especially cysts and suspended solids in water, giving a high filtration

flow rate, and which is effective for extended periods of time as compared to similar filters of the prior art using a filter comprising layers of filtration media comprising a non-pleated layer and a pleated layer but the maximum amount of cyst that
5 could be removed was limited viz. the log removal of cyst, when the filter was new, was in the range of 1.8 to 3.6 without compromising on the flow rate. However, the cyst removal was found to drop to less than 3 log after some use.

10 The main limitation of this prior art is that it does not remove bacteria and viruses from water which will not make it microbiologically safe for consumption.

Our co-pending application 180/Mum/2009, discloses a filter
15 comprising a carbon block especially of an annular cylindrical shape enveloped with spirally wound layer of non-pleated fabric enveloped with spirally wound layer of pleated fabric that ensures reliable filtration of particulate solids including cysts while giving a high filtration flow rate and longer life.

20 It is particularly preferred that the carbon block is of annular cylindrical shape.

However this filter only works well on gravity fed device and also it is not capable of removing bacteria and viruses when
25 used stand alone.

US2009045106 (Access Business Group, 2009), discloses a water treatment system that includes a prefilter, a carbon block filter and a microbiological interception filter that operate
30 in combination to treat a fluid stream, such as water. The water treatment system may include two prefilters, for example, both a multi-layer nonwoven prefilter and a pleated fabric prefilter. The microbiological interception filter includes

carbon particles and a binder, and the carbon particles have a mean particle diameter ranging from about 60 microns to about 80 microns and with a particle size distribution in which no more than about 10 percent by weight of the particles are
5 larger than about 140 mesh and no more than about 10 percent by weight are smaller than about 500 mesh. This refers only to a prefilter and does not have an ultrafiltration membrane. Using this type of water treatment system one will not be able to achieve 4 log reduction in viruses from the water to be
10 purified. As the particle size of the microbiological interception filter is between 60 microns to about 80 microns the flow rate through the filter will be very low. To use this system with an ultrafiltration membrane use of a pump would be essential to achieve the required flow rate.

15

WO2007010549 (Gupta, 2007), discloses a house hold reverse osmosis based drinking water purifier having controlled natural mineral content in purified water. This system essentially requires the use of a pump as it is reverse osmosis based
20 purification and will not function at pressures in the range 5-20 psi. As the system discloses a simple sediment filter and a carbon filter it will not be very efficient and the number of interventions will be many.

25 WO2003068689 (Innova Pure Water Inc., 2003), discloses a portable filtration assembly that includes a housing containing a sub-micron filter disposed in the housing having hydrophilic sub-micron rated membrane filter elements. The sub-micron filter is configured to effect a six log reduction of bacteria
30 (99.9999 percent) and a four log reduction of protozoa (99.99 percent) at a flow rate between 10-30 mL/sec requiring a pressure of 1.5-10 psi. There is no disclosure to mention the removal of viruses and as there is no specific mention about

the nature of the membrane filter used, the system will not be capable of removing 4 log viruses.

The above mentioned prior art have at least one of the problems
5 such as not achieving 4 log removal of viruses or flow rate being low and requiring several interventions at the filter or the membrane level. Some of them will essentially require the use of a pump to get the desired flow rate, but even then will not be able to provide the longer life of the membrane without
10 interventions.

It has now been possible by way of the present invention to design a water purification device with fewer numbers of interventions and with higher life time of the membrane which
15 is capable of delivering microbiologically safe water. The present inventors have now been able to design a filtration system that comprises a filtration unit comprising a carbon block along with a non-pleated layer and a pleated layer of fabric and a filtration membrane unit and provides water that
20 is microbiologically safe in respect of bacteria, viruses and cysts and also free of organics, dissolved salts and other particulates. This provides flexibility of flow rate and pressure of input water. The water purification device according to the invention will enable the ultrafiltration
25 membrane to function for up to 15000 liters without any intervention at the membrane and at the same time achieving six log reduction in bacteria, four log reduction in viruses and three log reduction in cysts.

30 **Objects of the invention**

One of the objects of the present invention is to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Another object of the invention is to provide an inline water purification device with very few interventions.

It is another object of the present invention to provide a device that functions at wide range of flow rate and input
5 water pressure.

It is a further object of the invention to provide a water purification device with long lasting membrane.

It is yet another object of the present invention to provide pure water which is substantially free from bacteria, viruses
10 and cysts.

It is another object of the present invention to provide water purification device that is capable of filtration of 15000 litres of water without the requirement of any intervention.

15 **Summary of the invention**

Accordingly, the present invention provides a water purification device comprising:

- i. a filtration unit including a carbon block enveloped with a spirally wound layer of non-pleated fabric which in turn
20 is enveloped with spirally wound layer of pleated fabric, encased in a housing having an inlet and an outlet and
- ii. a filtration membrane in series and in fluid communication with the filtration unit whereby the water exiting the filtration unit flows through the filtration
25 membrane,
wherein the filtration membrane is a reverse osmosis membrane or an ultrafiltration membrane that has a molecular weight cut off of <100kD.

30 In another aspect the invention provides a method of filtering water comprising passing water successively through a filtration unit including a spirally wound layer of non-pleated fabric enveloped with spirally wound layer of pleated fabric

comprising a carbon block and then through a filtration membrane unit, wherein the filtration unit is connected to a faucet and the water passing into the filtration unit is at an inline pressure from 5 to 20 psig.

5

In another aspect the invention provides the use of a device according to the invention for 6 log removal of bacteria, 4 log removal of viruses and 3 log removal of cysts from water over 15000 litres of water without the requirement of any

10 intervention of the filtration membrane.

Detailed description of the invention

Thus the present invention provides for a water purification device comprising:

- 15 i. a filtration unit including a carbon block enveloped with a spirally wound layer of non-pleated fabric which in turn is enveloped with spirally wound layer of pleated fabric, encased in a housing having an inlet and an outlet and
- ii. a filtration membrane in series and in fluid
- 20 communication with the filtration unit whereby the water exiting the filtration unit flows through the filtration membrane,
- wherein the filtration membrane is a reverse osmosis membrane or an ultrafiltration membrane that has a molecular
- 25 weight cut off of <100kD.

The filtration unit according to the present invention requires a spirally wound non-pleated layer of fabric to first overlay the carbon block. By fabric, is meant a woven, knitted or non-

30 woven fabric. The fabric may be made of natural fibers or material or may be of synthetic origin. Preferred fabric is non-woven. Preferred material of the fabric is synthetic preferably polymeric. Suitable polymeric materials of

construction of the fabric are cotton, polyester, polypropylene, or nylon. The average pore size of the non-pleated fabric is preferably in the range of 1 to 400 micrometers, more preferably in the range of 10 to 300 microns, 5 most preferably in the range of 25 to 200 microns. The fabric forming the non-pleated layers has a thickness preferably in the range of 1 to 10 mm, more preferably in the range of 2 to 6 mm. The number of spiral windings of non-pleated layers is preferably in the range of 1 to 10, more preferably in the 10 range of 1 to 7. The total thickness of the spirally wound layers of non-pleated fabric is preferably from 1 to 30 mm more preferably 2 to 20 mm. The total surface area of non-pleated layer is preferably from 100 to 2500 cm² more preferably from 200 to 1500 cm².

15

The non-pleated fabric has zeta potential preferably greater than -40 mV, more preferably greater than -30 mV. Zeta Potential is the electrical potential that exists at the "shear plane" of a particle, which is some small distance from its 20 surface. Zeta Potential is derived from measuring the mobility distribution of a dispersion of charged particles as they are subjected to an electric field. Mobility is defined as the velocity of a particle per electric field unit and is measured by applying an electric field to the dispersion of particles 25 and measuring their average velocity.

The non-pleated fabric has specific liquid permeability preferably less than $2 \times 10^{-11} \text{ m}^2$, more preferably less than $1.75 \times 10^{-11} \text{ m}^2$. The permeability is defined as the volumetric flow 30 rate of liquid passed through a unit surface area of fabric per unit time at a constant unit differential pressure of water. The intrinsic permeability, also called the specific permeability or absolute permeability of a fabric is a

characteristic feature of the fabric structure and represents the void capacity through which a fluid can flow. The specific liquid permeability k is defined by Darcy's law as:

$$q = - \frac{k}{\mu} \frac{dp}{dx}$$

Where q = volumetric flow rate of the fluid in a unit flow area (m/s), k is the specific permeability (m²), dp is the difference in hydraulic pressure (Pa), dx is the fabric thickness (m), μ is the liquid viscosity (Pa.s)

The non-pleated fabric has surface porosity preferably less than 20%, more preferably less than 15% and most preferably less than 12%. Surface porosity is defined as the ratio of voids in the plane cross section of the porous medium to the total area of cross section.

Without wishing to be limited by theory it is believed that fabrics of spirally wound layers of pleated fabric having surface porosity and liquid permeability values in the preferred range provide relatively better cyst removal whilst requiring relatively less number of rejuvenations.

The invention requires that the pleated fabric envelopes the non-pleated layers. The properties of the material of construction of the pleated layers could be different from the non-pleated layers or could be the same, but it is preferred that it is the same. It is preferred that the total thickness of the spirally wound layers of pleated fabric is from 1 to 5 mm more preferably 1 to 2 mm.

The filter of the invention comprises a carbon block which is enveloped with spirally wound layer of non-pleated fabric enveloped with spirally wound layer of pleated fabric. It is preferred that the filter comprises multiple layers of the non-pleated fabric.

The carbon block used in the filter of invention comprises activated carbon particles bound together with a polymeric binder. Activated carbon particles are preferably selected from one or more of bituminous coal, coconut shell, wood and petroleum tar. Surface area of the activated carbon particles preferably exceeds $500 \text{ m}^2/\text{g}$, more preferably exceeds $1000 \text{ m}^2/\text{g}$. Preferably, the activated carbon has size uniformity coefficient of less than 2, more preferably less than 1.5, Carbon Tetrachloride number exceeding 50%, more preferably exceeding 60%. The activated carbon preferably has an Iodine number greater than 800, more preferably greater than 1000.

The activated carbon particles are in the size range of 5 to 300 mesh, more preferably in the size range of 16 to 200 mesh and most preferably in the size range of 30 to 200 mesh.

The activated carbon particles in carbon block are bonded to each other using a polymeric binder. Polymeric binders having a Melt Flow Rate (MFR) of less than 5 g/10 minutes are further preferred. The binder material preferably has an MFR of less than 2g/10 minutes, more preferably less than 1 g/ 10 minutes. Optimally the MFR is near zero. The melt-flow rate (MFR) is measured using ASTM D 1238 (ISO 1133) test where the tests are done at 190 °C at 15 kg load.

The amount of polymer collected after a specific interval is weighed and normalized to the number of grams that would have been extruded in 10 minutes: melt flow rate is expressed in grams per reference time.

5 The binder is preferably a thermoplastic polymer. Suitable examples include ultra high molecular weight polymer preferably polyethylene, polypropylene and combinations thereof, which have these low MFR values. The molecular weight is preferably in the range of 10^6 to 10^9 g/mole. Binders of this class are
10 commercially available under the trade names HOSTALEN from Tycona GMBH, GUR, Sunfine (from Asahi, Japan), Hizex (from Mitsubishi) and from Brasken Corp (Brazil). Other suitable binders include LDPE sold as Lupolen (from Basel Polyolefins) and LLDPE from Qunos (Australia).

15

Bulk density of the binder used as per the invention is preferably less than or equal to 0.6 g/cm^3 , more preferably less than or equal to 0.5 g/cm^3 , and further more preferably less than or equal to 0.25 g/cm^3 . The binder content can be
20 measured by any known method and is preferably measured by Thermo-gravimetric analysis. The particle size of the polymeric binder is preferably in the range of 20 to 200 micrometers, more preferably in the range of 40 to 60 micrometers.

25 The weight ratio of polymeric binder to activated carbon particles is preferably in the range of 1:1 to 1:20, more preferably in the range of 1:2 to 1:10.

The carbon block is preferably in the shape of an annular
30 cylinder, a dome, a hemisphere or a frustocone. The annular cylindrical shape is more preferred. It is preferred that the shortest path length across the carbon block i.e. the shortest

distance from the inlet surface where the water enters the carbon block to the outlet surface where the water exits the carbon block is from 5 to 50 mm, more preferably 10 to 30 mm.

- 5 The carbon block is preferably prepared by a process which comprises the following steps:
- (a) the particles of the activated carbon are mixed with the polymeric binder in the presence of water to prepare a moist mixture;
 - 10 (b) the moist mixture is then added to a mould of desired size;
 - (c) the mould is then heated to a temperature in the range from 150°C to 350°C; and
 - (d) the mould is cooled and the carbon block is then
 - 15 demoulded.

Mixing of the activated carbon particles, the polymeric binder, and water is preferably done in vessels which include an agitator, mixer with dulled impeller blades, ribbon blender, 20 rotary mixer, sigma mixer or any other low shear mixer that does not significantly alter the particle size distribution. The mixing is carried out to prepare a uniform mix. The mixing time is preferably from 0.5 to 30 minutes. Preferably, amount of water used in preparing the moist mixture is not more than 4 25 times the amount of particles, more preferably not more than 3 times the amount of particles. Optimally the amount of water used is from 0.5 to 1.5 times the weight of the carbon particles. The binder is then added to the above mixture and is further mixed. The most preferred mixer is sigma mixer.

30

The material in the mould before heating is preferably compacted. Compaction pressure may be from 0 to 15 kg/cm².

Suitable compaction pressures are not more than 12 kg/cm², preferably from 3 to 10 kg/cm² and most preferably from 4 to 8 kg/cm². The pressure is preferably applied using either a hydraulic press or a pneumatic press, more preferably a 5 hydraulic press.

The mould is usually made of aluminum, cast iron, steel or any material capable of withstanding temperatures exceeding 400°C. A mould release agent is preferably coated on the inside 10 surface of the mould. The mould release agent is preferably selected from silicone oil or aluminum foil, or Teflon or any other commercially available mould release agent that has little or no adsorption onto the filter medium.

15 The mould is then heated to a temperature of 150°C to 350°C, preferably in the range of 200°C to 300°C. The mould is kept heated for more than 60 minutes, preferably 90 to 300 minutes. The mould is preferably heated in an oven using a non-convection, forced air or forced inert-gas convection oven.

20

The mould is then cooled and the moulded filter released from the mould.

The present invention requires the use of a filtration membrane 25 following the filtration unit. The filtration membrane used can either be an ultrafiltration membrane or a reverse osmosis membrane.

Ultrafiltration membranes can be manufactured in the form of a 30 flat sheet, spiral or in the form of hollow fibres. The hollow fibre form is particularly preferred for the present invention. Ultrafiltration separates particles and microorganisms on the

basis of their size. Size may be co related with molecular weight. The concept of molecular weight cut-off may be used to characterize the membranes. In view of the present invention the ultrafiltration hollow fibre membrane is characterized by a
5 molecular weight cut-off of less than 100 kD and more preferably less than 70 kD.

The ultrafiltration membrane is preferably a hollow fiber ultrafiltration membrane.

10 The material of construction of the hollow fiber ultrafiltration membrane is polysulfone, polyvinylidene fluoride (PDVF), cellulose acetate and all other standard materials. These hollow fibre modules are commercially available for industrial and domestic use. The present
15 invention uses these commercially available hollow fibre modules.

In case of any filtration flow rate is one of the important factors. In case of inline device the flow rate of output water
20 is of prime concern. In case of the present invention the hollow fibre modules are selected such that the flow rate of output water should at least be 100 milliliters per minute, preferably between 200 milliliters per minute to 1 liter per minute.

25

For the device to work effectively when UF membrane is used, the inline pressure of the water line should be in between 5 and 20 psig

30 In another embodiment the present invention provides an RO module following after the filtration unit.

The material of construction of the RO membrane is polysulfone, polyvinylidene fluoride (PDVF), cellulose acetate and all other standard material. These RO modules are commercially available for industrial and domestic use. The present invention uses
5 these commercially available hollow fibre modules. RO membranes are made in a variety of configurations, with the two most common configurations being spiral-wound and a hollow-fiber.

In case of RO membrane, as the pore size is much smaller than
10 UF membrane we need to have a larger input pressure than for the UF membrane. Due to this reason there is provided one pump at the inlet line of the RO membrane and after the filtration unit. The inlet pressure to the RO membrane is at least 80 psig.

15

The invention also provides a method of filtering water by the water purification device, comprising passing water successively through a filtration unit including a spirally wound layer of non-pleated fabric enveloped with spirally wound
20 layer of pleated fabric comprising a carbon block and then through a filtration membrane unit. The output water from the filtration membrane unit is microbiologically safe and free from organic substances and particulates.

25 The device according to the present invention is capable of achieving 6 log removal of bacteria, 4 log removal of viruses and 3 log removal of cysts from the input water.

The device can either be used as a gravity fed device using a tank of stored water as input water to be fed into the
30 filtration unit or can be directly connected to a faucet.

The invention will now be demonstrated with examples. The examples are for the purpose of illustration only and do not limit the scope of the invention in any manner.

5

EXAMPLES

The water purification device consisted of a filtration unit encased in a housing and an ultrafiltration membrane module downstream. Water was first passed through the filtration unit
10 then passed through the filtration membrane. In operation the water entering into the housing of the filtration unit first filled up the space between the housing and the filtration unit and then flowed radially through the filtration unit where it first passed through the pleated layer then the non-pleated
15 layer and finally the carbon block. The water then filled up the space around the ultrafiltration membrane and by the pressure build up inside the module was pushed through the hollow fibers before it exits.

20 Test of efficacy of the gravity fed water purification device:

Test water having 2 -5 ppm organics, 15 - 20 ppm particulates and ~1200 ppm total dissolved solids was used to test the efficacy of the device. In order to test the efficiency of the device according to the invention the following filtration
25 units along with the ultrafiltration membrane were used and the data on bacteria, virus and cyst removal efficiency, number of interventions to get the required flow rate through the filtration unit and fouling of the ultrafiltration membrane was analysed and is presented in Table 1.

30

Example 1: The filtration unit had a cylindrical carbon block made of 78% powdered activated carbon of particle size 75 - 250 μm and 22% polyethylene binder. The water exiting the

filtration unit was passed through a 67 kDa Ultrafiltration (UF) membrane obtained from M/s Aquapulus, India. In this case, a more efficient filtration unit + UF membrane was used which is known in prior art.

5

Example 2: The filtration unit was pleated fabric that had a thickness of 1.2 mm, weight of 78 grams and a total of 25 - 26 pleats. The water exiting the filtration unit was passed through a 67 kDa Ultrafiltration (UF) membrane obtained from M/s Aquapulus, India. In this case a less efficient filtration unit + UF was used which is also a known technology.

Example 3: The filtration unit had 3 parts. It had a central cylindrical carbon block made of 78% powdered activated carbon of particle size 75 - 250 μ m and 22% polyethylene binder. The carbon block was covered by 2 layers of spirally wound fabric which was covered by a layer of pleated fabric. The spiral fabric had a thickness of 1.8 mm, surface area of ~ 1000 sq. cm and a total weight of about 50 grams. The pleated fabric had a thickness of 1.2 mm, weight of 78 grams and a total of 25 - 26 pleats. The flow of water was radially through the device where it first passed through the pleated layer, then the spiral layer and finally the carbon layer. The water exiting the filtration unit was passed through a 67 kDa Ultrafiltration (UF) membrane obtained from M/s Aquapulus, India. This was according to the present invention.

Example 4: Filtration unit as described in Example 3 consisting of a central cylindrical carbon block made of 78% powdered activated carbon of particle size 75 - 250 μ m and 22% polyethylene binder. The carbon block was covered by 2 layers of spirally wound fabric which was covered by a layer of pleated fabric. The spiral fabric had a thickness of 1.8 mm,

surface area of ~ 1000 sq. cm and a total weight of about 50 grams. The pleated fabric had a thickness of 1.2 mm, weight of 78 grams and a total of 25 - 26 pleats. The flow of water was radially through the device where it first passed through the 5 pleated layer, then the spiral layer and finally the carbon layer, but no ultrafiltration membrane was present.

Table 1

	Example 1	Example 2	Example 3	Example 4
Log removal of bacteria, viruses and cysts	6/4/3	6/4/3	6/4/3	<6 bacteria <4 viruses <3 cysts
No of interventions for the filtration unit	High. 3 interventions in 300 L. Complete recovery of UF flow rate	Low. 1 interventions in ~ 2000 L. No recovery of UF flow rate	Low. Constant flow rate over 4000L. Complete recovery of UF flow rate	Low. 2 interventions in 6000 L.
Fouling of UF due to particulates and organics	No	Yes	No	Not applicable
Maximum liters water passed without intervention at the filtration unit	~ 100	~ 2000	~ 2000	~ 3000
Maximum liters water passed without intervention at membrane	~ 15000 L	~ 8000 L	~ 19000 L	Not applicable

Data presented in Table 1 show that efficient filtration units conventionally used when used with an ultrafiltration membrane provide good microbiological safety and keep the membrane functioning without causing fouling of the same due to particulates and organics, but require several interventions at the filtration unit stage to restore the required flow rate. If a less efficient filtration unit is used the flow rate of the filtration unit can be maintained but that will affect the membrane and cause fouling. The filtration unit selected for use in the device of the present invention when used alone does

not provide the required virus removal and will not be capable of removal of total dissolved solids. Thus the combination of this filtration unit with an ultrafiltration membrane will provide a device with good flow rate requiring minimal
5 interventions until 3000 L of water has been purified and will be capable of virus removal. Thus the water purified using the device according to the invention will be microbiologically safe and will have a good taste, and large amount of water can be purified with minimal effort.

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In line water purification device:

The water purification device consisted of a filtration unit upstream and an ultrafiltration membrane module downstream. Water was first passed through the filtration unit then passed
15 through the filtration membrane. The filtration unit was connected to the faucet. The water fed into the device was ground water. It was found that more than 15000 L of water could be passed in the device according to the invention without the requirement of any intervention at the filtration
20 membrane.

Efficacy of the membrane for Virus removal using a gravity fed device:

5L of water spiked with MS2 bacteriophage at a level of virus
25 per spike approximately $1 \times 10^5/\text{ml}$ (5-log₁₀ spike) was passed at a 10 psi pressure through a ultrafiltration membrane with a molecular weight cut off <100 kD which is according to the invention and one with a molecular weight cut off >100 kD, obtained from M/s Aquaplus water purifiers Pvt. Ltd. The water
30 after passing through the membrane was collected and analysed by a serial dilution of the water sample for residual viruses and the data is presented in Table 2.

Table 2

Examples	Molecular weight cut off of the membrane	Log reduction of viruses
Example 5	67 kD	4.04
Example 6	150 kD	1.84
Example 6	150 kD	1.76

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The data presented in Table 2 show that when the molecular weight cut off of the membrane is below 100 kD as per the invention, then we obtain a 4 log reduction in removal of viruses and not otherwise. When the molecular weight cut off of the membrane was 150 kD the removal of viruses was significantly low and not acceptable as per standards for water purification.

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Claims

1. A water purification device comprising:
 - i. a filtration unit including a carbon block enveloped with a spirally wound layer of non-pleated fabric which in turn is enveloped with spirally wound layer of pleated fabric, encased in a housing having an inlet and an outlet and
 - ii. a filtration membrane in series and in fluid communication with the filtration unit whereby the water exiting the filtration unit flows through the filtration membrane, wherein the filtration membrane is a reverse osmosis membrane or an ultrafiltration membrane that has a molecular weight cut off of <100kD.
2. A water purification device as claimed in claim 1 wherein the carbon block comprises activated carbon particles bound together with a polymeric binder.
3. A water purification device as claimed in claim 1 wherein the fabric is a non-woven fabric with an average pore size in the range from 1 to 400 micrometers.
4. A water purification device as claimed in any one of the preceding claims wherein the fabric has a surface porosity of less than 20%.
5. A water purification device as claimed in any one of the preceding claims wherein the fabric has a specific liquid permeability less than $2 \times 10^{-11} \text{ m}^2$.

6. A water purification device as claimed in any one of the preceding claims wherein the total thickness of the spirally wound layers of non-pleated fabric is from 1 to 30 mm.
7. A water purification device as claimed in any one of the preceding claims wherein the total thickness of the pleated fabric is from 1 to 5 mm.
8. A water purification device as claimed in any one of the preceding claims wherein the ultrafiltration membrane comprises hollow fibre ultrafiltration membrane.
9. A water purification device as claimed in claim 1, wherein there is a pump at the inlet line of the RO membrane and after the filtration unit.
10. A method of filtering water by the water purification device as claimed in any one of the preceding claims comprising passing water successively through a filtration unit including a spirally wound layer of non-pleated fabric enveloped with spirally wound layer of pleated fabric comprising a carbon block and then through a filtration membrane unit, wherein the filtration unit is connected to a faucet and the water passing into the filtration unit is at an inline pressure from 5 to 20 psig.
11. Use of a water purification device as claimed in any one claims 1 to 9 for 6 log removal of bacteria, 4 log removal of viruses and 3 log removal of cysts from water.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/056693

A. CLASSIFICATION OF SUBJECT MATTER

INV. C02F1/00 C02F1/28 C02F1/44 B01D29/21 B01D61/02
B01D61/14

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/36248 A1 (PRIME WATER SYSTEMS GMBH [DE]; SCHARSTUHL JOHAN JAN [NL]; SCHARSTUHL E) 10 May 2002 (2002-05-10) page 1, lines 1-5 page 2, line 6 - page 8, line 19 figures 1-5 claims 1-9	1-11
X	US 2009/045106 A1 (KUENNEN ROY W [US] ET AL) 19 February 2009 (2009-02-19) paragraphs [0001], [0004] - [0007], [014] - [0023] figures 1-4	1-11
A	JP 2002 331286 A (TORAY INDUSTRIES) 19 November 2002 (2002-11-19) abstract the whole document	1-11

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006 015199 A (TOTO LTD; KITZ MICROFILTER CORP) 19 January 2006 (2006-01-19) abstract the whole document -----	1-11
A	WO 00/20093 A1 (CUNO INC [US]) 13 April 2000 (2000-04-13) the whole document -----	1-11
A	US 2008/087596 A1 (BOMMI GOVIND [SG] ET AL) 17 April 2008 (2008-04-17) the whole document -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/056693

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