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Water Purification Techniques Using Polyurethane Coated with Silver Nanodots for Clean and Healthy Environment

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In this study, a filtrate system for water purification is developed using polyurethane foam (PUFS) coated with silver nanodots synthesized using monosaccharide sugars. Repetition of washing and drying results in stable PUFS with uniform coating. Highly antiresistant *E. coli* bacteria of 100 colony-forming units per ml are prepared to be used for testing. Silver-nanodots-coated PUF filter is soaked in this water for 20 minutes and analysed. The result shows very high reduction in bacterial population. This ensured pure drinking water can be obtained by this method at very low cost. Drinking water treatment using silver nanodots paves way for a healthy and safe living for mankind at places, where this precious commodity is.

У цьому дослідженні розроблено систему фільтрату для очищення води з використанням пінополіуретану (ППУС), покритого наноточками срібла, синтезованими з використанням моносахаридних цукрів. Результатом багаторазового промивання та сушіння є стійкий ППУС з рівномірним покриттям. Для тестування підготовлено високорезистентні бактерії *E. coli* по 100 колонієутворюючих одиниць на мл. Цідило з ППУ із покриттям срібними наноточками замочують у цій воді на 20 хвилин і аналізують. Результат показує дуже високе пониження бактеріяльної популяції. Це ґарантує, що чиста питна вода може бути одержана таким методом з дуже низькими витратами. Очищення питної води за допомогою срібних наноточок відкриває шлях до здорового та безпечного життя людства в місцях, де знаходиться цей дорогоцінний продукт.

Key words: polyurethane foam, silver nanodots, *E. Coli*, water purification, health issues.

Ключові слова: пінополіуретан, срібні наноточки, кишкова паличка, очищення води, проблеми зі здоров'ям.

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1. INTRODUCTION

Drinking water has become a precious commodity today. The available drinking water is contaminated and is the common breeding ground for many pathogens like *E. coli* bacteria. In conventional methods, chlorine is commonly used for purification process.

The application of silver nanodots for water purification and disinfection of water was tried in this experimental study. For this purpose, the antibacterial properties of the polyurethane foam coated with synthesized silver nanodots were studied. The polyurethane foams were coated with silver nanodots by exposure of the foams to silver nanodots' solutions. Thereafter, repeated washing and drying yields uniformly coated stable polyurethane foam. These silver-coated foams can be used as a water filter. *E. coli* bacteria in the drinking water was chosen as indicator of contamination. The contaminated water contained a bacterial load of 100 colony-forming units (CFU) per ml, in which contact time of PU foam in water was one hour; the output bacterial load count of *Escherichia coli* was highly reduced.

This is a low-cost, simple and high-efficient procedure to remove pathogens in drinking water.

2. MATERIALS AND METHOD

2.1. Fabrication of Silver-Coated Polyurethane Foams

Polyurethane (PU) foams of sizes 5 cm×5 cm×2 mm were cut and washed by deionised water repeatedly. Then, they were dried and, then, soaked in silver solutions for a day. Impurities and adsorbed substances were eliminated by washing with water. It was found that the coatings of silver nanodots were stable on the foam.

2.2. Microbiological Method

The contaminated water was analysed. It was found to contain bacteria like *E. coli*, *Staphylococcus*, *Streptococcus* species like *Dysenteriae*, *Salmonella* species. *E. coli*, *Staphylococcus aureus* (gram positive bacterium) and *Pseudomonas aeruginosa* (gram negative bacterium) were selected as major indicators of bacterial contamination of water. Then, nutrient broth was used as the growing medium for the microorganisms. Bacteria were grown in nutrient broth at 32°C for 10 h. The cultures were centrifuged; the cells

were washed and suspended in distilled water, reaching a final concentration of $1 \cdot 10^5$ to $1 \cdot 10^6$ CFU/ml.

2.3. Test Tube Analysis

For the study, 10 ml of *E. coli*, *S. aureus* and *P. aeruginosa* cells suspended in water was taken in sterilized test tubes. Foam sizes of 5 cm×5 cm×2 mm were cut and inserted into the tubes. At 30°C, the tubes were incubated. After one hour, the foam samples were taken out. The liquids were collected at the end of incubation; plating was done with this treated water by serial dilution method for 10^0, 10^{-3} and 10^{-5} dilutions with tryptic soy agar (TSA). Plating was also done for the initial CFU count and with uncoated PU-treated solution. For every dilution, 10 µl of the solution were plated. Plating was done by the wet-plate method. The bacterial colonies were counted after 48 hours of incubation at 30°C.

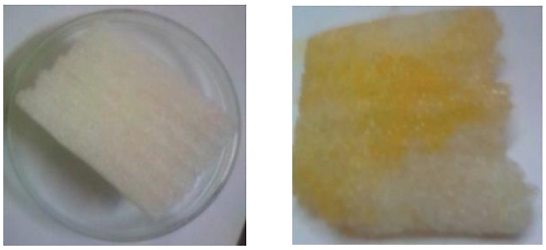
3. RESULTS AND DISCUSSIONS

The results of the experiment showed excellent performance of the PUFS coated with silver nanodots. The first picture in Fig. 1 shows pure polyurethane foam, and it is white in colour. The second picture (Fig. 1, *b*) is silver-nanodots-coated polyurethane foam, and the colour changes from white to yellow.

The polyurethane foam coated with silver nanodots had zero bacterial colonies after contact time of thirty minutes. For *E. coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* strains, the output count was nil.

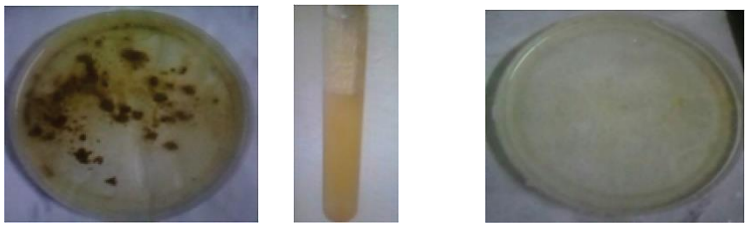
The water treated with the control sample (pure PU) showed substantial growth on the plates. Initial water sample showed overgrowth in almost all the cases.

The bacterium count was decreased in the output water after



a *b*

Fig. 1. *a*—Pure polyurethane (PUF); *b*—PUF coated with silver nanodots.



a *b* *c*

Fig. 2. *a*—Contaminated water; *b*—test with PUF; *c*—clear water.

TABLE. Reduction in bacterial counts in PU foam coated with silver nanodots.

No.	Bacterial strains	Pure polyurethane foam	Coated polyurethane foam
1.	*Escherichia coli*	$4.0 \cdot 10^6$ CFU/ml	nil
2.	*Staphylococcus aureus*	$5.0 \cdot 10^6$ CFU/ml	nil
3.	*Pseudomonas eruginosa*	$2.0 \cdot 10^7$ CFU/ml	nil

passing through the coated foam for *E. coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*. This was checked for input loads of $1 \cdot 10^5$ and $1 \cdot 10^6$ CFU/ml. There was no growth below the PU coated with silver nanodots, while growth was seen in case of pure PU, which again confirms the antibacterial property of PU coated with silver nanodots (see Fig. 2).

The following Table gives an idea about the antibacterial effect of silver-coated polyurethane foam on various kinds of bacteria.

4. CONCLUSION

The polyurethane foams coated with silver nanodots had a stable binding even after repeated washing and drying.

With high input bacterial load, the foam material was checked for its antibacterial properties, and the bacterium count was zero in the treated water.

It was found that the coated polyurethane foam could remove all types of pathogens.

The life cycle of the coated PU was tested many times and found to function with the same efficiency.

The method employed here is an eco-friendly approach, and the chemicals involved are nontoxic, commonly available and cost effective.

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