

The Toxic Effects of Nanometer Zinc Oxide on Aquatic Organisms

(A review)

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Abstract. Nano-ZnO is a typical engineered nanomaterial, which is used in many fields. With its mass production and wide application, more and more nano-ZnO discharge into the water body. Water ecological environment is facing a huge threat. This article summarizes the toxic effects of nano-ZnO on different types of aquatic organisms and looks into the directions for further research on the bio-toxicity of nano-ZnO in aquatic environments.

Introduction

Nano-ZnO is a typical nano-material with excellent performance and wide application. Although numerous studies have demonstrated that nano-zinc oxide can cause damage to aquatic ecosystems, the mechanism of its poisoning remains inconclusive [1, 2], Nano-zinc oxide is easily dissolved in aqueous environments, making it highly toxic to aquatic organisms [3, 4]. In this paper, the toxicological effects of nano-ZnO on aquatic organisms in recent years are summarized for reference in subsequent studies.

Toxic Effects of Nanometer Zinc Oxide on Algae

Some research showed that nano-ZnO exposure significantly inhibited the growth of algae [5], such as *Selenastrum capricornutum* [6]. Studies have also shown that nano-ZnO caused a decrease in chlorophyll a content and a decrease in protein content in *Chlorella* cells [7]. In addition, the exposure of nano-ZnO can also cause changes in the morphology of *Chlorella* and the destruction of its membrane integrity [8]. Miller et al. [9] tested the effects of nano-ZnO on population growth rates of four species (*Skeletonema marinoi*, *Thalassiosira pseudonana*, *Dunaliella tertiolecta*, *Isochrysis galbana*) of marine phytoplankton representing three major coastal groups (diatoms, chlorophytes, and prymnesiophytes), found that nano-ZnO inhibits the population growth rate of all four marine phytoplankton species. Manzo et al. [10] found that nano-ZnO exposure had a significant effect on the growth rate of *D. tertiolecta*. Wong et al. [11] found that nano-ZnO is toxic to *Skeletonema*

costatuma and *T. pseudonana*. In addition, Peng et al. [12] also found that the growth of *Chaetoceros gracilis* was completely stopped after exposure of 10 mg L⁻¹ nano-ZnO for 24 hours, while *Phaeodactylum tricornutum* continued to grow at a slow rate.

Table 1 The Toxic Effect of Nanometer Zinc Oxide on Algae

Partical size[nm]	Test species	Exposure duration	Concentration [mg L ⁻¹]	Results	References
50-70	<i>P. subcapitata</i>	72 h	EC ₅₀ 0.042		[13]
30	<i>P. subcapitata</i>	72 h	IC ₅₀ 0.068		[14]
20-30	<i>S. marinoi</i>	96 h	1.0	growth rate was reduced by a factor of 2	[9]
	<i>T. pseudonana</i>	96 h	0.5	growth rate was significantly reduced	
	<i>D. tertiolecta</i>	96 h	1.0	growth rate was significantly reduced	
	<i>I. galbana</i>	96 h	1.0	growth rate was significantly reduced	
<100	<i>D. tertiolecta</i>	4 d	EC ₅₀ 1.94		[10]
20	<i>S. costatuma</i>	96 h	LC ₅₀ 4.56		[11]
	<i>T. pseudonana</i>	96 h	LC ₅₀ 2.36		
6、16	<i>T. pseudonana</i>	>100 h	10	cell division rate was significantly reduced	[12]
	<i>C. gracilis</i>	>100 h	10	completely stopped after 24 h	
	<i>P. tricornutum</i>	>100 h		continued to grow at a slow rate	
20	<i>Chlorella</i>	6 d	EC ₃₀ 20		[5]
30	<i>Chlorella</i>	96 h	EC ₅₀ 2.41		[7]

The toxic effect of nano-zinc oxide on arthropods

The toxicity of nano-ZnO to aquatic arthropods is mainly aimed at *Daphnia magna* and *Thamnocephalus platyurus*. In addition, studies have shown that the 96 h EC₅₀ value of nano-ZnO to *Elasmopus rapax* was 1.19 mg L⁻¹, to *Tigriopus japonicus* was 0.85 mg L⁻¹ [11].

Table 2 The Toxic Effect of Nanometer Zinc Oxide on Arthropods

Partical size[nm]	Test species	Exposure duration	Concentration [mg L ⁻¹]	References
50-70	<i>D. magna</i>	48 h	LC ₅₀ 3.2	[15]
	<i>T. platyurus</i>	24 h	LC ₅₀ 0.18	
<200	<i>D. magna</i>	48 h	EC ₅₀ 7.5	[16]
70	<i>D. magna</i>	48 h	EC ₅₀ 2.6	[17]
	<i>T. platyurus</i>	24 h	LC ₅₀ 0.14	
20	<i>T. japonicus</i>	96 h	LC ₅₀ 0.85	[11]
	<i>E. rapax</i>	96 h	LC ₅₀ 1.19	

The toxic effect of nano zinc oxide on molluscs

Some studies on bivalves found that exposure to nano-ZnO increased the respiratory rate of *Mytilus galloprovincialis* [18, 19]. Some have observed loss of mitochondrial ridges, increased number of cytoplasmic vesicles, and disruption of mitochondrial cell membranes, and changes in GR activity in *Crassostrea gigas* [20]. Studies of two freshwater mussels have shown that nano-ZnO leads to increased zinc accumulation, MT and LPO levels in digestive glands of *Elliptio complanata* [21], increased MT levels, tissue Protease D and SOD activity in *Unio tumidus* [22].

In addition, some studies on gastropoda have found that *Lymnaea luteola* exposed to nano-ZnO after 96 h, the GSH, GST, and GSH-Px in digestive glands are significantly reduced, whereas MDA and CAT are significantly elevated and cause DNA damage [23].

Table 3 The Toxic Effects of Nanometer Zinc Oxide on Molluscs

Partical size[nm]	Test species	Exposure duration	Concentration [mg L ⁻¹]	Results	References
50	<i>L. luteola</i>	96 h	0.032	GSH, GST, GSH-Px significantly decreased, MDA, CAT increased significantly, DNA damage	[23]
20–30	<i>M. galloprovincialis</i>	12 wk	0.1-2	Breathing rate increased	[18]
28-88	<i>C. gigas</i>	96 h	LC ₅₀ 30	Mitochondrial damage, changes in GR, protein thiol levels, LPO and GSH-Px activity	[20]
50	<i>C. Cahayensis</i>	14 d	0.1-2.0	Increased SOD, CAT activity and MDA content GST activity is significantly inhibited	[24]
35	<i>E. complanata</i>	21 d	0.002	Zinc accumulation in digestive glands, elevated levels of MT and LPO	[21]
35	<i>U. tumidus</i>	14 d	0.2 (Zn)	Increased levels of MT, SOD, and cathepsin D activity and decreased protein carbonyl levels	[22]

The toxic effect of nano-zinc oxide on vertebrate animals

The toxicity of nano-zinc oxide to aquatic vertebrates is mainly for *Danio rerio*, especially embryo hatching [25-27]. There are also studies on other fish, such as *Cyprinus carpio* [28], *Carassius auratus* [29] and *Oreochromis niloticus* [30].

Table 4 The Toxic Effect of Nanometer Zinc Oxide on Vertebrate

Partical size[nm]	Test species	Exposure duration	Concentration [mg L ⁻¹]	Results	References
20	<i>D. rerio</i>	96 h	84 hpf EC ₅₀ 23.06		[31]
9	<i>D. rerio</i>	96 h	1.0	The 96 hpf hatching rate was only 3.1 ± 2.7 %	[25]
30	<i>C. carpio</i>	30 d	50	Histopathological changes, GSH, SOD activity decreased, protein carbonyl, MDA content increased	[28]
< 50	<i>C. auratus</i>	14 d	1、12.5、50	MDA content increases, SOD activity is inhibited, GSH changes	[29]
10-30 100	<i>O. niloticus</i>	14 d	1、10	SOD, CAT, and GSH levels fluctuate significantly	[30]

Outlooks

With the wide application of nano-ZnO, people are paying more and more attention to its potential harm to organisms and possible environmental risks. However, most of the current researches are conducted under laboratory simulation conditions. The main reason is that nano-ZnO has unique mechanical, optical, magnetic, and thermal properties, physical and chemical parameters, and the environmental behavior of nano-ZnO is affected by many factors, but chemical analysis methods are limited and can not clearly analyze its changes in the environment.

Although there are many researches on nano-ZnO, the toxic mechanism of nano-ZnO also needs more in-depth study. Combined with the current toxicological studies of nano-ZnO on aquatic organisms and the aforementioned limitations, the following research work can consider the following aspects:

- (1) Improve the corresponding chemical analysis methods. After the nano-ZnO enter the environment, its fate and transformation is extremely complicated. It is important to fully detect and characterize the morphology and changes of the nano-ZnO in the environment. Many studies believe that dissolved nanoparticles are important factors that cause biological effects. Therefore, understanding the dissolution kinetics of nanoparticles can help assess their environmental and health risks.
- (2) The effects of nano-zinc oxides on the marine organisms and toxic mechanisms must be explored at different levels of ecosystems, communities, populations, individuals, cells, and gene proteins. Zinc has an extremely strong assimilation efficiency, and its toxic effects on the food chain transmission pathway and gene expression are studied, which helps humans to control this process and reduce the damage of nanomaterials to the ecosystem.
- (3) Nanomaterials often appear in the form of compound pollution in the natural water environment, and are affected by many factors such as temperature, salinity, pH, etc. Therefore, it is necessary to strengthen the research on the combined toxicity of nano-zinc oxide and other pollutants. To study the toxic mechanism of nano-zinc oxide in order to protect the marine ecosystem, maintain human health, and promote nanotechnology to be safer, more efficient, and more effective.

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