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Antimicrobial Properties and Applications of Polymers: A Review

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Abstract—*Control of microbial infection is a very critical issue in our society and a leading cause of morbidity and mortality. We know that, treatment of microbial infection is very difficult. But the use of polymers in the various fields has reduced the suffering of humans. Especially, for the microbial infections polymers which have antimicrobial properties are produced by adding antimicrobial agents. The antimicrobial polymers are used to protect against negative impact of the pathogenic microorganisms. Some metals have a biocidal activity that's why they are used as antimicrobial agents. Silver, gold, magnesium oxide, copper oxide, titanium dioxide and zinc oxide are used as antimicrobial agents. The addition of metals into polymers shows antibacterial properties and there are numerous techniques of counting microbial growth. Antimicrobial polymers are used in different fields such as food industry, medicine and healthcare product, water treatment, textile product etc. Research in the field of antimicrobial polymers is increasing due to intense demand for the practical applications. This article covers the introduction of polymers, working mechanisms of antimicrobial polymers, types of antimicrobial agents, methods of measuring microbial growth and the applications of antimicrobial polymers in different fields.*

Keywords*: Polymers, microbial infection, antimicrobial agents, metals.*

1. INTRODUCTION

With the beginning of plastic industry, the use of polymers in variety of applications was increased. Polymers are defined as large molecules having high molecular mass 10^3 -$10^{7.}$ All polymers are macromolecules and formed by the combining together of a large number of small molecules called monomers. The repeating unit of monomer is called degree of polymerization.

Polymers can be classified into two types: Natural polymers occur in nature (proteins, cellulose, starch etc.) and Synthetic polymers can be prepared in the laboratory by synthetic route (PVC, polyethene etc.) and are classified in a number of ways [11, 21, 22].

Effect of structures on the properties of polymers [9, 22]:

a. Molecular mass.
b. Nature of monomers.
c. Solubility.
d. Shape of polymers.
e. Crystallinity.
f. Intermolecular forces of attraction.

2. CLASSIFICATION OF ANTIMICROBIAL POLYMERIC MATERIALS [5, 6, 7, 12]:

Antimicrobial polymeric materials can be classified into four categories:

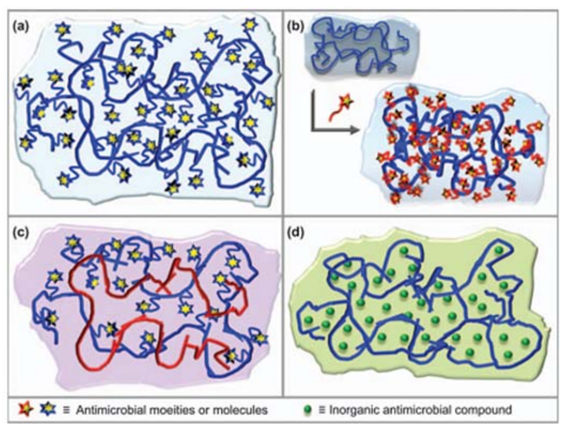

Fig. 1: Representation of: (a)Polymers with antimicrobial activity, (b) chemical modifications to achieve anti-microbial activity, (c) Polymers containing antimicrobial organic compounds, (d) Polymers incorporating antimicrobial inorganic compounds

(a) Polymers with antimicrobial activity:

Polymers which show the antimicrobial activities are: methacrylic polymers, polysiloxanes, polyoxazolines, synthetic peptides, arylamide and phenylene ethynylene backbone polymers, halogen polymers, fluorine or chlorine-containing polymers, polymers containing phospho- and sulfo-derivatives, phenol and benzoic acid derivative polymers, organometallic polymers and other.

(b) Polymers that undergo chemical modifications to achieve anti-microbial activity

There are different approaches to achieve antimicrobial activity into polymers. If chemical modification is involved: i) A small molecule with antimicrobial activity is covalently attached to the polymer; (ii) antimicrobial peptides are fixed on an inactive polymer and (iii) antimicrobial polymers are grafted to regular polymers.

(c) Polymers containing antimicrobial organic compounds

In this case, the antimicrobial activity is due to:

(i) Non covalent links between anti-microbial agents, either natural or synthetic
(ii) The mixture of anti-microbial polymers and non-active polymers to confer their biocide characteristics.

(d) Polymers incorporating antimicrobial inorganic compounds

In this, the antimicrobial activity in the final material is obtained by transfer of the biocidal action of inorganic systems, such as metals, metallic oxides into the polymers**.**

3. WORKING MECHANISM [13]

There are three general types of antimicrobial polymers:

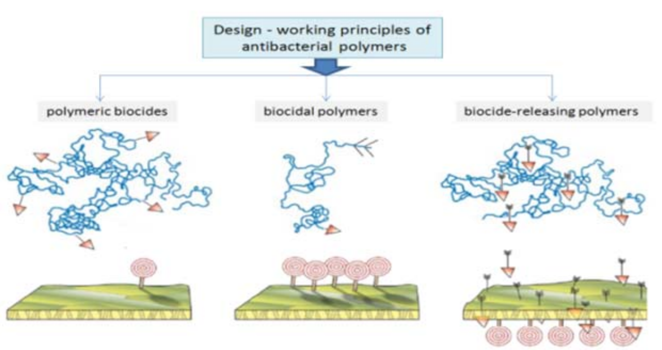

Fig. 2: Working principle of antimicrobial polymers.

Polymeric biocide

In this biocidal groups attached to a polymer. In this, polymers are just multiple interconnected biocides, which act like monomers.

Biocidal polymers

Active principle is embodied by the whole macromolecule. It does not necessarily demand the use of antimicrobial repeating units. Microbial cells generally carry a negative net charge at the surface due to their membrane proteins.

Biocide-releasing polymers

They are usually the most active systems, because they can release their biocides close to the cell in high local concentrations.

4. TYPES OF ANTIMICROBIAL AGENTS [1, 3, 10, 14, 15]:

Silver: Silver and their derivatives are used as antimicrobial agents. They can be synthesize and used for disinfecting filters and coating materials. It has been demonstrated that composites of silver nanoparticles with polymer results in the improvement of antimicrobial activities of silver nanoparticles at lower concentrations. In case of Staphylococcus aureus and Staphylococcus epidermidis silver is used.

Gold:

Gold particles are biocompatible and biologically inert. The efficacy of the antibacterial activity of gold nanoparticles can be increased by adding antibiotics. Au nanoparticles can be used to coat a wide variety of surfaces for instance implants, fabrics for treatment of wounds and glass surfaces to maintain hygienic conditions in the home, in hospitals and other places.

Magnesium oxide:

Magnesium oxide can retain for a long time. They also exhibit biocidal activity against Gram-positive bacteria and Gram-negative bacteria. Their extremely small size allows many particles to cover the bacteria cells to a high extent and bring halogen in an active form in high concentration in proximity to the cell. Standard bacteriological tests have shown excellent activity against E.coli and Bacillus megaterium and a good activity against spores of Bacillus subtilis.

Copper oxide:

Copper oxide is cheaper than silver and easily mixes with polymers and stable in both chemical and physical properties. It is used as antimicrobial agents. They are very effective in killing bacterial pathogens. But when we use high concentration of nano Copper oxide it will increase the bactericidal effect.

5. METHODS OF MEASURING MICROBIAL GROWTH [12]:

There are numerous techniques of counting microbial growth, measuring either cell mass or cell number, the following are examples:

(a) Dry/wet weight measurement:

(b) Absorbance/turbidity:

(c) Total cell count:

(d) Viable count:

(e) Cell-counting instruments

6. APPLICATIONS OF ANTIMICROBIAL POLYMERS [4, 9, 19, 20]:

Food industry:

Use of antimicrobial agents in food packaging can control the microbial growth to provide higher safety and quality products. Edible coatings and films can be prepared from polysaccharides. To control food contamination, edible coating or biodegradable packaging has been recently introduced in food processing. For keeping high concentration of preservatives on the food surfaces the packaging should carry antimicrobial and antioxidant compounds.

Medicine and health care product:

The safety of the healthcare environment is very important in our society. Bacterial exposure during surgical procedures or can be transferred from patient-to-patient from infected hospital surfaces. Antimicrobial polymers used as an antimicrobial wound dressing. Sometimes Catheters and other medical devices which placed inside human body are prone to bacterial infection because of antiseptic loosening and cause serious risk to patients. Infections associated with implants are difficult to resolve that's why antimicrobial polymers are used. Antimicrobial paper is use to reduce the proliferation of bacteria in office environment, hospitals, living rooms with pets, inside vehicles and many other places. Zinc oxide nanoparticles have been coated onto paper, giving an antibacterial surface suitable for use as wall paper in hospitals.

Water treatment:

Antimicrobial polymers are used to disinfect surfaces and hand-held water filters. For new water treatment techniques insoluble pyridinium-type polymers are used. Antimicrobial properties of benzaldehyde derivatives used in many biomedical applications and water treatment.

Textile product:

Antimicrobial polymer have been used enormously in sportswear, women's wear, undergarments, shoes, furnishing, hospital linens, towel and wipes and aesthetic clothing to impart biostatic properties of polymers. Nowadays various advancements are taking place in the field of antimicrobial polymers for textile coating and finishing. Antimicrobial agents are used in the textile sector, especially for hygiene application. The characteristics of an ideal antimicrobial textile are: permanent antimicrobial properties, antimicrobial activity on a wide range of microorganism, it should not contain toxic substances.

7. CONCLUSION

Microbial infection is very prominent in our society, but with the use of polymers in various fields has reduced the suffering of humans. Polymers which have antimicrobial properties are produced by adding antimicrobial agents. Silver, copper oxide, Magnesium oxide and gold are used as an antimicrobial agent and are used to protect against negative impact of the pathogenic microorganisms. These are used in different fields such as food industry, medicine and healthcare product, water treatment, textile product etc.

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