Effect of Nanomaterials Exposure on Microecosystem: a Review

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Abstract: The development and application of nanomaterials has become a global trend, and nanomaterials may harm the health of humans and animals through various mechanisms. Humans inevitably come into contact with these nanomaterials through multiple exposure pathways. In recent years, studies have shown that intestinal microecology is closely related to individual health, and its composition may be affected by nanomaterials. In this paper, the effects of nanomaterials on microecosystem and the application of nanomaterials were reviewed to provide basic information for further research.

1. Introduction

Nanomaterials, as a new material with the most potential for market application, are of undoubted importance. Many countries, including some developed countries America, Japan, Germany and so on, have invested a lot of money in nanomaterials research. Nanomaterials are materials in which at least one dimension of the three-dimensional space is nanoscale (1-100 nm) or is composed of them as basic units. Nowadays, nanomaterials have been widely used in various fields, including food [1], biomedical [2], chemical [3], electronics [4] and other fields.

According to different classification standard, nanomaterials can be divided into many categories. The major structural classes of nanomaterials (Figure 1) and application are briefly summarized here.

Nanomaterials Categories	Morphological Characteristics	Main Applications
Nano powder	Powder or Particle	Medical, Battery and Chip
Nano fiber	Filiform	Quantum computer and Photon computer
Nano film	Membrane	Superconducting and Environmental protection
Nano block	Grain	Home appliances

Fig.1 The Classes of Nanomaterials and Application

The most commonly used nanomaterials include metal nanomaterials, inorganic nanomaterials, organic nanomaterials, etc. However, with the rapid development of nanotechnology, it also causes a lot of safety problems. We are bound to be exposed to these nanomaterials through multiple exposure pathways. Therefore, it is necessary to study the effects of nanomaterials exposure on our health. In this review, the biosafety of nanomaterials is studied, especially the influence of nanomaterials exposure on microecosystem.

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2. Application and Influence of Nanomaterials

The special properties of nanomaterials have helped that scientists make breakthroughs in many fields. This makes the application of nanomaterials very wide. Applications of these nanomaterials in food, biomedical, chemical and electronics fields are discussed below.

2.1 Food Field

Applying nanotechnology to food field can optimize structure and performances, thereby ensure the quality of food. Nanomaterial packaging is divided into nanomaterial packaging material and nanomaterial coating liquid. Nanomaterial packaging material dispersed nanomaterials into other food packaging materials to improve the performance. Nanomaterial coating liquid is a mixture of nanomaterial and other materials, directly coated onto food. At present, nanomaterials are mainly applied to food packaging in food field.

Nanomaterials widely used in the food packaging industry such as beer, beverage, fruits and vegetables, meat, milk and products, and has achieved good packaging effect. Nanomaterials can effectively improve the quality of food packaging, prolong the delivery time of food, maintain the quality of food and inhibit the breeding of microorganisms. Nanomaterial food package contains the function of preservative. Too much ethylene is released in conventional packaging, which speeds up the decay of fruits and vegetables and reduces their taste and quality. And some nanocomposite packaging can reduce the content of ethylene, thus playing a role in preservation [5]. He Kui et al. successfully developed *Hypsizygus marmoreus* packaged by nano-film [6]. Li Baoxiang et al. explored the effect of the addition of nanocrystal cellulose (NCC) on the Preservation of Shatangju Mandarin [7]. Ma Xiao et al. prepare a new type of degradable composite preservative film and study its preservation effect on carp [8]. The research on preservative materials is not deep enough and the relevant products are not rich enough. However, it can be foreseen that nanomaterial packaging will be one of the most important development directions of food, and its prospects are very broad.

2.2 Biomedical Field

Nanomaterials play an important role in promoting the development of biomedicine due to their properties. Compared with traditional methods, the application of nanomaterials showed more clinical advantages in medical diagnosis and treatment.

Early diagnosis of tumor plays an important role in improving the survival rate of patients. However, traditional diagnostic methods can detect cancer only when the tissue has visible changes. At this time, there are often a large number of malignant tumor cells differentiated and metastasized, therefore miss the best time for treatment. Based on the advantages of good stability, biocompatibility and sensitivity of nanomaterials, nanomaterial biosensors and nanomaterial bioimaging techniques are usually used for cancer diagnosis. Giovanni Rizzi 's team [9] and Jered B Haun 's team [10] designed nanomaterial biosensors that can screen for malignancy by high-throughput analysis of the correlation between different biomarkers and network signals. Deju Ye et al. designed self-assembled nanoparticles that target in situ ligands to track in vivo tumor profiles at the molecular level [11].

There is a close relationship between nanomaterials and biological tissues in size. Nanostructures are also fundamental to the phenomena of life, ranging from DNA, RNA, proteins to viruses in sizes ranging from 1 to 100nm. In recent years, the application of nanomaterials for tumor surgery has become a new research direction. Traditional surgical treatment is mainly to remove the diseased tissue by external force, which will inevitably cause damage to the normal tissues or organs of the body. Among them, intraoperative or postoperative hemorrhage is one of the factors that endanger the life of patients. Therefore, many nanomaterials have been used to construct rapid and efficient hemostatic measures, significantly improving the safety of surgical treatment. Xin Zhao et al. proposed a nano-composite porous crystalline gel prepared by carbon nanotubes and chitosan derivatives, which showed excellent hemostatic effect on deep wound bleeding [12]. Secondly, nanomaterials are also widely used in artificial skin, blood vessels and tissue scaffolds

[13]. Rotimi A Bakare's research shows that the nanoparticles loaded PHBV film can inhibit the bacterial growth and greatly enhance bone cell adhesion, growth and proliferation [14, 15]. If the human heart stops beating in an accident, artificial nanored blood cells can be injected immediately to provide more oxygen [16]. Finally, nanomaterials are also used in drug delivery, which is a drug delivery system using nanoparticles as the drug carriers [17].

The application of nanomaterials has become a hot spot and frontier in the medical field. The development of nanomaterials is of great significance to medical diagnosis and treatment, and has wide application prospect and industrialization development space.

2.3 Chemical Field

Chemical is a huge field that affects every aspect of human life. The advantages of nanomaterials will no doubt bring good news to daily life, and show its unique charm and nanomaterials can play an important role. Nanomaterials have good absorption function and thin, light, wide, strong and others characteristics.

The application of nanomaterials in stealth technology is particularly noteworthy. In radar stealth technology, the preparation of ultra-high frequency (SHF, GHz) electromagnetic wave absorbing material is the key [18]. Nanomaterials are being developed as a new generation of stealth materials. The quantum size effect of nanomaterials makes the electron energy level split and creates a new absorbing channel for nanomaterials. The atoms and electrons in the nanomaterial are irradiated by a microwave field, which intensifies the motion and increases the efficiency of converting electromagnetic energy into heat, improving the absorption performance of electromagnetic wave.

In the next place, the ultra-sensitive properties of nanomaterials make their quantitative and rapid detection of trace substances become a research focus in chemical field. They are widely used in the production of special materials, due to various special properties of nanomaterials. At the same times, it promotes the application of nanomaterials more and more widely. It means that nanomaterials open up new horizons for chemical research.

2.4 Electronics Field

With the continuous development of nanotechnology, the research of nano-electronic technology has gradually made a breakthrough. Nano-electronic technology is the driving force for the development and expansion of national information technology. It is also an important factor to maintain the rapid development of electronic technology in the world. The application of nanomaterials in electronics field is mainly reflected in Network communication and nanostructured devices two aspects. Key nanodevices in network communication, such as laser, filter, resonator, micro capacitor, electronics and so on. Nanostructured devices use chip technology and high definition digital display technology. Electron devices include optoelectronic, molecular electronic and giant magnetic electronic devices.

For example, traditional silicon-based electronic components have the disadvantages of being bulky and slow to process [19]. However, nano-electronic components are very small, highly integrated, and very fast in computing and processing [20]. It also uses a lot less energy to dissipate heat. Nano-electronic devices with the above advantages to achieve many technologies such as quantum computing, cloud computing, VR technology and so on. It is believed that the continuous development and manufacture of new nano-electronic components will promote the emergence of nanoscale computer technology in the future. We can realize quantum transistor technology through nano-electronic technology, promote the development of quantum computer and make outstanding contributions to the progress of world science and technology.

3. Intestine Microecosystem

Intestine, a most important digestive organ, refers to the longest digestive canal from the stomach to the anus. Intestines system is a network of neurons in the muscular and submucosal layers of the gastrointestinal tract [21]. The complex system in the human body is the microecosystem, which are made up of the intestine and the gut microbiota that live in it [22]. Intestinal microorganisms and

their hosts constantly exchange materials, energy and information, jointly promoting and maintaining the body's health. Under normal physiological conditions, intestinal microecology maintains a relative dynamic balance. The balance of microecosystem is closely related to a variety of diseases, such as, irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), colon cancer, etc [23]. If the balance of intestinal microecology is broken, gut microbiota will become disordered in terms of species, quantity and function.

On this basis, gut microbiota may interact with a variety of biological effects produced by nanomaterials. The possible effects of nanomaterials on intestinal microflora are mainly studied in animal models, but the clinical application is rarely reported.

4. Effects of Nanomaterials on Gut Microbiota

Nowadays, with the rapid development of nanotechnology, various forms of nanomaterials have been widely used in various fields. While promoting human progress, nanomaterials also cause many undesirable biosafety problems. Intestinal system is an important organ for nutrient absorption and physiological barrier and may be the main target of nanomaterial exposure.

Zinc oxide nanoparticles (ZNP) can inhibit *Escherichia coli* and *Staphylococcus aureus* by contacting free Zn^{2+} on the surface and releasing free radicals [24]. At the same time, ZNP materials have been widely used in the medical field. Studies have shown that ZNP used as drugs can be absorbed into the body through the gastrointestinal tract, damaging intestinal epithelial cells, destroying intestinal barrier and revealing the possibility of bacterial translocation [25]. Studies at home and abroad have reported that ZNP has acute toxic effects on algae, crustaceans and vertebrates [26]. Other studies have revealed that ZNP has neurotoxic developmental toxicity and genetic toxicity, and after intraperitoneal injection of ZNP, the diversity of intestinal microflora in mice decreases and the heterogeneity increases [27].

In food packaging, silver nanoparticles (Ag NPs) had a broad spectrum of antibacterial properties, such as bacteria, fungi, protozoa, and some viruses. And the packaging of Ag NPs can extend the shelf life of food. Due to the size, AgNPs can penetrate the body through oral exposure and reach the gastrointestinal tract. AgNPs absorption (transcellular and paracellular transport and vesicular phagocytosis) through the gastrointestinal tract epithelium could take place. In addition, the nanoparticles that escape the absorption process reach the colon where they could modulate the composition and/or activity of gut microbiota, affecting the production and toxicity of bacterial metabolites [28]. A study showed that silver nanoparticles involved the secretion of the pro-inflammatory cytokine interleukin-8 (IL-8) in vitro model of the intestinal mucosal barrier by Caco-2 cells [29]. IL-8 promotes the occurrence of intestinal inflammation. In one of these studies, it was found that Ag-NPs increased oxidative stress, inflammation and apoptosis in the human gingival fibroblast cell line (CRL-2014) [30]. Emerging research showed that nanosilver can lead to cell membrane dysfunction through the release of Ag^{+} in the sphingolipid metabolic pathway [31].

Epidemiological studies have also shown that exposure to nanoparticles is closely related to the occurrence and development of diseases, for example, gastrointestinal inflammation.

5. Conclusion

Nanomaterials have a promising future ahead in our life. We inevitably come into contact with these nanomaterials in a variety of ways. And the disorder of intestine microecosystem is closely related to many diseases. Therefore, it is necessary to assess the health effects of the use of nanomaterials.

To date, effects of nanomaterials on the intestinal microecosystem and metabolic activity are largely unknown, but what is known is that there are numerous factors that can produce an imbalance in the intestinal bacterial populations, like food, triggering certain diseases. That is why the investigation of the NPs- microecosystem relationship is so important and should continue. Furthermore, it is also necessary to continue studying the different types of nanoparticles including form, size distribution as well as dose and modes of administration/exposure of them to state

detrimental effects on health. Finally, it is suggested that we should establish standards for the use of nanomaterials in different fields for health reasons.

It is hoped that this review will draw attention to intestinal nanotoxicology and provide basic information for further research.

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