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# TO STUDY THE CRITICAL PARAMETERS INFLUENCING PERFORMANCE OF CLAY CERAMIC WATER FILTER DISK

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**Abstract**

Water purification is needed to ensure safe drinking water. The main aim of this paper is to produce a clay ceramic water filter disk using clay, sawdust and Ag-Cu bimetallic nanoparticles synthesized using Tulsi leaf extract and to study critical parameters influencing the performance of disk produced. For the present study a laboratory scale unit was made with different ratios of clay and saw dust. Water collected from nearby lake was passed through the disk filter and filtered water through the disk filter was collected in the container. Physiochemical parameters of water before and after filtration were tested. Flow rate was calculated .For material analysis EDX of ceramic disk and bimetallic nanoparticles were performed. Water quality analysis results showed that the ceramic water filter disk was effective in removing microbes and turbidity to 88% .Flow rate was 575ml/hr was observed.

**Keywords:** Bimetallic nanoparticles, Ceramic disk, EDX, Flow rate and Water purification.

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## 1. Introduction:

The contamination of water bodies is known as water pollution or aquatic pollution. People who use polluted water for drinking, bathing, washing, or irrigation risk contracting water-borne illnesses caused by pathogenic micro-organisms [1.2.8,9,10]. Contaminants in water may include organic and inorganic substances.

Drinking contaminated water may result in transmission of diseases like typhoid, diarrhea, cholera hepatitis A, and polio [4,6,7]. Bacterial contamination is the major water quality problem [1,2,3,4,5].Access to safe drinking water is very limited in developing countries like India [1,2,3,11.16].In this context, the need for, the point-of-use water treatment (PoU) systems characterized as mature and fundamental, are required for improving the water quality at the household level in developing countries[11,13,17,18].To counter this, several low-cost water treatment methods at the household level have been developed to provide access to safe drinking water in developing countries[11,12,13,14,15].Several PoU technologies like flocculation and coagulation, filtration, and disinfection can be used to treat microbiological, physical and chemical contamination. For turbidity removal flocculation and coagulation can be used ,there by reduces the microorganisms [19].Filtration is a simple treatment technique capable of removing microorganisms , microorganisms larger than the pore size of the filter will be retained within the system[20].Inactivation and destruction of microorganisms in the system to a safe level is disinfection[21].Depending on the type of microbe, different disinfectants have different dosages and exposure times.Nanoparticles, which range in size from 1 to 100 nm, differ from their usual macro-scale counterparts in terms of their properties and specific surface area. As a result, nanoparticles are more effective at treating water. Extensive research in nanotechnologies have opened new door for development of water treatment techniques[22].Nanotechnology had been applied in PoU as well . Nanoparticles had great potential in advanced oxidation process and disinfection. However, the long-term effects of nanoparticles are largely unknown [23].Ceramic Water Filter is usually made by combining clay, water and sawdust to create a disk-like ceramic filter with small pores are now used for household water treatment solution. Ceramic material is an organic and nonmetallic material produced by heating and cooling[24].These CWFs physically remove colloidal particles and microorganisms such as bacteria and even viruses by passing the water through a filter [11, 12, 14, 25, 26,27,28].These ceramic water filter systems are often impregnated with nanoparticles to disinfect and control bacterial growth[13,14,17,25,27,29,30,31].Ceramic filters ability to remove contamination from water is determined by its pore size and the surface charge[32] .In this study, we evaluated the performance of a modified point-of-use ceramic disk filter impregnated with Ag-Cu bimetallic nanoparticles to remove *E. coli* and other contaminants. Present study aims to provide safe and clean drinking water by designing a ceramic disk with locally available material at low cost .

## 2. Materials and Methods:

Clay, sawdust which acts as combustible material and green synthesized bimetallic Ag-Cu nanoparticles were precursors utilized for ceramic disk filter production. Synthesis of bimetallic Ag-Cu nanoparticles using leaf extract has been reported in our previous work [36].Sawdust was sourced from a nearby furniture shop. Table 1 shows the composition of ceramic disk filter making. Saw dust was chosen because it results in uniform pore size distribution which helps to increase the porosity of the ceramic filter and it does not cause bloating [33,34,35].Equipment used are , 0.25 mm sieve, disk mould, covered plastic box and kiln. The production processes were carried out with the help of local potter available at Kummarbasti, Asif Nagar area, Telangana State. The mixture of clay, grog, sawdust was moistened by the addition of water, wedged and rolled to obtain an even, homogeneous mixture. 2.76 mg of bimetallic Ag-Cu nanoparticles per disk were added. [39]

## 2.1 Ceramic Disk Filter Design:

Clay mixtures were molded into disk shape. The molded disk filters were air dried at average temperature of 24 °C in a dry place for 10 days to prevent disk filters from cracking due to drying or heating during the firing process. Molded dry ceramic disk filters were positioned inside a kiln furnace and sintered at 800 °C to 900 °C. The produced ceramic disk filter elements were 10.5 cm in diameter, and 1.5 cm thickness .The ceramic disk filter samples shown in Table [1] were tested for various critical parameters like flow rate, microbial removal efficiency, and physiochemical characteristics. Ceramic disk filter designed was shown in figure [1].


Figure 1: Ceramic disk filter

| Disk no | Clay(g) | Sawdust(g) | Grog(g) | Nanoparticles(mg) |
|---|---|---|---|---|
| 1 | 500 | 75 | 25 | 2.76 |
| 2 | 500 | 50 | 25 | 2.76 |
| 3 | 500 | 25 | 25 | 2.76 |
| 4 | 500 | 10 | 25 | 0 |
| 5 | Normal Water filter(Ganga Steel filter) | | | |

Table 1: Composition of Raw materials in grams (g).

### 2.2 Experimental Method

Water samples collected from Nerella Lake was taken to water quality analysis before filtration located at Kukatpally.A laboratory testing unit designed for this study consists of ceramic disk with two plastic containers one for water holding and another one to store water after filtration as shown in figure[1]. By gravitational force water passed through the ceramic disk filter. Filtered water flow rate was measured as ml/hr and is stored in the second container with tap. Stored water was taken to water quality analysis after filtration and before filtration.

## 3. Characterization:

### 3.1. Water Quality Analysis:

Using standard methods Physical &Sensory Characteristics like colour, pH, Turbidity and EC were determined General Chemical Characteristics like Total Hardness, Alkalinity, Calcium, magnesium were determined. Total Coli form was determined before and after filtration of water . Flow rate was calculated. Flow rate is an important parameter in water filtration as it determines how quickly water can pass through the filter .Water samples were collected from Nerella Lake near Kondapur and Water quality tests were carried out within 24hrs as described in table [2a &2b].

### 3.2. Flow rate:

The amount of water which filters through the filter in the first hour is the flow rate. To ensure that the air in the open pores of the disks was replaced by the distilled water and for effective and constant flow rate, the disks were saturated in distilled water for 24hr and then boiled for 2hr.Dust and burning materials were cleaned during this process. Table [3] shows the flow rate of the ceramic disk filters.

### 3.3. Material Analysis:

EDX was carried out at Osmania University lab to determine the chemical composition of the ceramic disk filter before fig [2] and after filtration fig [3] of water. And also to confirm presences of Ag and Cu elements in bimetallic nanoparticles.

## 4 .Results and Discussion:

**Water Sample-1**

**Physical &Sensory Characteristics:**

| **Parameters** | **Permissible limit** | **Water sample (1 )Before filtration** | **Water sample (1) After Filtration** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 | Normal filter |
| Colour PCU(Hazen) | 5 | <1 | <1 | <1 | <1 | <1 | <1 |
| Odour Rating | Agreeable | Agreeable | Agreeab le | Agree able | Agree able | Agreeable | Agreeable |
| Turbidity(NTU) | 1 | .40 | .23 | .30 | .25 | .20 | .35 |
| pH at $25^0$C | 6.5-8.5 | 7.86 | 7.49 | 6.49 | 7.29 | 7.69 | 7.84 |
| Conductivity μ Siemens/cm | ≤ 2250 | 743 | 82.9 | 69.9 | 64.5 | 46.2 | 748 |

**General Chemical Characteristics:**

| **Parameters** | **Permissible limit** | **Water sample (1 )Before filtration** | **Water sample (1) After Filtration** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 | Normal filter |
| Total Alkalinity As $CaCO_3$ mg/L | 200 | 175 | 25 | 20 | 18 | 19 | 120 |
| Total Hardness As $CaCO_3$ mg/L | 200 | 170 | 20 | 12 | 10 | 8 | 154 |
| Calcium As Ca++ | 75 | 42.4 | 5 | 3.2 | 4.8 | 3.5 | 34.4 |
| Magnesium As Mg mg/L | 30 | 16.5 | 2.1 | .9 | 1.7 | 1.5 | 15.5 |
| Nitrite As $NO_2$ mg/L | 3.0 | .08 | BDL | BDL | BDL | BDL | BDL |
| Nitrate As $NO_3$ mg/L | 45 | 4.0 | 1.1 | .09 | .06 | .04 | 3.0 |
| Chloride As $Cl^-$ mg/L | 25.0 | 71.4 | 21.3 | 13.4 | 15 | 16.5 | 66.9 |
| Fluoride As $F^-$ mg/L | 1 | .49 | .39 | .10 | .15 | .18 | .29 |
| Sulphate As $SO_4$mg/L | 200 | 82.9 | 5.68 | 2.74 | 6.89 | 8.89 | 43.0 |
| Iron Fe mg/L | 1.0 | BDL | BDL | BDL | BDL | BDL | BDL |
| Manganese As Mn mg/L | .1 | BDL | BDL | BDL | BDL | BDL | BDL |
| Sodium As NA+ mg/L | - | 60.0 | 8.9 | 5.6 | 6.5 | 9.0 | 59.6 |
| Potassium As K+ mg/L | - | 1.8 | .3 | 0.1 | .4 | .7 | 1.8 |

*BDL- Below Detection Level

**Bacteriological Analysis**

| Parameter | Permissible limit | **Water sample (1 )Before filtration** | **Water sample (1) After Filtration** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 | Normal Filter |
| Total Coliforms MPN /100ml(95%CI) | Absent | 542 | Not detected | Not detected | Not detected | 501 | 130 |
| Thermotolerant Coliforms Absent/Present | Absent | Absent | Absent | Absent | Absent | Absent | Absent |

Table 2a Physical, Chemical and biological characteristics of water before and after filtration

**Water Sample-2**

**Physical &Sensory Characteristics:**

| **Parameters** | **Permissible limit** | **Water sample (2 )Before filtration** | **Water sample (2 )After Filtration** | | | |
|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 |
| Colour PCU(Hazen) | 5 | <1 | <1 | <1 | <1 | <1 |
| Odour Rating | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable |
| Turbidity(NTU) | 1 | .50 | .28 | .38 | .32 | .42 |
| pH at $25^0$C | 6.5-8.5 | 7.80 | 7.69 | 7.49 | 7.9 | 7.1 |
| Conductivity µSiemens/cm | ≤ 2250 | 845 | 92.9 | 79.9 | 74.5 | 48.2 |

**General Chemical Characteristics:**

| **Parameters** | **Permissible limit** | **Water sample (2 )Before filtration** | **Water sample (2) After Filtration** | | | |
|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 |
| Total Alkalinity As $CaCO_3$ mg/L | 200 | 178 | 27 | 20 | 16 | 21 |
| Total Hardness As $CaCO_3$ mg/L | 200 | 180 | 22 | 14 | 11 | 7 |
| Calcium As Ca++ | 75 | 46.4 | 5 | 3.8 | 4.9 | 3.7 |
| Magnesium As Mg mg/L | 30 | 16.8 | 2.2 | .7 | 1.9 | 1.3 |
| Nitrite As $NO_2$ mg/L | 3.0 | .08 | BDL | BDL | BDL | BDL |
| Nitrate As $NO_3$ mg/L | 45 | 4.0 | 2.0 | .08 | .06 | .05 |
| Chloride As $Cl^-$mg/L | 25.0 | 75.4 | 31.3 | 13.5 | 20 | 26.5 |
| Fluoride As $F^-$mg/L | 1 | .69 | .49 | .10 | .25 | .17 |
| Sulphate As $SO_4$mg/L | 200 | 92.9 | 5.65 | 2.74 | 6.79 | 9.89 |
| Iron Fe mg/L | 1.0 | BDL | BDL | BDL | BDL | BDL |
| Manganese As Mn mg/L | .1 | BDL | BDL | BDL | BDL | BDL |
| Sodium As NA+ mg/L | - | 70.0 | 8.9 | 5.5 | 7.5 | 1 |
| Potassium As K+ mg/L | - | 1.8 | .5 | 0.1 | .3 | .9 |

***BDL- Below Detection Level**

**Bacteriological Analysis:**

| Parameter | Permissible limit | **Water sample (2 )Before filtration** | **Water sample (2) After Filtration** | | | |
|---|---|---|---|---|---|---|
| | | | Disk 1 | Disk 2 | Disk 3 | Disk 4 |
| Total Coliforms MPN /100ml(95%CI) | Absent | 243 | Not detected | Not detected | Not detected | 200 |
| Thermotolerant Coliforms Absent/Present | Absent | Absent | Absent | Absent | Absent | Absent |

Table 2b Physical, Chemical and biological characteristics of water before and after filtration

Table [1a&1b] shows results of water sample 1 and water sample 2 before and after filtration of water through disk1, disk2, disk3 and disk 4.Physical parameters turbidity which is caused by chemical precipitates, organic waste, silt and bacteria, turbidity efficiency of the disk filters varied from 50% to 87.5%.This study confirmed that percentage increase in saw-dust results decreasing turbidity removal efficiency.pH of the water samples were decreased after filtration.EC was relatively high and it was decreased after filtration.EC is directly related to the amount ions in the sample. It is possible that the 100% nitrite removal efficiency observed in the ceramic disk filter samples was due to the exclusion of nitrite molecules based on their size, as the pores of the disk may have been too small to allow them to pass through. Water hardness is caused by Mg2+ and Ca2+. It is possible that the removal of calcium and magnesium ions was caused by ion exchange on the ceramic surface and the precipitation of these cations as oxides and hydroxides.

Ag-Cu bimetallic nanoparticles are applied to achieve bactericidal quality of silver and copper in the purification of water during filtration and to prevent the formation of slime layer of bacteria on the disk surface. Bactericidal effects are defined here as those that completely kill the bacteria cell, while Bacteriostatic effects prevent a cell from replicating DNA.Disk impregnated with 2.76mg of nanoparticles removed microbes.

**Flow rate analysis:**

From the table[2] it can be observed that flow rate is highest for disk 2, the flow rate increases with increase in saw dust percentage and lowest for disk 4,Filters with very low flow rate are good at removing turbidity and microbial organisms due to decrease in pore size[37].Flow rate is also affected by filters with greater surface area have high flow rate and low flow rate for small surface area [38].Water with high turbidity will have low flow rate because the pores are clogged with microorganisms and other insoluble solids. Decrease in water level in the upper container of the filter results in low pressure and hence low flow rate [40].

| **Disk** | **1hr** | **2hr** | **5hr** | **12hr** |
|---|---|---|---|---|
| 1 | 400 | 600 | 900 | 800 |
| 2 | 300 | 500 | 800 | 700 |
| 3 | 250 | 400 | 600 | 450 |
| 4 | 100 | 200 | 350 | 150 |

Table 3-Flow rate of ceramic disk filter (ml/hr)

**Material Composition Analysis:**

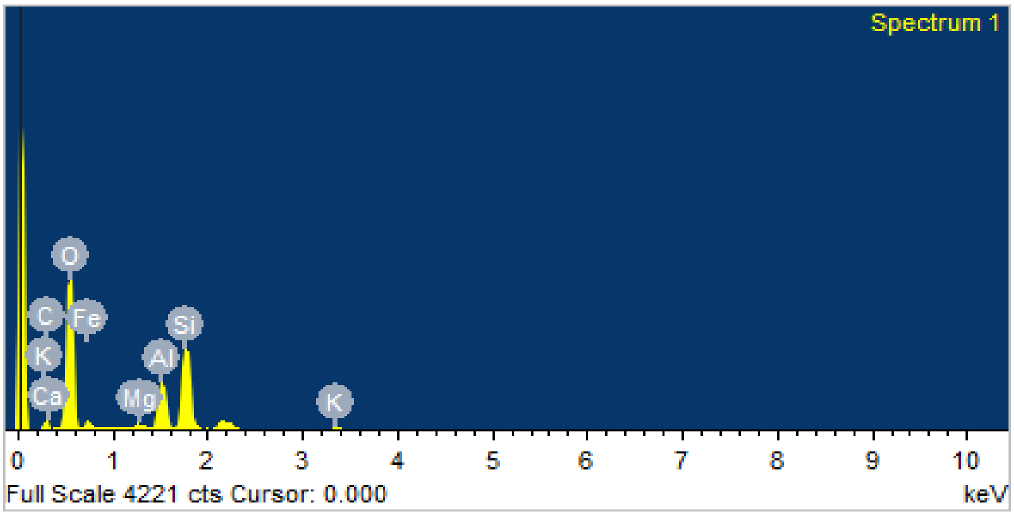


Figure2: EDX spectrum of the ceramic disk before filtration

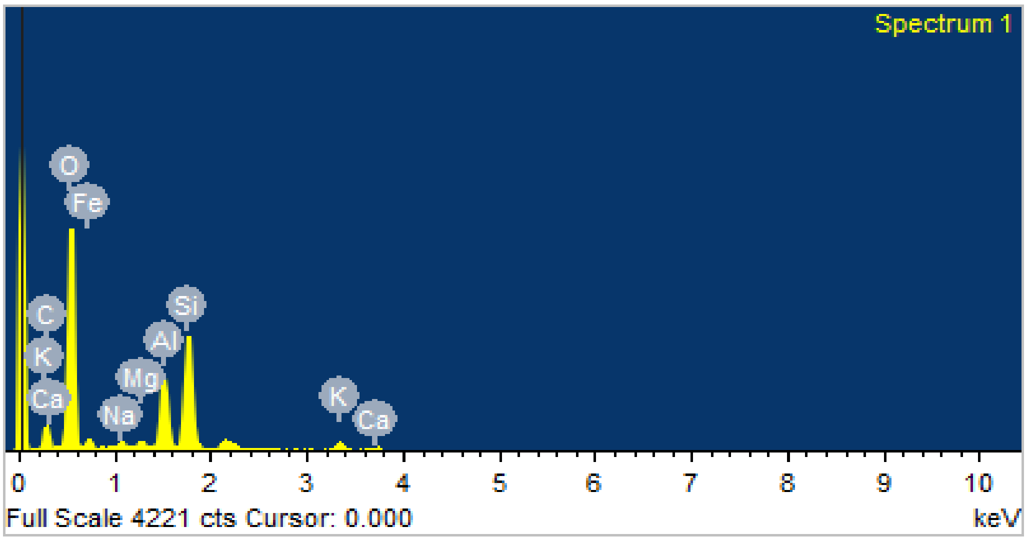


Figure3: EDX spectrum of the ceramic disk before filtration

Figure [2] and Figure [3] shows EDX spectra of disk 2 before and after filtration. This spectrum shows the presences of the elements C, O, Na, Al, Mg, Si K and Fe.

The carbon content in a ceramic disk water filter has decreased after filtration, it could be an indication that the carbon has been used up in adsorbing impurities from the water. The oxygen content in the water passing through a ceramic disk filter appears to increase after filtration, it is possible that the water source itself has higher oxygen content. As water passes through the filter, impurities are removed, but oxygen levels in the water should remain relatively constant. While some water filtration systems, such as reverse osmosis, can reduce the oxygen content of water due to the removal of dissolved gases, this is not typically the case with ceramic disk water filters. Sodium in the sample after filtration may be due impurities present in the water source.

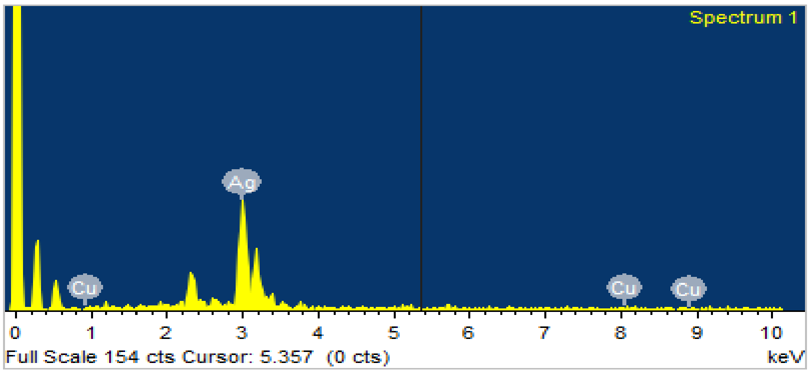


Figure4: EDX spectrum of the green synthesized bi-metallic Ag-Cu nanoparticles

EDX spectrum in figure 4 confirms presence of Ag and Cu elements in the green syntheised Ag-Cu nanoparticles using Tulsi leaf extract. It was also observed that the signals for silver were stronger than copper indicating greater amount of silver compared to Copper.

**Conclusion:**

Critical parameters were studied and results showed that the ceramic disks are effective in removing microbes resulting in waterborne diseases 100%. Turbidity removal was 50%-88%.Main advantage of this filter is that all the materials used are locally available. Filtration rate was high for disk filter 2.Using physical, chemical and biological parameters it is difficult to identify best filter. Compared with drinking water standards based on flow rate disk filter 2 is best.

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