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Zinc Oxide Nanoparticles in Cement-Based Antibacterial Coatings: A Pathway to Hygienic and Durable Construction Materials

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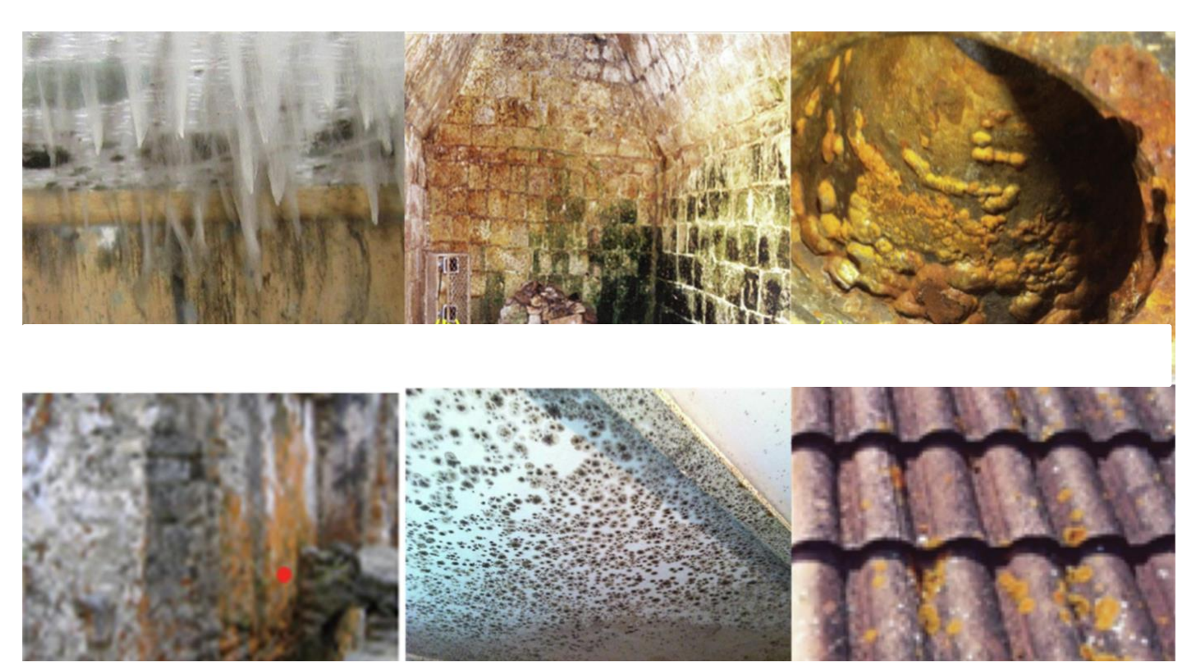
INTRODUCTION & AIM

In environments prone to bacterial contamination, antibacterial coatings on building materials are essential to prevent microbial growth and improve hygiene (Yong and Calautit 2023). Recently, zinc oxide (ZnO) nanoparticles have emerged as a highly effective antimicrobial additive for this purpose and have gained popularity due to their unique properties, such as high surface area, photocatalytic activity, and ability to produce reactive oxygen species. ZnO nanoparticles deliver dual benefits when incorporated into cementitious coatings by improving mechanical properties and antimicrobial performance.

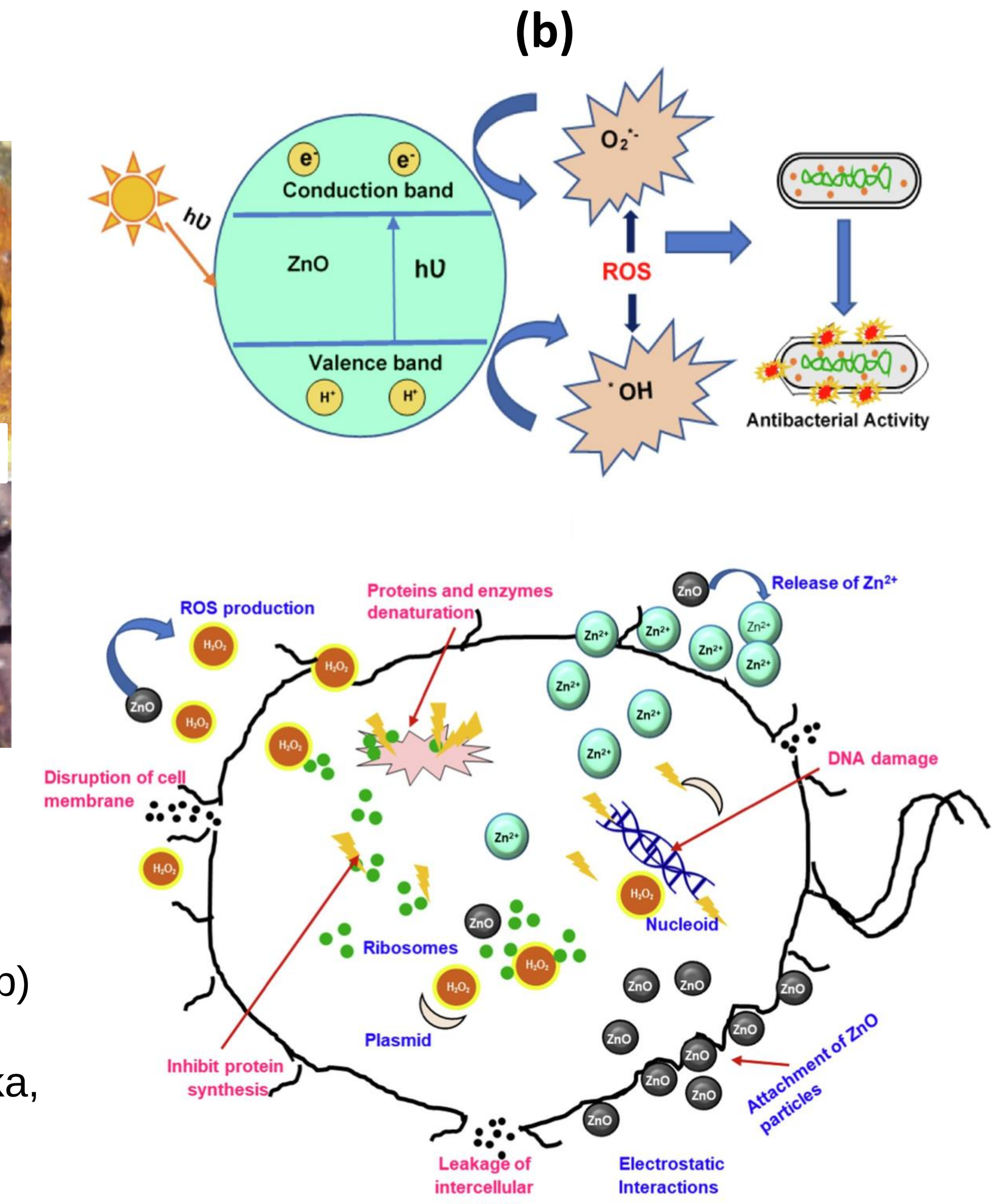
Cement-Based Antibacterial Coatings by Zinc Oxide Nanoparticles

Integrating antibacterial properties into construction materials has gained significant attention in recent years, particularly in applications where hygiene is critical, such as hospitals, schools, and food-processing facilities (Yong and Calautit 2023). In this regard, one promising approach is to incorporate zinc oxide (ZnO) nanoparticles into cement-based coatings. These nanoparticles are highly effective in combating microbial growth due to their unique physicochemical properties, which include a high surface-to-volume ratio, photocatalytic activity, and the capacity to produce reactive oxygen species (ROS). Recent research has shown that cementitious materials modified with ZnO nanoparticles exhibit strong antibacterial effects against common pathogenic bacteria such as Escherichia coli and Staphylococcus aureus. In this regard, the mechanism of action primarily involves disruption of bacterial membranes and oxidative stress caused by ROS, which ultimately leads to inhibition of microbial colonization on treated surfaces (Kirthika, Goel et al. 2023). Furthermore, by uniformly dispersing ZnO in the cement matrix, consistent antibacterial performance can be achieved across the coated surface (Carvalho, Sampaio et al. 2014). Along with antimicrobial performance, the incorporation of ZnO nanoparticles also enhances the mechanical functionality of the material. These coatings are both hygienically effective and structurally reliable, improving compressive strength and overall durability. This dual functionality is especially valuable in environments subject to both high bacterial load and mechanical wear (Kirthika, Goel et al. 2023).

(a)



(b)



(a) Microbial degradation of various building materials,(b) ZnO biocidal mechanisms, including photocatalytic, electrostatic interaction, and release of Zn^{2+} ions (Kirthika, Goel et al. 2023)

CONCLUSION

Recent studies have revealed that ZnO-based antibacterial coatings represent a sustainable and innovative approach to addressing hygiene challenges in construction while maintaining high material performance. Future research is needed to optimize nanoparticle concentrations, guarantee long-term antimicrobial efficacy, and consider the environmental and economic impacts of these coatings. This integration of functionality and durability highlights the transformative potential of ZnO nanoparticle-based coatings in modern construction and infrastructure.

In conclusion, ZnO nanoparticle-enhanced cement coatings represent a sustainable and multifunctional advancement in building materials. By combining hygiene upgrade with improved durability, these coatings offer a transformative solution to modern construction challenges.

FUTURE WORK

Future studies should focus on resolving several important issues to fully realize the promise of cement-based coatings augmented with ZnO nanoparticles. First and foremost, figuring out the ideal concentration of nanoparticles is essential to guaranteeing optimum antibacterial effectiveness without sacrificing the cementitious material's mechanical integrity or workability. To evaluate these coatings' longevity and long-term antibacterial activity, long-term performance studies under a range of environmental factors, including humidity, temperature changes, and UV exposure, are required. To create multifunctional coatings (such as self-cleaning or anti-corrosive), it's also critical to investigate how well ZnO nanoparticles work with other functional additives. To determine whether large-scale implementation is economically and environmentally feasible, life cycle assessments and cost-benefit studies should also be carried out. Finally, standardized testing protocols for antimicrobial performance in construction materials will be essential for regulatory approval and commercial adoption. By addressing these areas, future advancements can facilitate the integration of nanotechnology into mainstream building practices, promoting safer, more hygienic, and longer-lasting infrastructure.

REFERENCES

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