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Design and application of nano silver based POU appliances for disinfection of drinking water

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Abstract: An economic and novel design is made to remove biological contamination from drinking water. Its upper portion consists of a water filling chamber along with a basic sediment filter and a combination GAC filter impregnated with nano silver colloid. They are in the form of a cartridge and are secured to the bottom of the top chamber. The filter uses two mechanisms to disinfect the water. The first is by filtration; any harmful microorganisms or particles larger than 1 µ m are removed from the water. The second mechanism is by colloidal silver induced antibacterial action. The disinfection rate of this equipment largely depends on the one to one contact between the nano silver ion and the microbe.

The microorganisms removal efficiency has been studied extensively and the results are very encouraging to offer a technology at an affordable price tag to the third world countries, where the water borne diseases are a threat to their everyday life. The outline of the study has been published (AWW, 2009).

Keywords: Drinking water filter, disinfection, nano silver colloid, purification.

Introduction

Silver based ceramic filters

Historical uses of silver for disinfection over the last 2000 years, suggest that silver may be used in low-tech applications. Small modifications to modern silver electrochemistry methods have proven that silver may act as an effective intermediate technology in water treatment for developing countries. The United Nations Environment Program (2004) has listed silver-treated ceramic water filters as an appropriate technology for water purifications in developing countries and regions affected by natural disaster.

Various hydraulic designs for POU (Point of Use Devices) for water storage and dispensing have been suggested. Some of the mechanisms given below are prototyped and tested for commercial applications.

Nano silver ceramic filter

The filter uses two mechanisms to disinfect the water. The first is by filtration; any harmful microorganisms or particles larger than 1 µ m are removed from the water. These would include most bacteria, and all protozoa and helminthes (Baker *et al*., 2005) Viruses and some bacteria would not be trapped. The second mechanism is by colloidal silver induced antibacterial action. Colloidal silver is composed of silver particles held in suspension in clusters between 10^{-9} and 10^{-6} m wide. The same toxic mechanism for controlling bacteria growth is used in the ceramic filter as in modern silver electrochemistry techniques. Silver inhibits bacteria multiplication by reacting with sulfydryl (-SH) groups in the bacterial cells, producing structural changes in bacterial cell membranes and interacting with nucleic acids (Da vies & Etris,1997).

Design of the apparatus

Silver coating

Manufacturing the filter requires simple, locally-available materials and methods. The filter is 5 cm in diameter, 25cm high. Either side or both sides of the filter are brushed with 0.32% Microdyn colloidal silver solution to impart its disinfectant properties, depending on the primary sediment filter whether installed on outer ring or inner ring or sandwiched. The pore size of the filter is 1 µ m. It rests inside a 10 inches tall plastic housing with an inlet connection and an outlet connection point to take out the treated water. Sketch (Fig.1-2) shows the design and the fabrication of nano silver ceramic filter trains. Ceramic media are prepared in various styles for identify the best possible method of application in terms of economy and efficiency. Models are developed at factory in Taiwan.

Fig 1.Nano silver coated plain ceramic cartridge

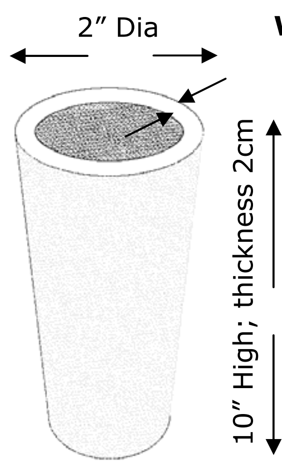


Fig.2. Filter holding bowl: water entry-exit is leak proof

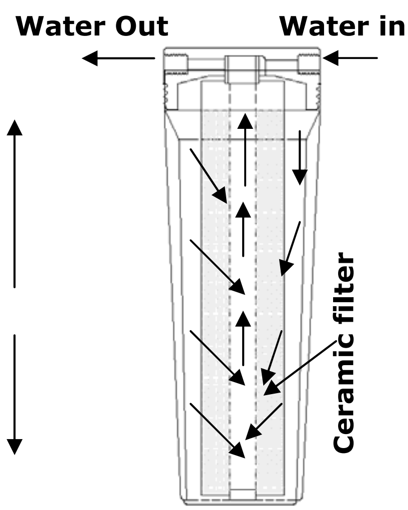
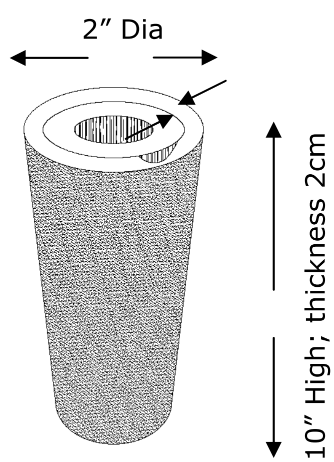


Fig. 3.Coated plain ceramic cartridge Inner side covered with a sediment filter



Hydraulic design

The primary concern on the design is the sufficient flow to make the microbe to contact the nano silver

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ions on an adequate time for disinfection. Accordingly the bowl has the capacity of 1.96 liters. The flow of the liquid is controlled to fill 500 mL per minute will have a retention time of 4 minutes approximately. Hence the contact time (CT) of 4 minutes versus the concentration of nano silver ions will make the disinfection a viable one using the ceramic filters.

The design in Fig.3 retains the same method as outlined in Fig.1-2. Additionally, a 2" dia polypropylene sediment filter is used to filter out the suspended particles of sizes lesser than the pore size of the ceramic filter. The significance of addition a polypropylene filter stage after the ceramic filter could be seen in two ways:

i. Adds certain degree of sediment filtration effect to suspended solids.

ii. The contact time of bacterial exposure can be increased significantly by introducing nano silver coated polypropylene filter.

Either the ceramic or the polypropylene filter can be silver coated or both can be coated to increase the concentration of silver ions to be populated in water. This model can accept an external pressure through a pump if the final product water quantity is needed in excess quantity. The hydraulic design can be worked out to meet both the contact time required and or the final flow required.

Mushroom head nano silver ceramic cartridge to be used in water dispensing pot

Mushroom head ceramic filters are essentially a gravity flow filter, although a pressure flow design in possible with a liquid tight bowl and filter arrangement. Additional pressure components are eliminated in this design to keep the cost very low. The apparatus can very well function as a protected water storage device, a disinfection unit and a water dispenser. A Tap is added to the apparatus to dispense water (Fig.4-5).

Fig. 4. Typical mushroom head ceramic filter

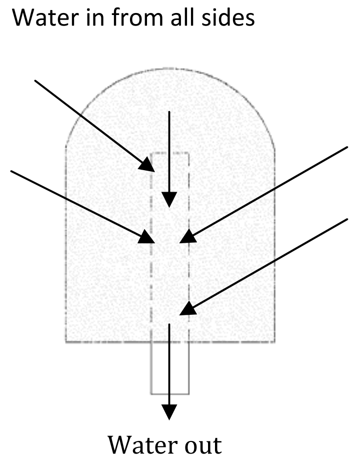

Fig.5. Single and double cartridges by supernatant water column method of increasing contact time and flow in water dispensing pot.

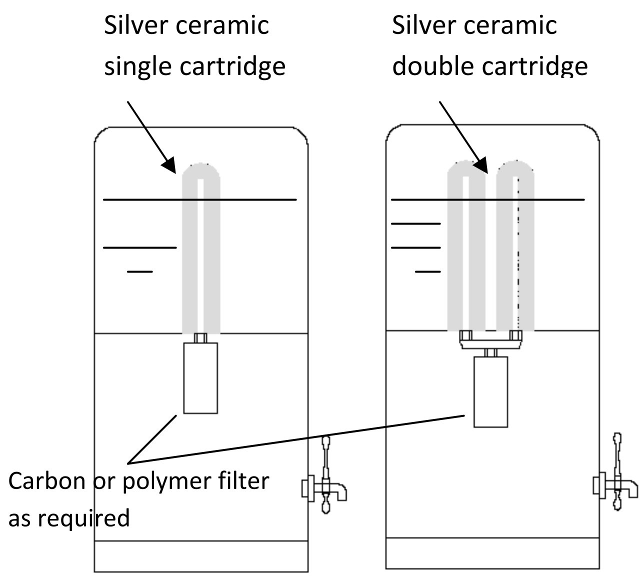

Fig. 6. Activated carbon

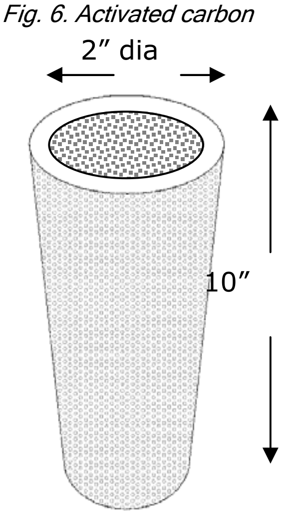

Fig.7.Granular activated carbon

The upper part of the unit has the inlet water provision. The nano silver coated ceramic filters are mounted between the filtered chamber and inlet chamber. Water leak sealing is provided between the two chambers. The bottom chamber is provided with a activated carbon filter or a polypropylene sediment filter or the combination as required. Water is disinfected first and then filtered for sedimentation and chlorine and odor components. The capacity of the filter can be designed either for 1 US Gallons or 2 US Gallons.

Nano silver impregnated activated carbon

Activated carbon has always been a choice of industry when it comes to cleaning of water or gas. The peculiar chemical and physical properties of activated carbon have rendered its full justice to the mankind in various applications. Granular Activated Carbon (GAC), a smaller size of granules, makes the life of water treatment very easy.

Impregnated activated carbons are carbonaceous adsorbents which have chemicals finely distributed on their internal surface (Fig.6). The impregnation optimizes the existing properties of the activated carbon giving a synergism between the chemicals and the carbon. This facilitates the cost-effective removal of certain impurities from gas streams which would be impossible otherwise. For environmental protection, various qualities of impregnated activated carbon are available and have been used for many years in the fields of gas purification, civil and military gas

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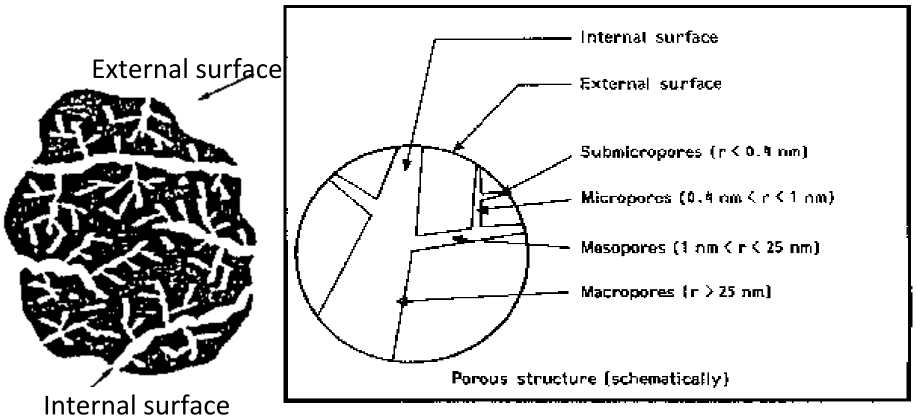
Fig.8. Schematic activated carbon model



protection and catalysis.

Granular activated carbon

Activated carbon is the trade name for a carbonaceous adsorbent which is defined as follows: Activated carbons are non-hazardous, processed, carbonaceous products, having a porous structure and a large internal surface area. These materials can adsorb a wide variety of substances, i.e. they able to attract molecules to their internal surface, and are therefore called adsorbents (Fig.7). The volume of pores of the activated carbons is generally greater than 0.2 ml g^{-1}. The internal surface area is generally greater than 400 $m^2 g^{-1}$. The width of the pores ranges from 0.3 to several thousand nm.

All activated carbons are characterized by their ramified pore system within which various mesopores (r = 1-25 nm), micropores (r = 0.4-1.0 nm) and sub micropores (r < 0.4 nm) branch off from what we call macropores (r > 25 nm) (Fig.8). Activated carbons have been used for many years quite successfully for adsorptive removal of impurities from exhaust gas and waste water streams. However, for cost-effective removal of certain impurities contained in gases (such as hydrogen sulfide, mercury and ammonia), the adsorption capacities and the feasible removal rates must be substantially boosted by impregnation of the activated carbon by suitable chemicals. When these chemicals are deposited on the internal surface of the activated carbon, the removal mechanism also changes. The impurities are no longer removed by adsorption but by chemisorption.

Fig. 9. Impregnation of silver on GAC

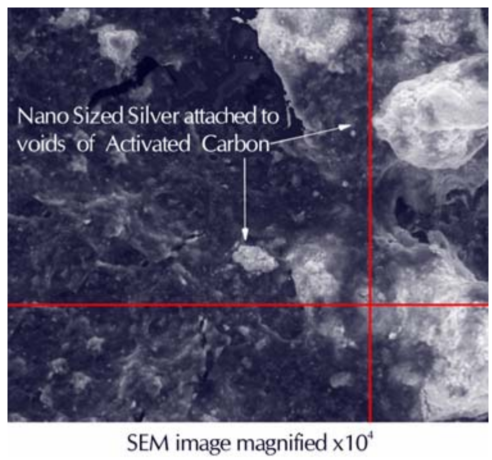
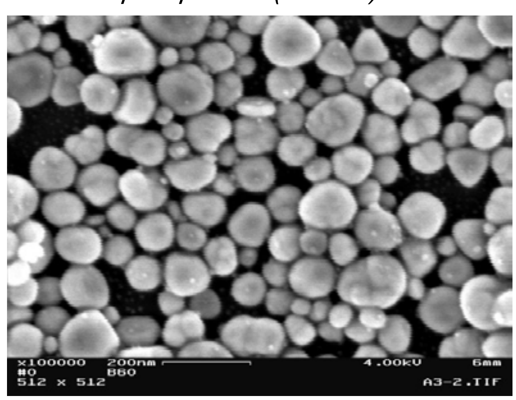


Fig.10. Nano colloidal silver in precipitation (size X4)



Method of silver impregnation on GAC

In this method, the GAC is mixed with a binding agent and extruded in cylindrical form. The binding agent is mixed with the salts of silver such as silver nitrate or silver chloride or silver sulphate. A silver containing plastic master batch is also acceptable as long as the binding material can hold its property at the melting temperature of plastic master batch. Another additive to the binding agent is by nano silver colloid with heating up to 200˚C to impregnate on to binding material. Finally the whole combination needs to be extruded in cylindrical form. Fig.9-11 are the scanning electron microscope photographs showing the impregnation of silver on GAC.

Nano silver impregnated polymer

The basic principle of application of this method is to have a geometrically designed polymer, which is mixed with nano silver particles, done on injection molding process (Fig.12-14). The basic method of mixing the nano silver into the plastic is by using a master batch mix. There are many industries selling master batch compounds, meant for addition of specific pigments to plastic base to obtain a specific variety of plastic. The master batch is essentially a concentrated mixture of the basic pigment (in this study, it is nano silver powder) with low density polypropylene pebbles. The mixture is packed and provided as 50 % or 100% concentration of silver.

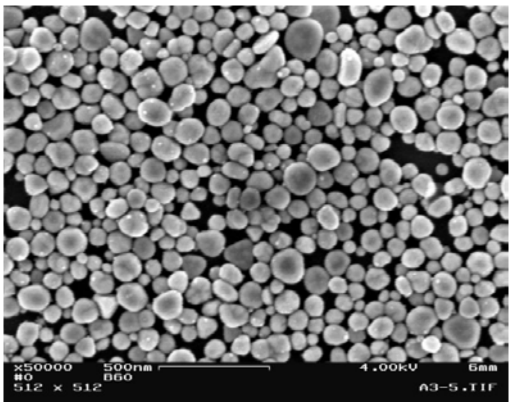
The master batch is mixed with the ratio needed in the raw plastic prior to injection molding. The raw materials are thoroughly mixed in a mixer and pre heated to master batch melting temperature. The master batch which has lower melting point will be liquefied first. The liquid master batch fixes on to the plastic raw material and once taken out it forms a uniform mixing of plastic granules already mixed with required concentration of nano silver.

The design for microbial contact

The disinfection rate of this equipment largely depends on the one to one contact between the nano silver ion and the microbe. The Fig.14, the nano silver water purifier, resembles a traditional water filter kept at homes in India.

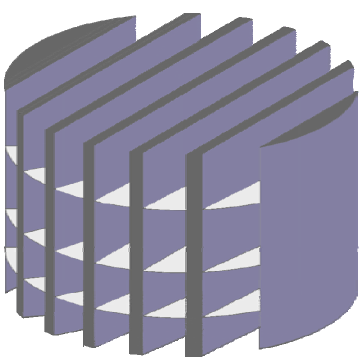
The upper portion of the filter consists of a water filling chamber along with a basic sediment filter and a combination GAC filter. They are in the form of a cartridge and are secured to the bottom of the top chamber. The

Fig. 11 Nano colloidal silver in precipitation



bottom chamber has a dispenser pipe. The nano silver polymer is just kept inside the chamber. The filtered water from the top chamber by gravity will need to pass through many turns of the nano silver polymer. Before it reaches the faucet it makes several contacts with the bends and curves of the nano silver polymer, thereby making a one to one contact between nano silver particles in the polymer and microbe. At the point of exit, the water is purified.

Fig.12. Nano silver mixed injection molding disinfection chamber for water filter



Instead of nano silver master batch mixing, the whole disinfection polymer can be made out of polyurethane and then the surface can be coated with nano silver by simple method explained earlier for polyurethane fiber coating process. Care should be taken to ensure that this method may have more leached silver as the silver holding mechanism is a surface phenomenon (or by London Forces).

Hydraulic design

The design of this water filter is based on the volume capacity needed per family per day. Accordingly, a 2 gallon (8 liter) water tank on upper and a 9 liter water tank on the lower is designed to meet the needs of pure drinking water per family. The filtered water flow is restricted by the pressure drop offered by the filtering units. Careful design can alleviate many hydraulic constraints.

The cost of this equipment is roughly Rs 800/- (US $16) for a mass production and affordable by most households.

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Fig.13. Nano silver disinfection: water purifier components split view

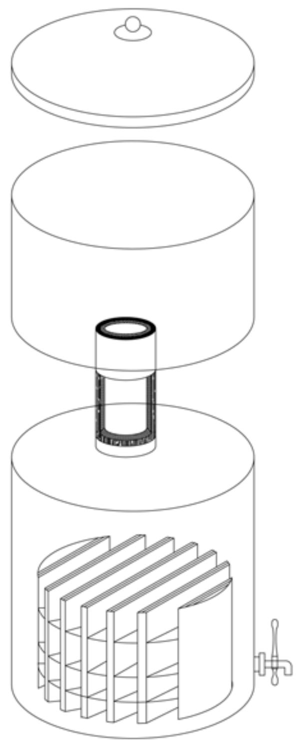

Fig.14. Nano silver disinfection: water purifier assembly view