A Review on Adsorption of Escherichia Coli (E. coli) With Different Types of Inorganic Nanomaterial's from Water

Ibsa Neme, Chandra Masi, Baru Debtera, N.R. Srinivasan

Abstract: ***This review examines the performance of latest highly capable nano materials in water purification. Easy synthesis and valuable nano-particles have plentiful applications in water disinfection. In recent times the existing researches explain an increasing applicability of (Zinc oxide, Copper, Silver, Titanium oxide & Iron oxide) nano-particles in the water disinfection. Environmental (i.e. water/air filter), industries (i.e. textile, animal husbandry, food packaging) and Biomedical (i.e. medical devices, hospitals) are some of different sector uses those nano-particles. Bacteria and protozoa are among the most typical pathogens of aforementioned untreated water, with gastroenteritis, urinary tract infection, intra-abdominal infections, and etc. harmful effects on human beings in developing countries. In this review, the aforementioned types of nano-particles as a disinfectant for E-coli removal from water have been included in detail.***

Keywords: **E-coli, Inorganic nano particles (i.e. ZnO, Ag, Cu, TiO_2 and Fe_3O_4)**

I. INTRODUCTION

Water contaminated by means of microorganisms such as bacteria, protozoa, virus and other parasites is able to bring diarrhea, diseases and death simply [1]. Among the numerous microorganisms, bacteria are reported as the most dangerous pathogens. Escherichia coli (E. coli), is one of the most frequent causes of many bacterial infections, including gastroenteritis in developing countries. It also causes urinary tract infection (UTI), neonatal meningitis, bacteraemia and intra-abdominal infections. E. coli can be originated from faecal pollution (i.e. animal/human, sewage wastes) in the microbiological examination of drinking water. Finding of E. coli shows, compulsory for a critical exploration of the water supply system in order to identify and remove the source of microorganisms [2]. To overcome these problems various methods have been used to reduce pathogenic microorganism's removal from water, such as UV disinfection, reverse osmosis (RO) membrane, chlorine disinfection system and activated carbon, however until now not totally eliminated from various parts of the world. For aforementioned types of methods, adsorption by activated carbon impregnated with nano-particles is commonly used methods for water disinfection, because of its antibacterial activity in the nanometer dimension range [3]. Different nanomaterials have been engaged as an antibacterial with optimizing their physicochemical properties. Hence, several inorganic nano materials such as TiO_2, ZnO, Ag, Cu and Au have also been investigated to understand their antibacterial properties impregnated with activated carbon or other adsorbent types [4].

Nano-particles kill bacterial cells due to generation of reactive oxygen species (ROS) [5]. Nowadays nano-based inorganic materials have good quality during removal of bacteria from water because of their special properties (i.e. size, shape, phases). These special properties of those inorganic nanomaterials and their compounds have primary applications in the air/water purification, medical devices, textile and food packaging fields. Iron Oxide, Zinc Oxide and Copper Oxide nano particles eliminate heavy metals for instance lead (II), Chromium (VI), Nickel (II), Iron (III) and Cadmium from waste water [6]. Studies proves that Silver nano particles and Zinc oxide nano particles be able to diminish the growth of microbes (i.e. Escherichia coli) when they are impregnated on porous supports like activated carbon, exclusive of affecting adsorption ability of the original activated carbon [7, 3]. Several researchers have concluded that water filters implanted with silver/zinc/titanium oxide nano particles proved efficient for the elimination and killing` of Escherichia coli. Their researches make known how different porous matrices like activated carbon [3], resin beads [8], polyurethane foam [9] and ceramic disk filter [7] impregnated with nano particles adsorb E-coli under different operation condition of filter such as contact time, bed height, initial E-coli concentration, adsorbent dose and concentration of nano particles influence the sorption process. This review paper compares the adsorptive ability of the different types of inorganic nanoparticles, discussing with the major helpful situation for the elimination of Escherichia coli from house hold water.

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II. APPLICATION OF INORGANIC NANOMATERIALS IN WATER DISINFECTION

Access to safe water for drinking should be one of the sustainable growth aims to be now and in the future. Currently, the different methods are accessible presently; the various methods are available in order to clean water [5]. Ultra violet (UV) based water treatment method is expensive and needs energy to control [3]. Reverse Osmosis membrane based methods is a force driven methods wherein a semi-permeable membrane discards dissolved substances and microorganisms existing in water. On the other hand, deterioration can be decline membrane flux and cut down membrane life [10]. Chlorine based methods commonly used as water treatment; however it has a few disadvantages for example bad awful and smell, in addition ineffective as a result of microorganism's resistance and generated harmful product in water [11]. Activated carbon based water disinfection methods is most cost effective to eliminate taste, smell and further microbes. In contrast, Escherichia coli bacteria can be stick on the exterior of activated carbon with the final as the carbon sources. So as to destroy Escherichia coli and other microbes, inorganic nanomaterials such as ZnO, Ag, Cu, TiO_2 and Fe_3O_4 are used with activated carbon/adsorbents as antimicrobial agent [12]. And also impregnation of Nano-particles on polyurethane foam and water filter ceramic be able to helpful disinfectant than easy water filter [13]. For that reason, integration of inorganic nanomaterials on adsorbent like ceramic, polyurethane foams, bead resin and activated carbon to design nano based devices have generated latest techniques for water disinfection than usual water disinfection techniques.

Nanomaterials have powerful adsorption capacities because of their remarkable properties (like small size, large surface area). Microorganisms (i.e. bacteria, virus) has been reported to be effectively eliminated by various kinds of inorganic nanomaterials [14]. According to several studies, inorganic nanomaterials show vast guarantee to remove bacteria from water. Recently, a large amount of widely studied inorganic nanomaterials used for water disinfections to remove bacteria mainly include ZnO, Ag, TiO_2, Cu and Fe_3O_4 nanoparticles.

A. Silver Nanoparticles (AgNPs)

At this time silver nanoparticles have received vast attention of the researchers because of their surprising defense against a wide variety of microorganisms (i.e. virus, bacteria and fungi) and also due to the form of medicine resistance against generally used antibiotics [14, 15, 16]. As a wide range of antibacterial agent, AgNPs have been widely used for the disinfection of water. Therefore, impregnation of AgNPs with different types of adsorbent (i.e. activated carbon, ceramic disk, polyurethane, resin beads and others) in water filter is useful purifier than easy filter. Actual impact of silver nano particles impregnated with activated carbon and beads on the E-coli and its absolute elimination from water by filtration has been discovered [3, 8, 12].

The time and cell concentration of E-coli are normally certainly interrelated. As increase of the time (min), there is decreasing colony count of E-coli.

The figure, can be written as given below.

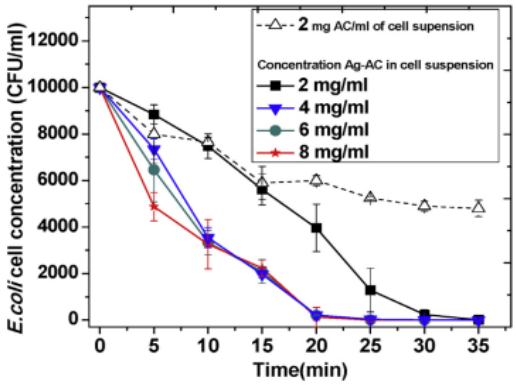

Figure 1: Batch mode cell-killing data for 2, 4, 6 and 8 mg Ag-AC/ml of cell suspension, measured by plate count method (*Pritam Biswas, Rajdip Bandyopadhyaya, 2016*)

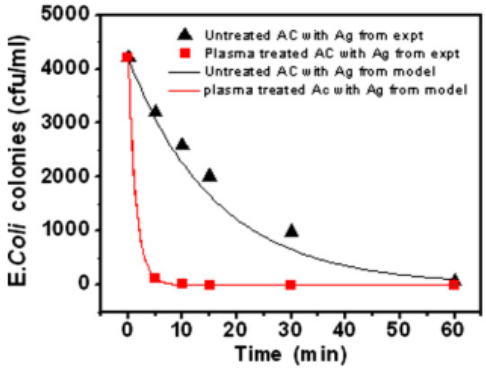

Fig. 2: Flask test of AgNPs for Escherichia coli removal (*N.R. Srinivasan, P.A. Shankar, Rajdip Bandyopadhyaya, 2013*)

B. TiO_2 Nanoparticles

At this time photo catalytic removal technology has been completely useful in the pollutant removal in waste water. The popular of photo catalysts are metal oxide; amongst titanium oxide has been widely investigated in the earlier period. Because of its high photo catalytic ability, reasonable cost, chemical and biological constancy, titanium oxide is good excellent photo catalyst up to now [17]. Matsunaga, studied for the earliest time, microbial cells could be destroyed during contact with platinum titanium oxide catalyst below illumination with ultra violet (UV) light for 60 - 120 minute. This discovery formed a latest method for sterilization and near to several photo catalytic disinfection studies using titanium oxide. Microorganisms and cancer cells are integrated in the broad range of organisms that be inactivated using this method [18]. Titanium oxide (TiO_2) photo catalysis promotes the peroxidation of Escherichia coli membrane phospholipids and induces main disorders in the cell membrane.

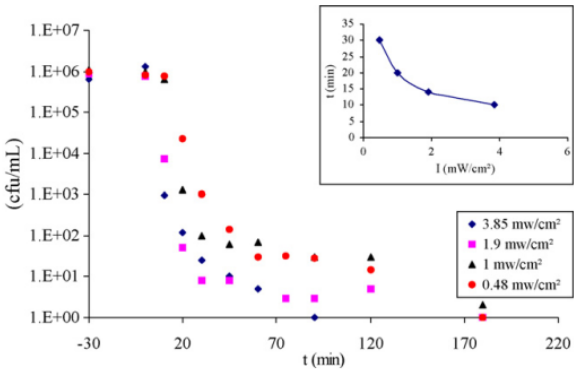

Fig. 3: Intensity effect of UV domain with titanium oxide on E. coli concentration (*Z. Derriche, C. Guillard, 2007*)

C. Zinc Nanoparticle

Zn nano particles are stronger contaminant elimination in wastewater treatment. And also zinc oxide nanoparticles have been used in industries, biomedical and air disinfection [19]. In addition, it is eco-friendly with environment, well-matched with microorganisms which make it appropriate for water disinfection [20]. Advantages of zinc oxide nanoparticles are low cost and nontoxic than other inorganic nanomaterials [21]. Besides, many studies have shown that impregnation of ZnO nano particles with adsorbent (like, activated carbon, ceramic disk) is a feasible approach for the reduction of Escherichia coli. The efficiency of adapted ceramic disk filters was affected by various variables in the filter production process. The decrease of Escherichia coli could be recognized to both filter retention and photo catalytic antibacterial activity of zinc oxide nanoparticles [7].

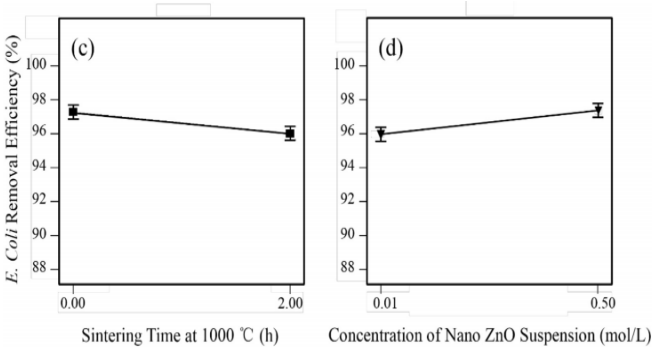

Fig. 4: Major variables affecting Escherichia coli elimination efficiency: (c) effect of sintering time at 1000 °C, (d) effect of concentration of nano ZnO suspension (*Guohe Huang, Yuan He, Yao, Peng Zhang, 2018*)

D. Copper Nanoparticles (CuNPs)

Copper based nanomaterials have shown amazing properties for sorption of microorganisms (i.e. Vibrio cholerae, E-coli, Salmonella. fungi and other parasites) activities due to their large specific surface area and high porosity resulting in an unexpected sorption capacity [22]. In addition, it can be integrated into fibrous materials to act as a long-lasting reservoir of copper ions for enhancing antimicrobial and catalytic activity [23]. The figure, can be described as given below

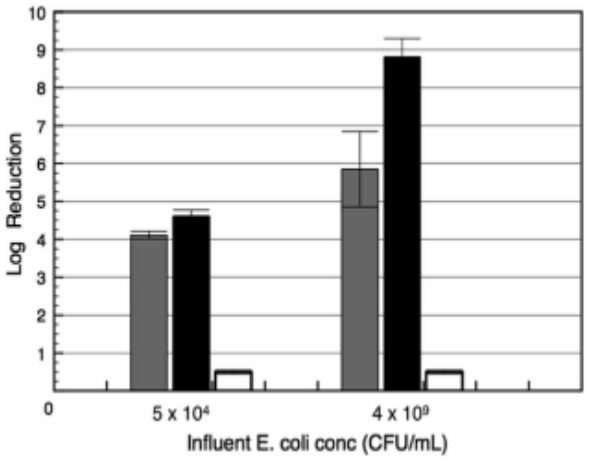

Fig. 5. *Escherichia coli* bacterial log reduction count after permeation through the CuNPs paper with paper. (*Theresa A. James A. Smith, 2014*)

E. Iron oxide nanoparticles

Naturally iron oxide materials exist in different forms, for instance maghemite (gamma Fe_2O_3) and magnetite (Fe_3O_4) and hematite (alpha-Fe_2O_3) [24]. Investigation of iron oxide nanoparticles in membrane separation is a modern study trend because of their adsorption properties, high BET surface area, high pore volume, cost effectiveness and non-toxicity. Sirshendu De, Munmun Mukherjee, et al. (2015) reported antibacterial activity of iron oxide nanoparticles impregnated with ultra filtration mixed matrix membrane. Hence, the adsorption of E-coli by mixed matrix membrane was quantified, and the efficiency of this membrane towards the elimination of microbes from water was investigated as a function transmembrane pressure and cross flow rate. The performance of iron oxide nanoparticles presented in figure 6 below. With an increase in concentration of Fe_3O_4 nanoparticles, the elimination of microbes increases due to surface adsorption.

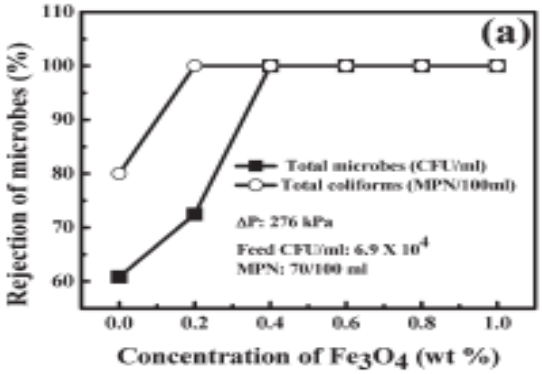

Fig. 6. (a) Microbe rejection in a batch cell of mixed matrix membrane using iron oxide nanoparticles (*Sirshendu De, Munmun Mukherjee, 2015*)

The types of inorganic nano particles and its ability to remove Escherichia coli are listed below.

Table 1: Nano particles and their ability to remove *Escherichia coli* (E-coli)

Adsorbent	Embedded Nano-particles	Experimental condition	Target microorganism	Microorganism removal	Reference
Granular activated carbon	Ag	(6) 30 sec (3) 9–10.5 wt% of Ag (1) 3.2 log - 2.7 log	E-coli	------	[23]
Ceramic disk filter	ZnO	(1) 10 to 10^7 cfu/ mL (6) 0 - 2 hr (3) 0.01 - 0.5 mol/L (2) 6.07 µm	E-coli	99.2 %	[7]
Plasma Treated Activated carbon	Ag	(6) 0 -60 min (3) 30 mg (*0.89%*) (1) (4500 - 0) cfu/ml (2) 44 - 149 µm	E-coli	41.88 h^{-1}	[12]
Polyurethane foam	Ag	(1) (1.29.10^2 - 0) cfu/ml (6) 5 hr (3) 0.02 - 0.12 mg	E-coli	100 %	[9]
Alginate composite beads	Ag	(6) 4 min (1) (10^6 - 0) CFU/ml	E-coli	89.4 %	[24]
Photo catalytic	TiO_2	(3) 0.25 g/L (6) 220 min (2) 44 - 149 µm (1) (10^8 - 0) CFU/ml	E-coli	99.5 %	[27]
	TiO_2	(6) 40 min (4) 5.8–6.0 (3) 0.1 g/l	E-coli	100 %	[28]
	TiO_2	(6) 30 min (3) 0.2 - 2 mg/ml (1) (10×10^{-7}) CFU/ml	E-coli	99.5 %	[29]
Cellulose paper fibers	CuNPs	(1) 4×10^9 - 5×10^4 CFU/ml (6) 50 hr (3) 225 mg Cu per g of cellulose	E-coli	------	[30]
Mixed matrix Membrane	Fe_3O_4 NPs	(1) 6.9 × 10^4 CFU/ml (3) 0.4 % (6) 1 hr (4) 8.5	E-coli	100 %	[26]

(1) Initial concentration, (2) particle/pore size, (3) adsorbent dosage, (4) effect of pH, (5) agitation speed, (6) effect of contact time, (7) effect of solution's volume

III. CONCLUSION

In recent times, the use of inorganic nanomaterials for water disinfection sectors has been increased. The journal and review of the literature have shown that water disinfection using nanomaterials is a promising field for current and future research. To keep away microbes infection, the ZnO, Ag, Cu, TiO_2 and Fe_3O_4 nanoparticles have been used from last few decades. By the broad advantages of ZnO, Ag, Cu, TiO_2 and Fe_3O_4 nanoparticles products in different places as antimicrobial agents, the exact impact of their corrosion, toxicity and their relatively high cost researcher concerned on zinc oxide (ZnO) and iron oxide (Fe_3O_4) nanoparticles can proceed as antibacterial option by means of fewer danger and price.

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