AMERICAN JOURNAL OF BIOLOGY AND NATURAL SCIENCES
https://biojournals.us/index.php/AJBNS
ISSN: 2997-7185

Article

Histological Assessment of Brain Tissue Following Exposure to Magnesium Oxide Nanoparticles

Riam Sabah[*1]
Department of Biology, College of Science, Mustansiriyah University, Bagdad, Iraq
*Correspondence: riamsabah.mc.s.zoo.2020@uomustansiriyah.edu.iq

Citation: Sabah, R. Histological Assessment of Brain Tissue Following Exposure to Magnesium Oxide Nanoparticles. American Journal of Biology and Natural Sciences 2026, 3(7), 8-16.

Received: 20th Apr 2026
Revised: 18th May 2026
Accepted: 20th Jun 2026
Published: 10th Jul 2026

Abstract: Magnesium oxide nanoparticles (MgO NPs) are increasingly utilized in biomedical, pharmaceutical, and industrial fields because of their distinctive physicochemical characteristics. Despite their widespread applications, concerns persist regarding their potential neurotoxic effects and overall biological safety. This study aimed to evaluate the neurotoxic impact of MgO nanoparticles on brain tissue in male Sprague-Dawley rats and to determine the influence of dose and exposure duration on tissue damage. Fifty-four adult male Sprague-Dawley albino rats were randomly assigned to nine groups, comprising one control group and eight treatment groups. Treated animals received 1 mL of MgO NP suspension by oral gavage at either a low dose (250 mg/kg) or a high dose (1000 mg/kg) for periods of 14, 28, or 56 days. At the end of each treatment period. Early exposure to MgO nanoparticles induced lipid accumulation, reduction of cerebral nerve fibers, neuronal degeneration, and apoptotic changes affecting both neurons and neuroglial cells. With prolonged exposure, the severity of tissue damage increased markedly, characterized by extensive apoptosis of neuronal and neuroglial cells, greater deposition of lipid complexes, and a pronounced loss of cerebral cortex nerve fibers. These pathological changes indicate progressive deterioration of brain architecture associated with increasing dose and exposure duration. The findings suggest that MgO nanoparticles can exert significant adverse effects on brain tissue and may represent a potential risk to neurological health. Further investigations are required to elucidate the mechanisms underlying MgO NP-induced neurotoxicity and to establish safe exposure limits for biomedical and consumer applications.

Keywords: MgO NPs, Brain, Neurons, Nanomaterial, Neuroglial Cells

Introduction

The brain is the central control organ of the human body, responsible for receiving sensory information, regulating movement,and controlling thought, behavior, and emotions. It consist of several major regions, including the cerebrum, cerebral cortex, thalamus, cerebellum, and brainstem,each of which performs essential functions related to sensation,coordination, language, vision, and vital body activities [1,2].The cerebral cortex contains billions of neurons that communicate through nerve fibers, enabling complex cognitive and motor functions. In addition, the brain regulates many physiological process through neural and hormonal mechanisms [3]. Because of complexity of the human brain and ethical limitations associated with direct experimentation humans, animal models

have become essential tools in neuroscience research for understanding brain structure and function [4].

And because the brain is a highly complex and sensitive organ that controls essential body functional,it is particularly vulnerable to environmental and chemical agents. Recently, nanoparticles have attracted considerable attention because of their widespread application in medicine and industry and their ability to interact with biological tissues, including the nervous system. Among these nanomaterial, magnesium oxide nanoparticles have gained interest due to their unique physicochemical properties and their potential therapeutic as well as toxic effects on brain tissues. Magnesium oxide nanoparticles (Mgo NPs) are in inorganic nanoparticles are tiny particles that have a diameter between 1nm and 100nm, which means one billionth, and nanotechnology is a broad area of technology that is involved in many aspects of our daily lives, among the industries where nanotechnology is employed are electronics, fabrics, cosmetics, sports, motor vehicles, delivery of chemicals, filters, and food additives, and it is a field that studies small features with broad applications [5]. Inorganic white odorless nanoparticles (MgO) are highly hard, pure, and have a high melting point, while exhibiting a low heat capacity and low hardness, this product is considered to be the most promising candidate because of its unique and excellent optical, electrical, thermal, mechanical, and chemical properties, in addition to being used in clinical, agricultural, environmental, medication, and food additive applications, it also has excellent optical, electrical, thermal, mechanical, and chemical properties [6]. The use in metallic nanoparticles in medical and pharmaceutical fields has increased because of their distinctive biological, chemical, physical, and thermal characteristics. Magnesium Oxide nanoparticles have been investigated as catalysts, antimicrobial agents,water remediation materials, and additives for refractory products, and they have also have also demonstrated potential anticancer activity, including effectiveness against breast cancer cell and other cancer cell lines [7,8]. It is possible for nanoparticles to penetrate bacterial cell walls and membranes and disrupt important molecular mechanisms in order to bypass drug resistance mechanisms and inhibit biofilm formation, thereby increasing their virulence potential [9]. Interestingly, they are particularly effective at neutralizing acids, and have been used to treat heartburn and dyspepsia by relieving their symptoms [10]. The biological activities of Mgo nanoparticles are largely attributed to their ability to generate reactive oxygen species (ROS), which induce oxidative stress, increase membrane permeability, and cause degradation of cellular membranes [11,12].

Nanoparticles are effective antimicrobial agents because they induce the generation of reactive oxygen species, leading to oxidative damage of bacterial cell membranes and ultimately bacterial death [13,14]. Despite these beneficial applications, several studies have suggested that nanoparticles may exert toxic effects in humans through respiratory and oral exposure, although the available findings remain inconsistent, emphasizing the importance of evaluating the safety of these nanomaterial and their effects on the human body.

Materials and Methods

MgO Nano magnesium powder

The magnesium oxide nano powder with purity exceeding 99% was measured and measured about 20nm in diameter. It was purchased from sky spring nanomaterial company.

Magnesium oxide was prepared in two different doses:

1. (Groups 4, 5 and 6) 250 mg/kg of MgO NPs rat groups.
2. (Group 7, 8 and 9) 1000 mg/kg of MgO NPs rat groups.

Dosing each rat with 1cc of the suspension by oral gavage based on its weight after blending with deionized water and stirring continuously for several minutes.

Research design and animal care

As a mammalian model, 54 male Spargue-Dawley albino rats (Rattus norvegicus) They were obtained from They were obtained from Biotechnology Research Center (BRC)/ AL Nahrain University were used for analysis of the histological parameters. Males (2.5 - 3 months), housed at the Animal House, College of Science, Mustansiriyah University, Baghdad, Iraq, were purchased as mature animals. Under climate-controlled conditions of the animal house, they were kept in standard plastic cages with a metal network cover and had a 10:14 light-to-dark cycle. Each day, the rats were checked for health, kept in standard plastic cages with a metal network cover under climate-controlled conditions, and their cages were cleaned out every day to remove their scent, making them more relaxed. They were also fed, watered, and provided with clean bedding. After a one-week adaptation period, fifty four male rats were randomly divided into nine groups of six rats each in this experiment. In groups 1, 2 and 3, rats were not given a dose, but were fed 18-20g of rat chow pellet for 14, 28, and 56 days afterward, a dose of 250 mg/kg of MgO nanoparticles was administered to Groups 4, 5 and 6 for 14, 28, and 56 days afterwards. Group 7, 8 and 9: (the experimental groups) that respectively received MgO nanoparticles in one dose of (1000) mg/kg every 24 hours for 14, 28, and 56 days except on public holidays days.

Collection of samples

For histological study, the animals were fully anesthetized, to prevent them from becoming stressed, with diethyl ether for several minutes and dissected. The brain was excised, blotted with filter paper, and preserved in a fixative solution (neutral buffered 10% formalin).

Histological preparation

The preparation for histological sections was performed. Grossing involves examining pathology specimens and trimming them to appropriate sizes, after which the best parts are selected for microscopic examination to obtain diagnostic information.

Ethical Approval Statement

The experimental protocol and study design were formally reviewed and approved by the Research Ethics Committee of the College of Science at Mustansiriyah University (Ref. No.: BCSMU/1026/00090Z, dated December 1, 2025). All procedures involving animal experimentation were conducted in strict accordance with the ethical standards outlined in the Declaration of Helsinki.

Results

The examination of brain sections from male control groups displayed normal histological structure and appearance of cerebral cortex showing the glial cells including granule neurons, lipid materials and brain cerebral fiber materials Figure 1. The two weeks (low dose) of MgO NPs exposure showed degenerative changes of neurons with apoptotic changes of neuroglial cells and an increase of lipid material in the cerebral tissue and decrease in cerebral fiber Figure 2,

while two weeks (High dose): demonstrated degenerative changes and apoptotic of neurons with apoptotic changes of neuroglial cell and increment of lipid materials and more decrease of fibers Figure 3. Moreover, four weeks (Low dose): showed apoptotic changes in neurons and neuroglial cells, little amount of cerebral brain fibers present, more accumulation of lipid complex materials Figure 4. Brain sections during the four weeks (High dose): marked prominent accumulation of lipid complex with prominent appearance of apoptotic changes in the neurons and neuroglial cells with very little amount of cerebral nerve fibers Figure 5.

In the rat brain receiving (Low dose) for 8 weeks, results marked permanent apoptosis of neurons and neuroglial cells, more accumulation of cerebral lipid complex and absence of cerebral nerve fibers

Figure 6. In, Figure (4) 8 weeks (High dose) exposure to MgO NPs displays more apoptotic of neurons and neuroglial cells, more accumulation of lipid complex and absence of cerebral cortex nerve fibers.

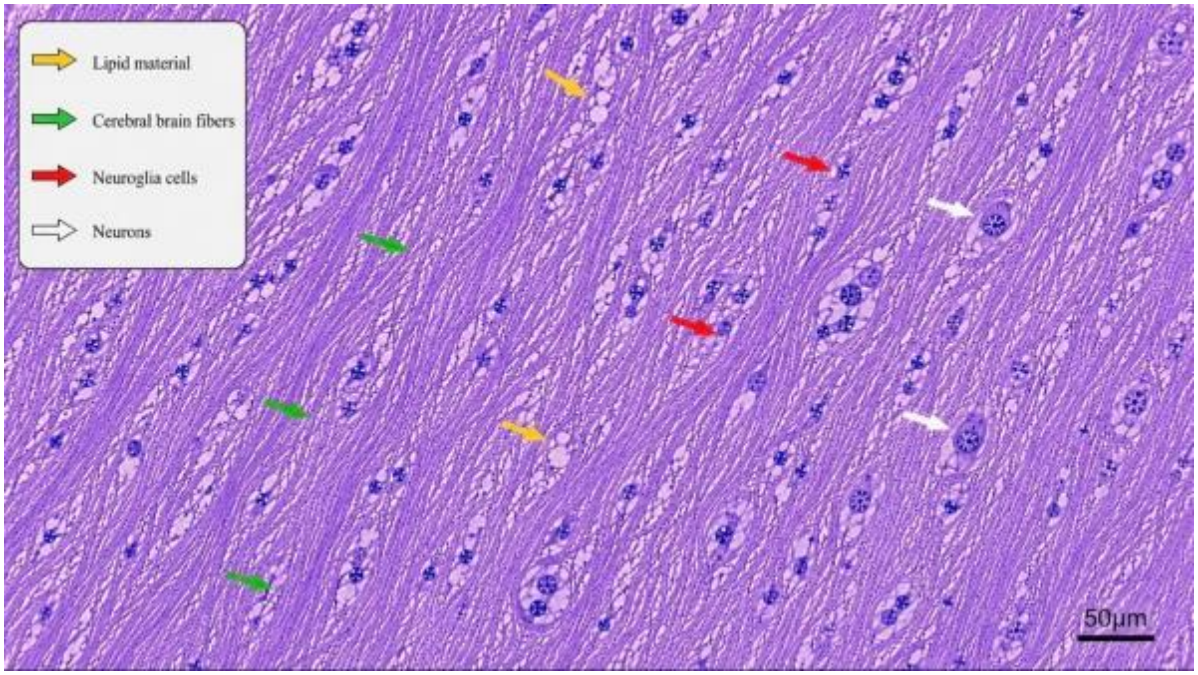

Figure 1. Control shows normal structure appearance of cerebral cortex showing the glial cells and granule neurons and lipid materials and brain cerebral fiber materials. (40 X) (H&E).

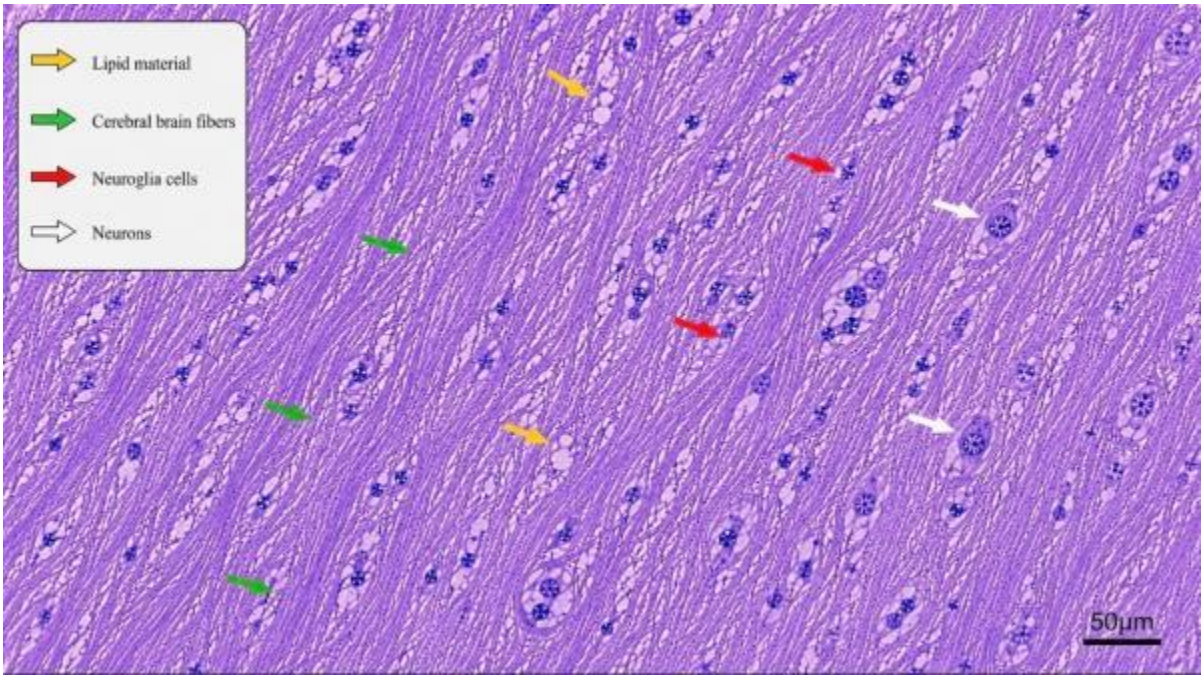

Figure 2. After weeks (low dose): Degenerative changes of neurons with apoptotic changes of neuroglial cells and an increase of lipid material in the cerebral tissue and decrease in cerebral fiber. (40 X) (H&E).

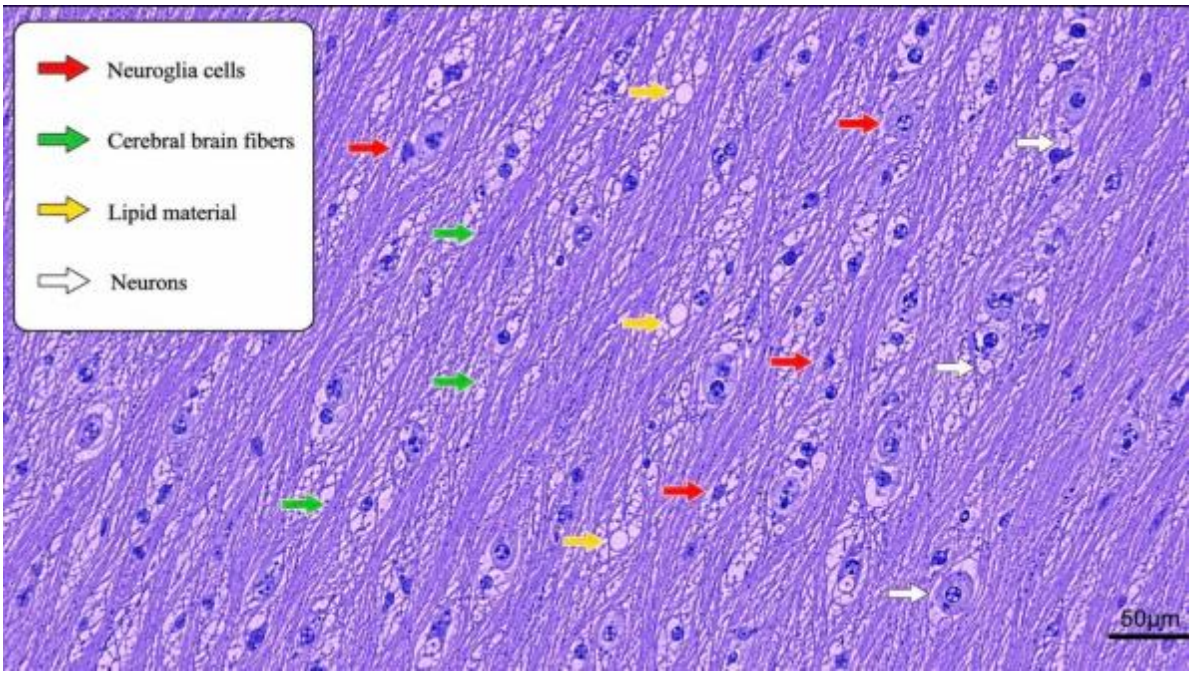

Figure 3. After 2 weeks (High dose): Degenerative changes and apoptosis of neurons with changes of neuroglial cells and increment of lipid materials and more decrease of fibers. (40 X) (H&E).

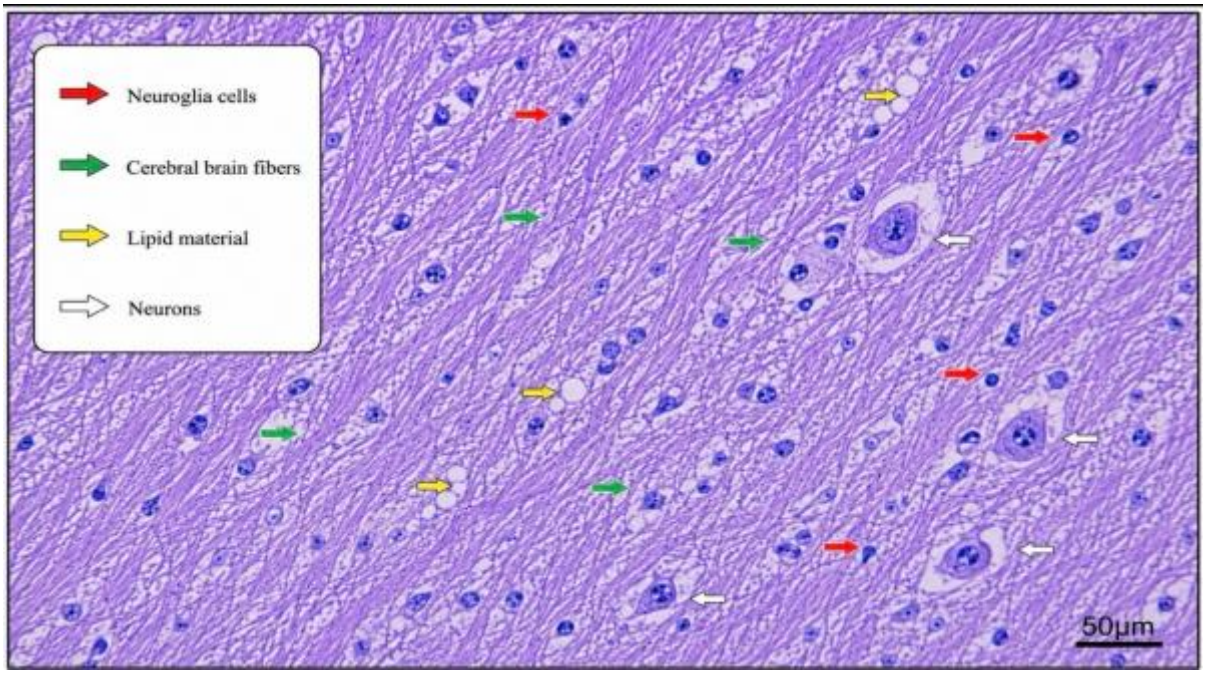

Figure 4. After 4 weeks (Low dose): Apoptotic changes in neurons and neuroglial cells, little amount of cerebral brain fibers present, more accumulation of lipid complex materials. (40 X) (H&E).

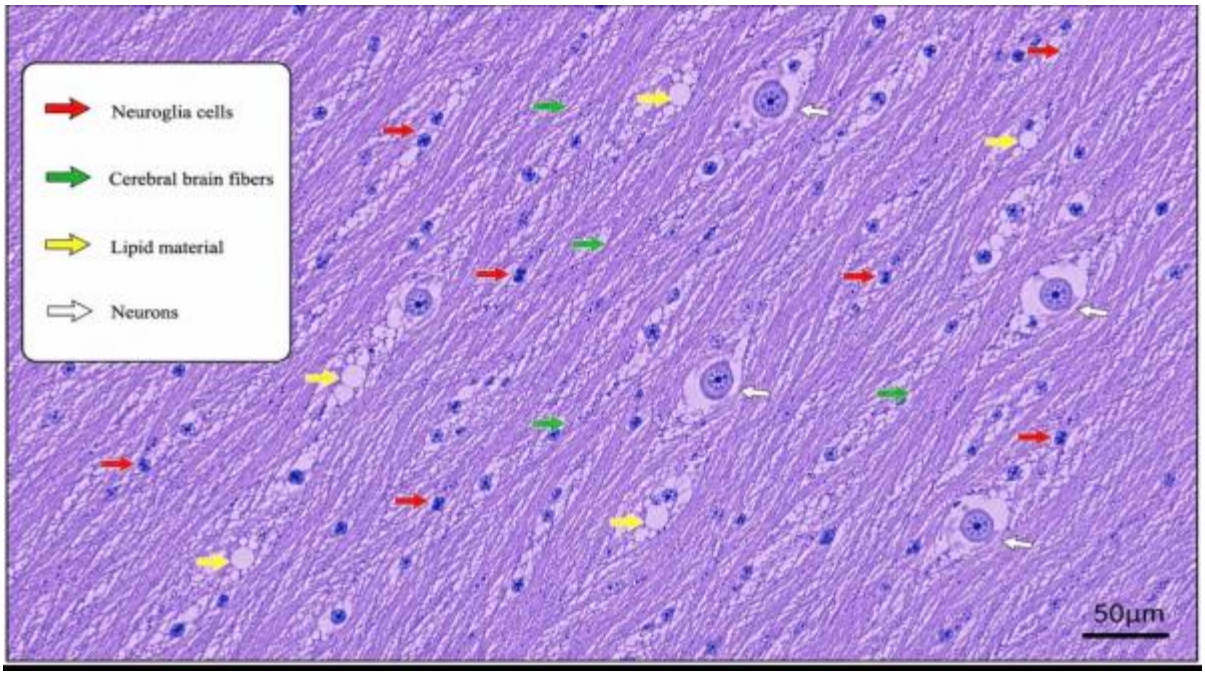

Figure 5. After 4 weeks (High dose): Prominent accumulation of lipid complex with prominent appearance of apoptotic changes in the neurons and neuroglial cells, with very little amount of cerebral nerve fibers. (40 X) (H&E).

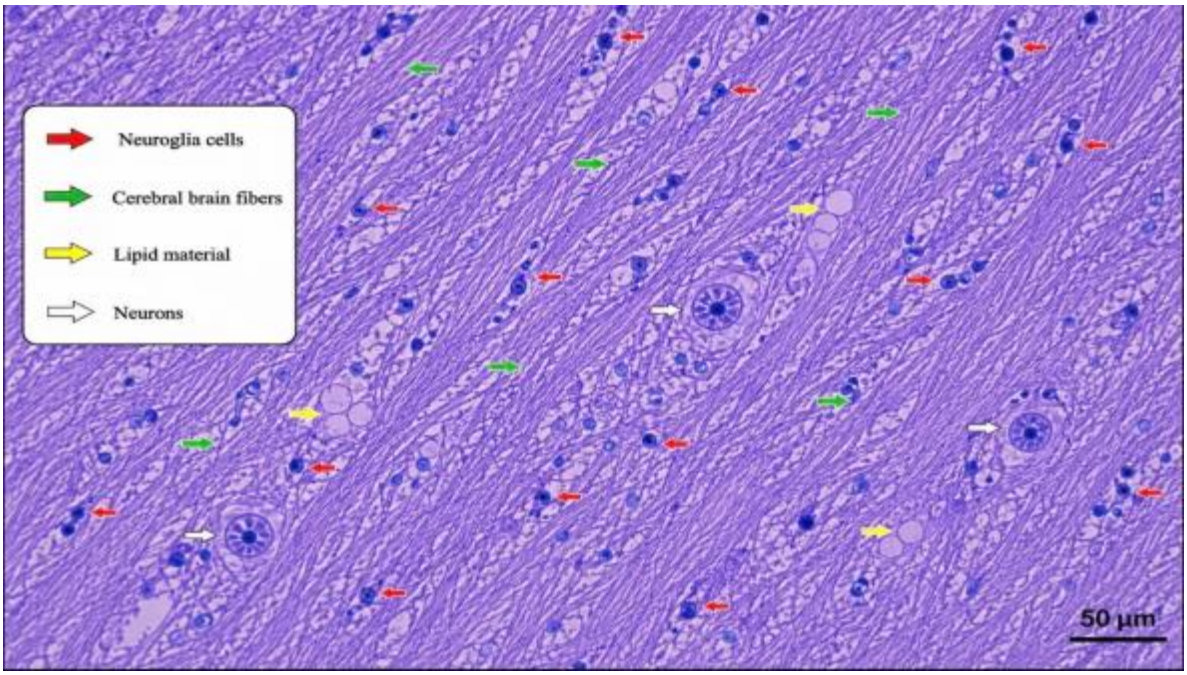

Figure 6. After 8 weeks (Low dose): Permanent apoptotsis of neurons and neuroglial cells, more accumulation of cerebral lipid complex and absence of cerebral nerve fibers. (40 X) (H&E).

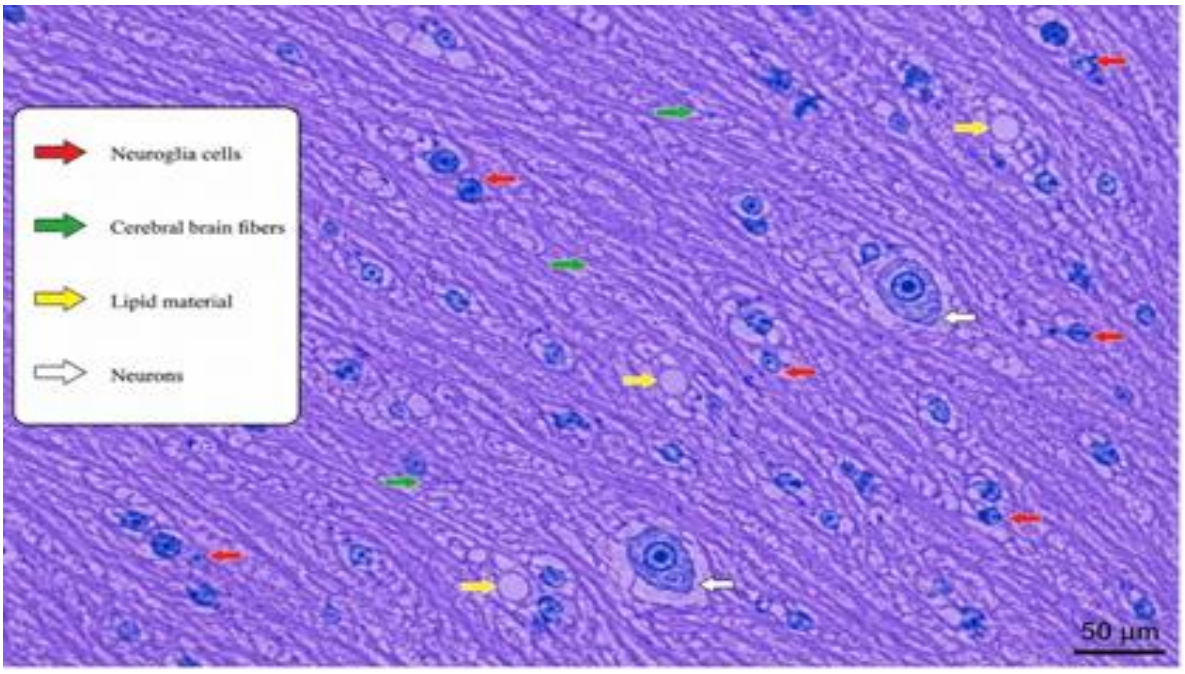

Figure 7. After 8 weeks (High dose): Permanent apoptosis of neurons and neuroglial cells, more accumulation of lipid complex and absence of cerebral cortex nerve fibers. (40 X) (H&E).

Discussion

The study was conducted to evaluate how far MgO NPs can be safely used for various applications: food additives, dental care, agriculture, electronics, drug delivery, medical therapy, etc.

Most NPs used in food and drugs enter the body via the gastrointestinal tract, and are distributed to various organs, such as the liver, kidney, brain, and others [15].

Magnesium oxide nanoparticles can enter the body through the skin, respiratory tract. and gastrointestinal system. and may subsequently accumulate in various tissue: however, their biological effects are still not fully understood [16]. Depending on the rout of exposure nanoparticles may trigger arrange of toxicological effects, including inflammatory responses and activation of immune system [17]. Through different routes, nanoparticles enter the body and can have a variety of toxicological effects and trigger biological reactions such as inflammation and immunity [18]. Furthermore, it was reported that NPs can cause cells to lose their biological activity and structure by increasing the level of oxidative stress within them [19]. In addition to analyzing the primary reasons for the cytotoxicity of nanoparticles, and their potential pathogenic effects, the over-production of ROS is the major contributor to their bio toxicity [13]. Reactive oxygen species (ROS) are described as molecules that play important roles in normal cellular signaling; however, their excessive production can lead to oxidative stress. Oxidative stress results from an imbalance between ROS generation and antioxidant defense systems, which may ultimately cause cellular damage [20]. The histopathological changes observed in this study,such as neuronal degeneration, apoptosis, and loss of nerve fibers, agree with previous reports showing that metal oxide nanoparticles can cause neurotoxic effects associated with oxidative stress [21]. Furthermore, oxidative stress can disrupt mitochondrial function and induce DNA damage via reactive oxidation products, leading to cellular dysfunction and tissue degeneration [22]. This may explain the marked apoptosis and loss of neural structure observed after prolonged exposure to high doses of Mgo nanoparticles.

Moreover, nanoparticles mainly exert toxicity through increased ROS production, leading to oxidative stress with in cell. This imbalance causes cellular damage and functional disturbances that may extended to endocrine system [23].

Conclusion

Based on the results of different studies, it has been observed that MgO nanoparticles have a potential harmful effect on human health, and brain tissue. MgO nanoparticles agglomerate in different brain animal models, interact with neurons, neuroglia, and neurofibrils, possibly causing oxidative stress. Human-consumable products should be cautious about excessive MgO NPs use.

REFERENCES

[1] J. E. Hall, *Guyton and Hall Textbook of Medical Physiology*, Jordanian ed. St. Louis, MO, USA: Elsevier Health Sciences, 2016.

[2] K. Dharani, *The Biology of Thought: A Neuronal Mechanism in the Generation of Thought—A New Molecular Model*. London, U.K.: Academic Press, 2014. doi: 10.1016/C2013-0-19045-9.

[3] R. Karki and A. A. Moustafa, "The Effect of Alzheimer's Disease on the Thalamus," in *Alzheimer's Disease: Understanding Biomarkers, Big Data, and Therapy*, A. A. Moustafa, Ed. London, U.K.: Academic Press, 2022, pp. 107–123. doi: 10.1016/B978-0-12-821334-6.00005-3.

[4] X. Zhao and A. Bhattacharyya, "Human Models Are Needed for Studying Human Neurodevelopmental Disorders," *American Journal of Human Genetics*, vol. 103, no. 6, pp. 829–857, 2018. doi: 10.1016/j.ajhg.2018.10.009.

[5] T. M. Joseph, D. K. Mahapatra, A. Esmaeili, Ł. Piszczyk, M. S. Hasanin, M. Kattali, *et al*., "Nanoparticles: Taking a Unique Position in Medicine," *Nanomaterials*, vol. 13, no. 3, p. 574, 2023. doi: 10.3390/nano13030574.

[6] A. Almontasser, A. Parveen, and A. Azam, "Synthesis, Characterization and Antibacterial Activity of Magnesium Oxide (MgO) Nanoparticles," *IOP Conference Series: Materials Science and Engineering*, vol. 577, no. 1, Art. no. 012051, 2019. doi: 10.1088/1757-899X/577/1/012051.

[7] M. K. Patel, M. A. Ali, M. Zafaryab, V. V. Agrawal, M. M. Rizvi, Z. A. Ansari, *et al*., "Biocompatible Nanostructured Magnesium Oxide-Chitosan Platform for Genosensing Application," *Biosensors and Bioelectronics*, vol. 45, pp. 181–188, 2013. doi: 10.1016/j.bios.2013.01.009.

[8] M. R. Khan, N. O. Alafaleq, A. K. Ramu, K. Alhosaini, M. S. Khan, T. A. Zughaibi, *et al*., "Evaluation of Biogenically Synthesized MgO NPs Anticancer Activity Against Breast Cancer Cells," *Saudi Journal of Biological Sciences*, vol. 31, no. 1, Art. no. 103874, 2024. doi: 10.1016/j.sjbs.2023.103874.

[9] M. Ozdal and S. Gurkok, "Recent Advances in Nanoparticles as Antibacterial Agent," *ADMET and DMPK*, vol. 10, no. 2, pp. 115–129, 2022. doi: 10.5599/admet.1223.

[10] B. Shetty and M. K. Vishwanath, "An Expert Opinion on Antacids: A Review of Its Pharmacological Properties and Therapeutic Efficacy," *F1000Research*, vol. 11, p. 1057, 2022. doi: 10.12688/f1000research.123456.1.

[11] A. Abdal Dayem, M. K. Hossain, S. B. Lee, K. Kim, S. K. Saha, G. M. Yang, *et al*., "The Role of Reactive Oxygen Species (ROS) in the Biological Activities of Metallic Nanoparticles," *International Journal of Molecular Sciences*, vol. 18, no. 1, p. 120, 2017. doi: 10.3390/ijms18010120.

[12] G. H. Naguib, G. S. Abd El-Aziz, H. A. Mously, S. M. Bukhary, and M. T. Hamed, "Assessment of the Dose-Dependent Biochemical and Cytotoxicity of Zein-Coated MgO Nanowires in Male and Female Albino Rats," *Annals of Medicine*, vol. 53, no. 1, pp. 1850–1862, 2021. doi: 10.1080/07853890.2021.2004163.

[13] Z. Yu, Q. Li, J. Wang, Y. Yu, Y. Wang, Q. Zhou, *et al*., "Reactive Oxygen Species-Related Nanoparticle Toxicity in the Biomedical Field," *Nanoscale Research Letters*, vol. 15, no. 1, p. 115, 2020. doi: 10.1186/s11671-020-03328-4.

[14] K. Krishnamoorthy, G. Manivannan, S. J. Kim, K. Jeyasubramanian, and M. Premanathan, "Antibacterial Activity of MgO Nanoparticles Based on Lipid Peroxidation by Oxygen Vacancy," *Journal of Nanoparticle Research*, vol. 14, no. 9, Art. no. 1063, 2012. doi: 10.1007/s11051-012-1063-6.

[15] N. Hadrup and H. R. Lam, "Oral Toxicity of Silver Ions, Silver Nanoparticles and Colloidal Silver—A Review," *Regulatory Toxicology and Pharmacology*, vol. 68, no. 1, pp. 1–7, 2014. doi: 10.1016/j.yrtph.2013.11.002.

[16] M. Ghobadian, M. Nabiuni, K. Parivar, M. Fathi, and J. Pazooki, "Toxic Effects of Magnesium Oxide Nanoparticles on Early Developmental and Larval Stages of Zebrafish (*Danio rerio*)," *Ecotoxicology and Environmental Safety*, vol. 122, pp. 260–267, 2015. doi: 10.1016/j.ecoenv.2015.07.010.

[17] A. M. Negrescu, M. S. Killian, S. N. V. Raghu, P. Schmuki, A. Mazare, and A. Cimpean, "Metal Oxide Nanoparticles: Review of Synthesis, Characterization and Biological Effects," *Journal of Functional Biomaterials*, vol. 13, no. 4, p. 274, 2022. doi: 10.3390/jfb13040274.

[18] R. Wang, B. Song, J. Wu, Y. Zhang, A. Chen, and L. Shao, "Potential Adverse Effects of Nanoparticles on the Reproductive System," *International Journal of Nanomedicine*, vol. 13, pp. 8487–8506, 2018. doi: 10.2147/IJN.S183035.

[19] H. J. Forman and H. Zhang, "Redox Signaling and Oxidative Stress: Concepts and Controversies," *Free Radical Biology and Medicine*, vol. 207, pp. 226–236, 2023. doi: 10.1016/j.freeradbiomed.2023.07.021.

[20] F. Aliakbari, F. Attar, M. Movahedi, and M. Falahati, "Human Tau Fibrillization and Neurotoxicity in the Presence of Magnesium Oxide Nanoparticle Fabricated Through Laser Ablation Method," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, vol. 278, Art. no. 121372, 2022. doi: 10.1016/j.saa.2022.121372.

[21] H. R. H. Mohamed, A. H. Farouk, S. H. Elbasiouni, K. A. Nasif, and G. Safwat, "Nanoparticle-Induced ROS Generation, Inflammation, and DNA Damage: Mechanistic Insights," *Scientific Reports*, vol. 14, Art. no. 13015, 2024. doi: 10.1038/s41598-024-62877-4.

[22] X. He, J. Xue, L. Shi, Y. Kong, Q. Zhan, Y. Sun, *et al*., "Recent Antioxidative Nanomaterials Toward Wound Dressing and Disease Treatment via ROS Scavenging," *Materials Today Nano*, vol. 17, Art. no. 100149, 2022. doi: 10.1016/j.mtnano.2022.100149.

[23] Y. W. Huang, M. Cambre, and H. J. Lee, "The Toxicity of Nanoparticles: Biological Interactions and Oxidative Stress Mechanisms," *International Journal of Molecular Sciences*, vol. 23, no. 9, p. 4875, 2022. doi: 10.3390/ijms23094875.