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Antiviral Textiles: A Review on their types and Significance

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ABSTRACT

The world is ever developing with new inventions and technology to cater the changing lifestyles of people. The COVID-19 pandemic has stressed an increased importance of health products. One such innovation is antiviral textile which are which are capable of preventing the microbes or viruses to contact the surface of textiles. Natural fibre textiles are the best medium for the growth of many microbes which leads to degradation and unpleasant odours. To prevent all these undesirable effects, textiles are impregnated with antiviral nanoparticles in the fibres or fabrics. The use of nanoparticles makes the textiles antimicrobial, anti odour, water and stain repellent. In the last few decades, natural polymers have gained much attention among scientific communities owing to their therapeutic potential. Antiviral textiles are classified into a few broad groups, such as polymeric materials, metal ions/ metal oxides, and functional nanomaterials, based on the type of materials used at the virus contamination sites. This review is an overview of antiviral textiles and their types, properties, structure of polymers and nanoparticles involved and their significance.

KEYWORDS:*Antivirals, antimicrobial textile, nanoparticles, polymers.*

I. INTRODUCTION

With an increasing global population and diseases, there is an immediate need for effective treatment-based antivirals and vaccines [1]. Textiles are the only medium of contact between our body and microbes. To prevent the microbial contact textiles can be treated with antimicrobial agents. Textiles are the woven or non-woven products which are produced by synthetic and natural fibres. Natural fibres textiles are the best medium for the growth of microbes because of their surface area and ability to retain moisture and they are also susceptible to accumulation, multiplication, optimal place for replication of microbes and proliferation of microbes into their surroundings [2, 3]. Therefore, it is necessary to treat textiles with anti-microbial agents to prevent the microbial contact with the body surface and also to avoid undesirable effects such as degradation, unpleasant odour and also potential health risks [2]. These undesirable effects can be controlled by antimicrobial resistant finishing of textiles. It can be done by many methods like impregnating antiviral nanoparticles into the textiles which allows them to become multifunctional. The antimicrobial agents either inhibit the growth of microbes or kill the microbes in textile by damaging the cell wall or alter cell membrane permeability, inhibit enzyme activity or inhibit lipid synthesis, denature proteins all of which are essential for microbial cell survival [4,5,6]. Since the early 2000s, the interest in silver as antimicrobial agent against bacteria and fungi has flourished again due the fact that silver ions (Ag+) are able to target almost all biomolecules in the bacterial cell. The interest in silver in medicine further surged with the more recent discovery that Silver [Ag] Nanoparticles are potent and broad-scope antiviral agents against numerous viruses, including several influenza viruses, hepatitis B virus, poliovirus, respiratory syncytial virus, and most recently even African swine fever virus[7] .A simple, cost-effective and eco-friendly method is airbrushing fabrication of antibacterial composite nanofibers using Nylon-6 and silver chloride (AgCl)[9].An ideal antimicrobial treatment of textiles should satisfy many requirements. It should be effective against broad spectrum of microbes, less toxic, it should meet the standards in compatibility tests namely cytotoxicity, allergy, irritation, sensitization and since textile products are repeatedly washed the finishing should be durable for laundering, dry cleaning, it should be cost effective and it should not produce harmful substances which have adverse effect on manufacturer and the environment. Most of all antimicrobial finishing of textiles should not harm or kill the non-pathogenic microbes on the skin of the consumer [5]. Exopolysaccharides [EPS] retrieved from probiotic bacteria with varied carbohydrate compositions possess a plenty of beneficial properties. The EPS finds applications in textiles. More attention has been given to the scientific investigations on antimicrobial, antitumor, anti-biofilm, antiviral, anti-inflammatory and immunomodulatory activities [8]. An ideal antiviral modified textile can be very useful to the present situation of pandemic and also in future. This review is about the antiviral textiles, their types and properties and application of this in present scenario.

ANTIMICROBIAL AGENTS IN TEXTILES

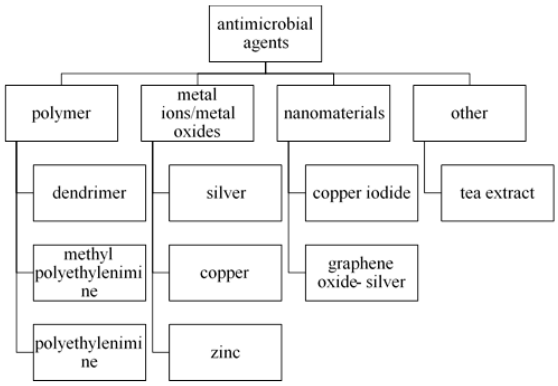

Figure 1: Classification of Antiviral textiles [10]

1.Dendrimers

Dendrimers discovered by Tomalia and co-workers in 1980's are also known as low molecular weight cascade molecules with a central core and terminal end groups [11,12]. Dendrimers can be made to possess antimicrobial properties either by converting primary amine groups into ammonium functionalities or producing silver nanoparticles complexes [13]. Dendrimers have unique properties owing to their globular shape and tunable cavities, which allows them to form complexes with a variety of ions and compounds. Modified dendrimers can be applied onto the Cotton/Nylon blend fabric [12]. Biocides immobilized on dendrimers are also considered as antimicrobial agents and they are effective in targeting the cell membrane and cell wall of microbes [14]. Dendrimer biocides are positively charged and bacteria are negatively charged causing electrostatic force of attraction. If concentration of dendrimer biocides exceeds, membrane permeability increases and bacterial membrane is disintegrates resulting in bactericidal effects [15]. Over the last decade, dendritic structures including hyperbranched polymers, dendrigrafts, dendrons and dendrimers have been used in the textile industries due to their distinct structural design and a large number of reactive end groups [16].

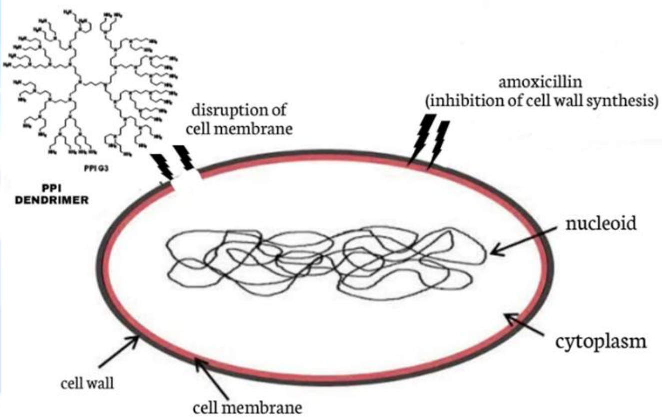

Figure 2: Schematic representation of antimicrobial action of dendrimer [17]

2.Methyl polyethylenimine

Several critical mechanistic and phenomenological aspects of the microbicidal surface coatings are based on immobilized hydrophobic polycations. Methyl Polyethylenimine exposed surfaces has exhibited a 109 fold reduction in the live bacterial count of Escherichia coli and Staphylococcus aureus by rupturing bacterial cell membranes. The bacteria fail to develop noticeable resistance to this lethal action over the course of many successive generations. Immobilized N-alkyl-PEI, while deadly to bacteria, is determined to be harmless to mammalian (monkey kidney) cells [18]. N, N-Dodecyl, methyl-polyethylenimine coatings applied to solid surfaces have been shown to disinfect aqueous solutions of influenza viruses. Upon contact with the hydrophobic polycationic coating, influenza viruses (including pathogenic human and avian, both wild-type and drug-resistant, strains) irreversibly adhere to it, followed by structural damage and inactivation; subsequently, viral RNA is released into solution, while proteins remain adsorbed [19].

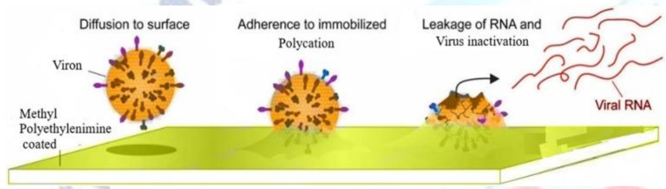

Figure 3: Schematic representation of antiviral action of Methyl polyethyleninime on coated surface [19].

3. Polyethyleneimine

Fabrics can be modified with polyethyleneimine (PEI) to increase the active sites. Modification of fabrics is affirmed by electron microscopy and infrared spectroscopy. PEI-modified fabrics are considered as a safely applicable and highly adsorptive material for the efficient elimination of pesticides from water with a good reusability [20]. Pieces of such cloths containing nonporous materials derivatized with N-hexylated+methylated high-molecular-weight polyethylenimine (PEI) are strongly bactericidal against several airborne Gram-positive and Gram-negative bacteria. The bactericidal textiles prepared here with are lethal not only to pathogenic bacteria but to fungi as well [21]. The process of producing electrospunfibers comprising polyethyleneimine nanoparticles (PEIN) is used to permit the antibacterial finishing of electro spinnable polymers, provide that these polyethyleneimine nanoparticles are particles of derivatizedpolyethyleneimine (PEI), since pure underivatized PEI has no antibacterial action. Preference is given to using quaternizedpolyethyleneimine. The electro spinnable polymers can be coated with PEIN during and/or after the electrospinning. The polymeric fibers obtainable by the process according to the invention can be used for textile fibers, for example for the production of fibres for functional apparel, for fibrous nonwoven webs or fibrous mats for cell culture substrates [22].

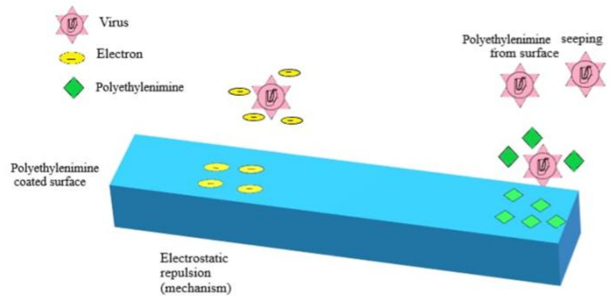

Figure 4: Schematic representation of antiviral action of PEI on coated surface [10].

4. Silver

Since ancient time most exclusive among all antimicrobial agents agent is silver. It is also known as 'oligo dynamic' because of bactericidal, antiviral and low toxicity characteristics [3]. Recently silver nanoparticles are extensively used because of its antibacterial, antiviral, antifungal, antiparasitic characters and also to its eco-friendly approach towards wide range of applications in industries like textile and medicine [1]. Silver nanoparticles are efficient against microbes because it affects the cellular mechanism of microbes by suppressing the cell growth, inhibiting respiration and basal metabolism of electron transport system, depletes the level of intracellular ATP and reducing the multiplication of microbes, cell membrane disruptions and dna damage of pathogens [23,24]. Combining silver with alginate and chitosin is used to make a novel antimicrobial material. Antimicrobial fabrics are produced by grafting cellulose wall with acrylic acid and treated with silver nitrate to make silver ions to bind with COOH group of graft co polymer and treated with tannic acid or ethylene diaminetera acetic dianhydride (EDTAD) for durable finishing of wool and this wool can react with silver and prevent the progression of microbes [25]. Silver nano particles also have a great effect on non-woven materials like water filters, air filters, medicinal clothing and textile woven fabrics which is a direct contact with human skin. It is also used in skin donor and recipient sites Plasma treatment [23]. Silver nanoparticles bought a new resolution in textile industries, medicinal industries and they represent the new generation of antimicrobial agents [26].

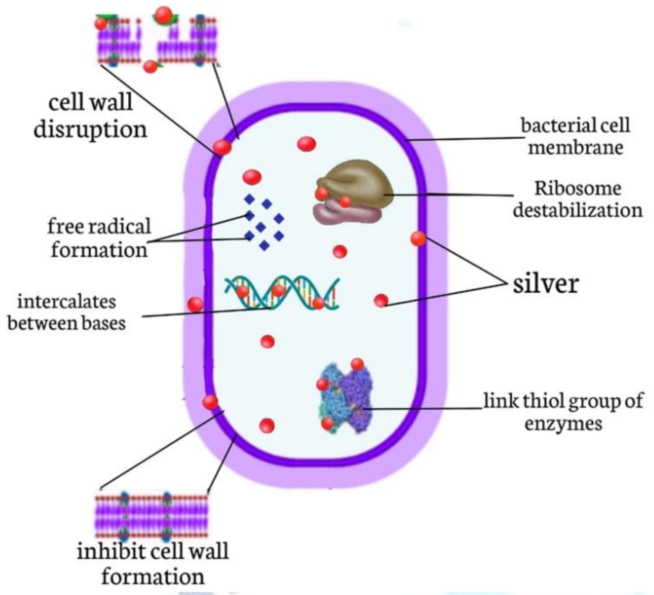

Figure 5: Schematic representation of antimicrobial action of silver nanoparticles [26].

5. Copper

Copper is a centuries old metal which has been in use for its wide spectrum of antifouling and bacteriostatic properties [27]. Nowadays copper and its compounds are more preferably used in textiles due to its antimicrobial property, low toxicity and less irritability for humans [28]. Textiles which are treated with copper shows broad range of antimicrobial and antimite properties which are used in production of antiviral gloves and filters; antibacterial and self-sterilizing fabrics, antifungal socks and antidust mite mattress cover [25]. Copper destroys the microbes by replacing essential metals from their native binding sites, interfering with oxidative phosphorylation and osmotic balance and also altering the conformational structure of proteins, nucleic acid and membranes [29]. Copper textile is prepared by cotton fibres with copper oxide and by impregnating copper ions in polyester, polypropylene, polyethylene, polyurethane, polyolefin or nylon fibres [27]. Textile coloration and electrically conductive textiles are also being prepared by electrolytic copper deposition [28]. The textiles treated with copper in different forms (Cu, CuO, Cu_2O) are used for medicinal purposes [28]. The copper carboxy methyl starch with trimethylolated melamine with cotton fabrics possesses a great antimicrobial property [25].

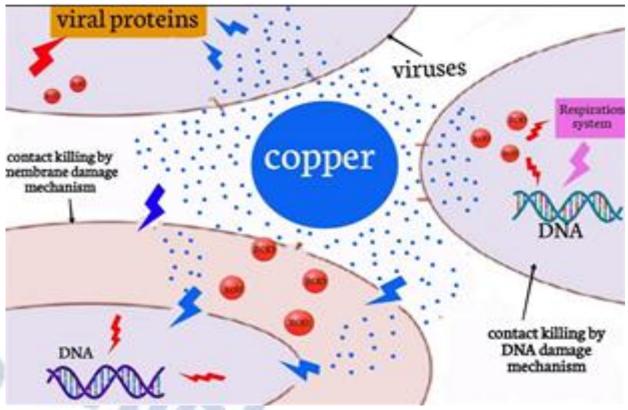

Figure 6: schematic representation of antimicrobial action of copper [30].

6. Zinc

Zinc plays a major role in textiles because of its properties like physical and chemical stability, high catalysis activity, unique optical properties and effective antibacterial activity [31]. Zinc oxide is mainly used to prepare antimicrobial textiles. To produce an efficient antimicrobial textiles cellulose fibre are used because it is the most attractive textile substrate for the application of Zinc oxide particles. Many procedures are used for the production of zinc oxide-based textiles among them sol gel, dip coating, padding, electro deposition and chemical bath deposition are usually performed [32]. Even zinc oxide nanoparticles are also used because of its antimicrobial properties and high specific surface area [33]. Zinc oxide has three unique characteristics, namely, semi conductivity, piezoelectricity, and bio safety compatibility with which we can make zinc oxide the most prospective nano material for future textile research. The effect of coating of nanoZnO particles on Polyester fabrics indicates that the antibacterial efficacy and washing stability of coated polyester samples depends on the composition of the coating solution [34].

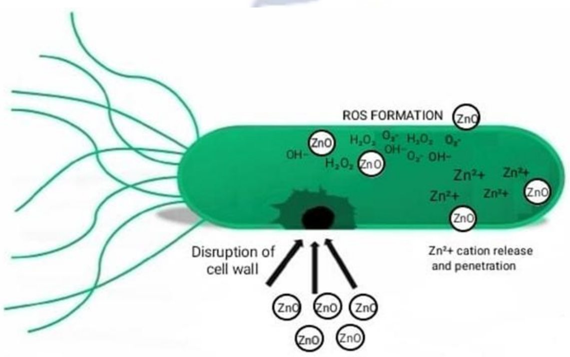

Figure 7: Schematic representation of antimicrobial action of Zinc Oxide [32].

7. Copper(I) iodide

Nowadays copper iodide is mainly studied because of its potential antimicrobial properties. Especially cuprous iodide (CuI) is the supreme starting material for the development of improved antimicrobial materials because of its neutral appearance and high antimicrobial activity as compared to other copper and silver materials and greater stability in air and water than other cuprous halides [35,36]. It is known that antimicrobial efficiency of cuprous iodide could be increased if they are made as a small particle in presence of vinylpyrrolidone polymers like this various CuI small particles are produced to be compatible with a various matrix with the help of co polymers [35]. However, studies showed that Cu-NPs (nano-sized 160 nm copper iodide CuI) exert antiviral activity on influenza A virus by degradation of viral proteins [36]. It is also demonstrated that antiviral activity was closely related to the generation of hydroxyl radicals derived from Cu (I) [30]. Cuprous iodide is an efficient antimicrobial agent in which particles are easily added to finished material with minimal or no change in appearance and they are also used to produce heat-stabilized thermoplastics which are approved to use for food contact applications. They are effective against broad spectrum of pathogens which includes viruses, bacteria, yeast and molds. It is an effective antimicrobial agent because of its safety and low-risk profile [35]. It is also used in making filters, facemask, protective clothing and kitchen wipes [36].

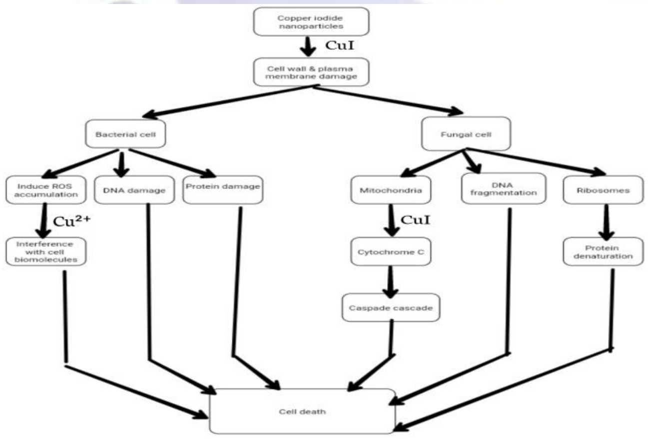

Figure 8: Schematic representation of antimicrobial activities of copper iodide [37]

8. Graphene oxide – silver nanoparticles (GO-Ag)

It is well known that silver nanoparticles have wide range of antibacterial, hypo toxicity properties but poor dispersion and low adhesion of silver nanoparticles obstruct their applications in textiles. So, it is necessary to introduce a suitable carrier material like graphene oxide which shows good biocompatibility and also its 2D is considered as a very good carrier to overcome limitations of silver particles [38]. Graphene-based materials have the ability to prevent the entry and replication of enveloped DNA virus (herpes virus) and RNA virus (coronavirus) in their respective target cells. The matrix of Graphene oxide- silver is highly dispersible in water, also contains specific surface area, exhibit good bactericidal activity at very low concentration and not corrosive in nature [39]. The bactericide effect of (GO-Ag) can be described in 4 levels firstly silver ions are released then they penetrate through the cell membrane after that ROS generation followed by DNA, protein, mitochondria, lipids and membrane damage which finally leads to death of a cell [40]. Antimicrobial active silver nanoparticles are incorporated into polyviscose medical textile substrate through simple wet chemical surface treatment process in which these treated substrates showed high air stability and chemical inertia by reduced graphene oxide - silver nanoparticles. By leaching test, it has been reported that even after accelerated washing cycles the novel composites exhibited high silver loading and high bactericidal activity over six hours of treatment. It has been reported that reduced graphene oxide – silver nanoparticles showed nearly 100% antibacterial activity against Ecoli [41].

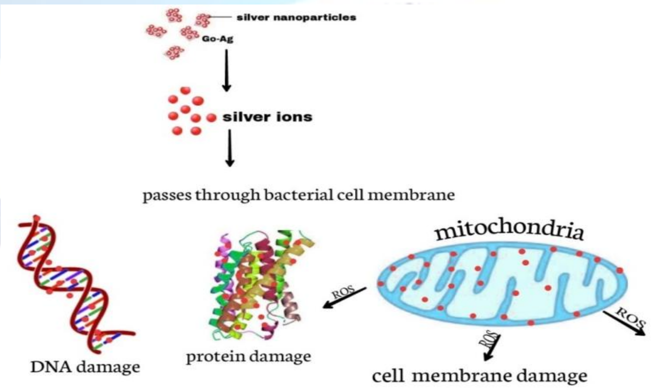

Figure 9: Schematic representation of antimicrobial activity of GO-Ag Nanoparticles [40].

9. Tea Extract

Tea tree (*Melaleucaalternifolia*) is native to North coast of New South Wales. This is world famous natural Australian product, used for ages by the Aborigines to help alleviate cuts, bites, burns and other skin ailments. The oil of tea tree has over 100 different compounds and is globally recognized as a natural medicinal product. Its oil is considered to have some of the best natural antiseptic / antifungal properties in the world. Its oil has gained widespread therapeutic use for fungal and microbial infections [42]. An antiviral mask having a nonwoven fabric impregnated with tea extract, can be easily produced commercially and is capable of maintaining a high virus trapping performance, inactivating the trapped viruses and preventing them from scattering. An antiviral mask can prevent the infectious viruses from entering the bearers oral and/or nasal cavities by trapping the viruses floating in the air at a high rate and inactivating the trapped viruses [43].

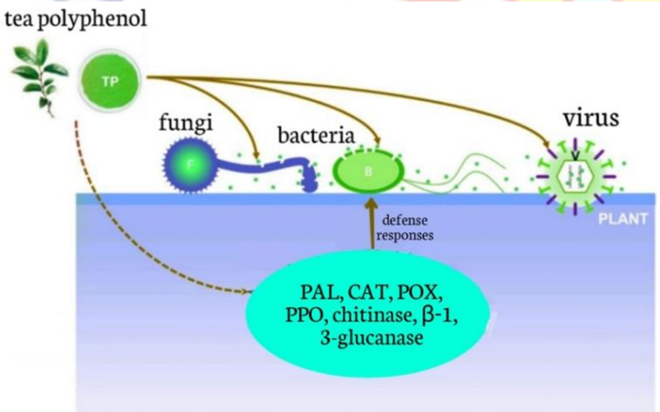

Figure 10: Schematic representation of the antimicrobial mechanisms of tea polyphenol [44].

CONCLUSION

Antimicrobial textiles were known from many centuries from antiquity, the ancient Egyptians used herbs and spices to conserve mummy wraps. In the recent year antimicrobial textiles has been taken as a great field of interest for many scientists around the world because of its broad spectrum of applications in various fields like healthcare, automotive textiles, sportswear, air and water filters. It is necessary to produce antimicrobial textiles to avoid the unpleasant effects and to prevent the reducing of textile's mechanical strength, stains the fabric. The antimicrobial textiles are prepared by the agents like dendrimer, silver, tea extract and so on widely used which are expected to address many challenges ranging from increased spreading of deadly diseases from bacteria, fungi, virus, spores and it should also be resistant with the microbes which generate unpleasant odour and protect the needs of life geotextiles and its artifacts. There is a high demand for the antimicrobial textiles all over the world because of its applications and they are also expected to function for the intended uses of textiles. By the considerable growth in the development of antimicrobial agents and technologies there is a high demand for antimicrobial textiles around the world. It will be break through in the field of textiles if the researches invent an antimicrobial agent which satisfies all the challenges.

FUTURE PROPECTIVE

The use of nanotechnology in the textile industry has increased rapidly due to its unique and valuable properties. There is a considerable potential for profitable applications of nanotechnology in cotton and other textile industries. Its application can economically extend the properties and values of textile processing and products. Nanoparticles have unique and well defined physical and chemical properties which can be manipulated suitably for desired applications. The future success of nanotechnology in textile applications lies in areas where new principles will be combined into durable, multifunctional textile systems without compromising the inherent textile properties, including process ability, flexibility. Moreover, their potent antimicrobial efficacy due to the large surface area to volume ratio has provided them an edge over their chemical counterparts which are facing the problems of drug resistance. Due to the public health awareness of the pathogenic effects on personal hygiene and associated health risks, over the last few years, intensive research has been promoted in order to minimize microbes' growth on textiles. Therefore, to impart an antimicrobial ability to textiles, different approaches have been studied, being mainly divided into the inclusion of antimicrobial agents in the textile polymeric fibers or their grafting onto the polymer surface. Any antimicrobial treatment performed on a textile, besides being efficient against microorganisms, must be non-toxic to the consumer and to the environment.

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