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ENVIRONMENTAL NANOTECHNOLOGY- ANTIBACTERIAL AND ARSENIC POLLUTION CONTROL PROPERTIES OF ZINC OXIDE NANOPARTICLES

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ABSTRACT

Nanotechnology is being used in several applications to improve the environment. The present study was designed to evaluate the removal of bacteria and arsenic from water to reduce pollution. Bacteriological anlyses of water samples collected from a well and a pond showed the presence of *E. coli* and *Klebsiella* bacteriae. It was evident from the study that after adding appropriate amount of Zinc oxide nanoparticles, water samples were devoid of these bacteria. Similarly water contaminated with arsenic also showed gradual removal of arsenic when zinc oxide nanoparticles were added. Arsenic solution was prepared by adding 5mg of Arsenic chloride in 1000 ml distilled water. An optimum amount of Silica gel (5gm) was added for better adsorption. 10 mg of ZnO nanoparticles were added to this. The initial and final amount of Arsenic was determined. The resutlt clearly indicated that the ZnO-NPs with silica was effectual adsorbent for the removal of As3+. Hence from the present study it became evident that ZnO nanoparticles are highly beneficial in environmental biotechnology to control bacteriology and heavy metal pollution effectively.

KEYWORDS: Environmental Nanotechnology, *E. Coli, Klebsiella,* Zn O Nanoparticles, Bacteriology, Heavy Metal Pollution

Nanotechnology can be defined as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties.

Nanotechnology is being used in several applications to improve the environment which includes cleaning up existing pollution, improving manufacturing methods to reduce the generation of new pollution, and making alternative energy sources more cost effective. Hence the present study has been conducted to find out whether ZnO nanoparticles are beneficial in environmental biotechnology to control bacteriology and heavy metal pollution.

MATERIALS AND METHODS

Microbiological Tests

Water samples were collected from two sites ie; a well (Kollam Corporation) and a pond (Kallada Panchayath) for Bacteriological analysis. Sterilized bottles were used for the sample collection for microbial analysis and were brought to the laboratory of Department of Zoology, Sree Narayana College for Women, Kollam. Bacterial identification was done. Streak culture was followed for making culture plates. ZnO nanoparticles were synthesised by Chemical method (Gnanasangeetha and Sarala Thambavani, 2013).

Arsenic Solution Preparation

Arsenic solution was prepared by adding 5mg of Arsenic chloride in 1000 ml distilled water. An optimum amount of Silica gel (5gm) was added for better adsorption (Gnanasangeetha and Sarala Thambavani, 2013). To this 10 mg of ZnO was added. The initial and final amount of Arsenic was determined.

RESULTS AND DISCUSSION

The results of the study are illustrated in Tables 1 – 3 and figure 1.

Study of bacteriology in water samples collected from the well showed the presence of bacteria. Similarly, bacteriology of water samples collected the pond also showed the presence of bacteria. It was noteworthy that when the bacteria were identified, they were similar in both the water samples. i.e, *Klebsiella* and *E. coli.* The study of bacteriology of water samples were conducted in the well water after adding ZnO nanoparticles. It was evident from table-2 that when an amount of 0.01 gm ZnO was added to 100 ml of well water sample, the presence of bacteria was evident. The observed and the identified organisms were again *Klebsiella* and *E. coli.* Then different amount of ZnO nanoparticles i.e., 0.02gm, 0.05gm and 0.1 gm ZnO were added to 100ml each of water samples. But it was interesting to note that when bacteriology study of water samples was conducted bacteria were absent in these samples.

When the bacteriology of water samples collected from the same pond water was studied in a similar way no

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bacteria were present in any of the water samples in which ZnO nanoparticles were added.

Table 1: Showing bacteriology of water samples from a well and a pond

Sl. No	Bacteria Present / Absent	Identification of Bacteria
Sample I Well Water	Present	*Klebsiella, E. coli*
Sample II Pond Water	Present	*Klebsiella, E. coli*

Table 2: Showing bacteriology of samples from the well after adding ZnO nanoparticles

Amount of ZnO_2/100ml (gm)	Bacteria Present / Absent	Identification of Bacteria
Sample-A 0.01 gm / 100 ml	Present	*Klebsiella, E. coli*
Sample-B 0.02gm / 100 ml	Absent	Nil
Sample-C 0.5gm / 100 ml	Absent	Nil
Sample- D 0.01 gm / 100 ml	Absent	Nil

A study on removal of arsenic using ZnO nanoparticles was conducted for a duration of five days continuously. Table 3 shows the result of arsenic removal using ZnO nanoparticles. Initially an amount of 5 mg/100 ml arsenic was added to a solution also containing silica. On the first day, the initial amount was 5mg/l. By the end of 1st day the amount of arsenic was reduced to 2 mg/litre. By second day, when the amount of Ar was tested it was found to be only 1 mg/l. After 27 hrs, the amount of Ar was reduced to 0.5 mg/l. By third day (51 hrs.), the initial amount was 0.5 mg/l and after 40 minutes heating and 2 hr. resting, it was found to be only 0.2 mg/l. By fourth day (75 hrs.), the initial amount was 0.2 mg/l and after 40 minutes heating and 2 hrs. resting, the amount of Ar was reduced to 0.1 mg/l only. By fifth day (96 hrs.) the initial amount was 0.1 mg/l and after 40 minutes heating and 1 hr. resting, the amount of Ar was reduced to 0.05 mg/l. By the end of 5th day (100 hrs.) the amount of Ar was reduced to 0.0mg/l.

Table 3: Showing the removal of Arsenic by the action of ZnO nano particles

Days	Reaction hours	Amount of Arsenic (Mg/Litre)	
		Initial	Final
1st day	12 Hrs.	5	5
End of 1st day	24 Hrs.	5	2
2nd day	26 Hrs.	2	1
2nd day	27 Hrs.	1	0.5
3rd day	51 Hrs.	0.5	0.2
4th day	75 Hrs.	0.2	0.1
5th day	100 Hrs	0.1	0

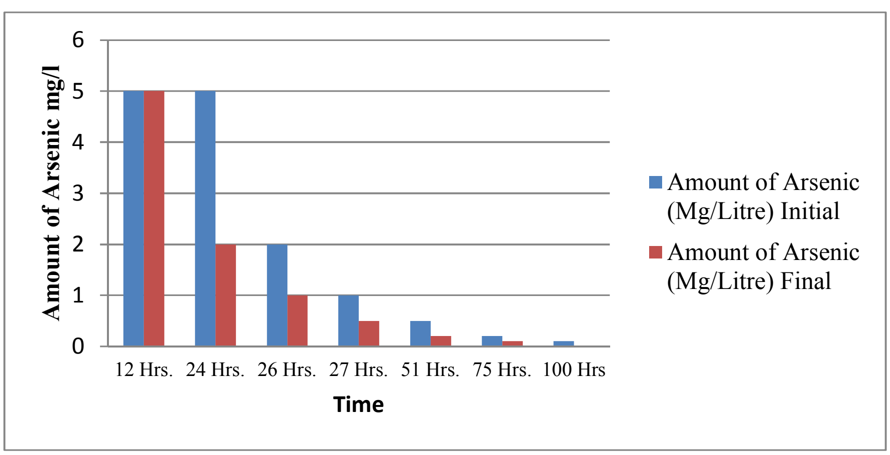

Figure 1 showing Arsenic removal by ZnO nanoparticles

It was evident from our results that ZnO nanoparticles are having an antibacterial effect. Similar finding were also done by various researchers in different countries. As *Klebsiella* is known to cause many diseases to mankind, such a method of effective prohibition of its growth in water is considered to be highly beneficial. It is reported that *Klebsiella* organisms can lead to a wide range of disease states, notably pneumonia, urinary tract infections, septicemia, meningitis, diarrhea, and soft tissue infections (Podschun and Ullmann, 1998). *Klebsiella* species have also been implicated in the pathogenesis of spondylitis and other spondyloarthropathies (Sieper and Braun, 2011). The majority of human *Klebsiella* infections are caused by *K. pneumoniae*, followed by *K. oxytoca*. Infections are more common in the very young, very old, and those with other underlying diseases, such as cancer (Bagley, 1985) and most infections involve contamination of an invasive medical device.

On the other hand, although, most *E. coli* strains do not cause disease, virulent strains can cause gastroenteritis, urinary tract infections, and neonatal meningitis. In rarer cases, virulent strains are also responsible for hemolytic-uremic syndrome, peritonitis, mastitis, septicemia, and Gram - negative pneumonia (Todar, 2007). It was found that *E. coli* growth can also be prevented by ZnO nanoparticle addition to polluted waters.

Uropathogenic *E. coli* (UPEC) is one of the main causes of urinary tract infections. It is part of the normal flora in the gut and can be introduced in many ways. In fact, it is previously reported that the ZnO nanoparticles can be used in the production of disinfecting suspensions to be used on surfaces, medical devices and home appliances (Fars News, Tehran, 2015). The present study shows that ZnO nanoparticles are very effective in removal of bacteria. So it can be used as an antibacterial agent.

When the arsenic removal property of ZnO was studied, maximum increase in adsorption area was obtained by adding 3gm silica to the ZnO solution. Adsorption here is due to greater availability of the surface area at higher concentration of the adsorbent. Any further addition of the adsorbent beyond 3gm did not cause any significant change in the adsorption. This may be due to over lapping of adsorption sites as results of overcrowding of adsorbent particle.

The maximum removal of As3+ was obtained in the adsorbent dose of 3 gm which is in accordance with other researchers (Namsivayam *et al*., 1998). We also reached maximum Ar removal by this method. It was found from our study that above 50% removal was easily possible by day one. On the consequent days similar Ar removal rate was again observed. This is in accordance with the findings of many workers (Namsivayam *et al*., 1998).

The studies involving different contact times help in determining the uptake capacities of the arsenic at varying time intervals keeping the amount of the Silica Ar adsorbents fixed at room temperature. The purpose of studying the effect of time on adsorption is to establish the equilibrium reaction time between adsorbent and As3+. The adsorption experiment was carried out using contact time ranging from 24 hrs 5 days and the results are depicted in the Figure 1 and 2. It was observed that metal adsorption occurred rapidly. This result was in accordance with the findings of (Gnanasangeetha and Sarala Thambavani, 2013). The adsorption efficiency of As3+ was maximum during the first day. Complete removal of arsenic was possible by the 5^{th} day itself. It proves the fact that ZnO have extensive applications in water purification (Sunandan *et al*., 2012). ZnO nanoparticles have been used to remove arsenic, sulphur from water even though bulk zinc oxide cannot absorb arsenic. It is because nanoparticles have much larger surface areas than bulk particles (Dhermendre and Behari, 2008).

As reported earlier, the final result of arsenic poisoning is coma and death. It is therefore essential to search benevolent product and to transform such materials to adsorbents of less toxic nature. It is evident from our findings that ZnO nanoparticles serve a dual function of removal of bacteria and heavy metals especially arsenic.

Highlight of the Research Paper

It is an effective method of environmental nanotechnology to reduce bacterial growth of pathogenic bacteria such as *Klebsiella* and *E. coli* in water and is useful in medical research as an antibacterial agent. It is also highly beneficial to control heavy metal pollution effectively. Hence ZnO nanoparticles serve a dual function.

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