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Development of Teaching Materials: Acid Rain Simulation Miniature Based on Recycled Materials as a Chemistry Learning Media

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Abstract: The process of acid rain formation is a chemical phenomenon that involves the interaction of pollutants, such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), with water in the atmosphere. This phenomenon has significant environmental impacts, making it essential to introduce it in school chemistry education. This study aims to develop an innovative learning medium based on a three-dimensional miniature that simulates acid rain using recycled materials. The miniature illustrates sources of air pollution, the formation of acid rain in the atmosphere, and its effects on the environment, and is designed to assist students in understanding complex chemical concepts. The method employed is an exploratory approach through the development of a miniature prototype, without conducting empirical testing of student comprehension. The results of the project indicate that recycled materials can be effectively utilized to create educational and engaging miniatures. The main challenges faced include the selection and processing of waste materials to accurately represent the chemical concepts. This project provides insights into the potential for developing economical and environmentally friendly learning media that supports sustainable education.

Keywords: acid rain simulation, chemistry learning media, prototype development, recycled materials, sustainable materials, teaching materials, three-dimensional miniature.

Introduction

Chemistry education at the secondary school level often encounters challenges in explaining abstract and complex phenomena to students. One topic that requires a deep understanding is acid rain, an environmental issue of increasing relevance in the industrial era. Acid rain occurs when pollutant gases such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water in the atmosphere, producing precipitation with a pH below 5.6 (Abbasi et al., 2013; Anjum, 2015; Bhargava & Bhargava, 2013; Bhatti et al., 1992; Bricker & Rice, 1993; Chen & Achal, 2020; Dai et al., 2013; Diatta et al., 2021; Fei et al., 2020; Ferenbaugh, 1976; Grennfelt et al., 2020; Irwin & Williams, 1988; D. W. Johnson et al., 1982; Krug & Frink, 1983; Larssen et al., 2006; Li et al., 2021; Likens et al., 1972; Likens & Bormann, 1974; M. Liu et al., 2019; Z. Liu et al., 2020; Lu et al., 2020, 2021; Mahdikhani et al., 2018; Maler, 1989; Menz & Seip, 2004; Mohnen, 1988; Reis et al., 2012; Singh & Agrawal, 2007; Underdal & Hanf, 2019; Wettestad, 2018; Yin et al., 2019; Zhang et al., 2022).

As students in a chemistry education program, gaining a deep understanding of effectively conveying chemistry concepts is crucial in preparing for future roles as educators. Visualizing the acid rain formation process presents one of the challenges in chemistry learning, as the complexity of atmospheric processes cannot be observed directly. Conventional learning media, such as textbooks and PowerPoint presentations, have limitations in demonstrating the dynamic processes involved in acid rain formation (Marfu'ah et al., 2022, 2023; Marfu'ah & Anwar,

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2018; Marfu’ah & Meristin, 2022; Wardani et al., 2019).

The use of interactive, three-dimensional learning media can serve as a solution to bridge this gap in understanding. Previous research has shown that using physical models in science education can enhance conceptual understanding and develop students' critical thinking skills (Abdinejad et al., 2021; Evagorou et al., 2015; Olympiou et al., 2013; Olympiou & Zacharia, 2012; Rahman et al., 2020; Wang & Tseng, 2018). Furthermore, the use of recycled materials in creating educational media not only offers economic value but also educates students on the importance of environmental sustainability.

In the context of higher education, collaboration between students and faculty in developing innovative learning media serves as an effective platform for refining the creativity and pedagogical skills of prospective teachers. The process of creating educational media not only provides practical experience in designing teaching aids but also cultivates critical thinking and problem-solving abilities, which are essential for future educators (Hidayat et al., 2021).

Innovation in developing chemistry learning media has become increasingly important to meet the demands of 21st-century education, which emphasizes critical thinking, creativity, and problem-solving skills. Effective educational media should be able to integrate cognitive, affective, and psychomotor aspects into the learning process (Cooper & Higgins, 2015; Septiani & Rejekiningsih, 2020). Miniature simulations as educational tools hold potential to meet these needs by providing a more concrete and meaningful learning experience.

The development of an acid rain miniature simulation using recycled materials is a collaborative effort between students and faculty to create innovative, economical, and environmentally friendly learning media. This approach aligns with the principles of Education for Sustainable Development (ESD), which integrate environmental issues into the learning process. By using recycled materials, students not only learn about chemistry concepts but also gain an understanding of waste management and environmental conservation (Burmeister & Eilks, 2012; Ifegbesan et al., 2017; Zuin et al., 2021).

This study aims to develop and describe the process of creating an acid rain miniature simulation using recycled materials as chemistry learning media. The development focuses on visualizing the acid rain formation process, from pollutant gas emissions to acid precipitation. Using recycled materials in the miniature not only considers economic aspects but also adds value through environmental education.

Materials and Methods

Study area

This developmental study was conducted at a university in South Sumatra and involved a research team comprising five second-semester chemistry education students and one supervising lecturer specializing in chemistry education. The method employed is an exploratory approach (Armstrong, 1970) through the development of a miniature prototype, without conducting empirical testing of student comprehension. The miniature development process took place from February to May 2024, with a focus on exploring and prototyping a visual demonstration of the acid rain formation process.

Procedures

This study adopted an exploratory approach in developing a miniature prototype focused on constructing and visualizing the acid rain phenomenon. The development process was conducted through several structured stages. In the initial exploration stage, the team conducted a literature review on the acid rain phenomenon and its formation mechanisms. They identified key components to be visualized and inventoried recyclable materials with potential for use, concluding this stage with sketches and initial designs for the miniature prototype. In the prototype development stage, the team experimented with various recycled materials to construct miniature components, including models of factories and vehicles as sources of emissions, along with a system to visualize clouds and rain.

The system was then assembled to illustrate the sequence of processes involved in acid rain formation, with subsequent enhancements made to the visual and structural aspects of the prototype to improve its appeal and informativeness. In the final documentation stage, the team recorded the entire development process, created technical descriptions for each miniature component, and prepared assembly and usage guidelines to ensure the prototype could be easily understood and implemented.

Data analysis

The data analysis in this study employed a descriptive-exploratory approach, focusing on several key aspects. First, the technical feasibility of the miniature construction was analyzed, covering evaluations of structural strength and stability, accuracy of the acid rain components' visualization, and clarity in process representation. Additionally, the team analyzed the use of recycled materials by identifying the types of materials used, evaluating their effectiveness in construction, and documenting the processing techniques applied. Each stage of the construction process was meticulously recorded, accompanied by a compilation of photos and technical diagrams, as well as the development of a replication guide to facilitate future reproduction.

Results and Discussion

Result

The development process of the acid rain simulation miniature resulted in a prototype capable of comprehensively visualizing the sequence of acid rain formation. During the initial exploration phase, a literature review identified three primary components that needed visualization in the miniature: pollution emission sources, the chemical transformation process in the atmosphere, and the environmental impacts of acid precipitation. The inventory of materials led to the selection of recycled materials, including cardboard, paper, and leftover crafting materials, which were used for miniature construction.

In the prototype development phase, the construction of the miniature components successfully visualized the acid rain formation scenario in three dimensions. Pollution emission sources were represented through a factory model with a cardboard smokestack and two motor vehicles placed on a roadway. The factory model was labeled "NOx" to indicate nitrogen oxide emissions, while the roadway was labeled "CO2" to signify carbon dioxide emissions from the vehicles.

The atmospheric transformation process was visualized by placing white paper clouds labeled "SO2" and "NOx," representing the transformation of pollutant gases in the atmosphere. Blue water droplets depicted acidified precipitation, illustrating the acidification process during rainfall. The environmental impact was represented through components such as green trees and a fish pond, symbolizing ecosystems affected by acid rain.

In the documentation phase, each miniature component was thoroughly documented, including material specifications, construction techniques, and assembly guidelines. The use of a black background provided a clear contrast to highlight the miniature components. Chemical labels and symbols were added to identify the various elements and compounds involved in the acid rain formation process. Figure 1 presents the results of the development of the acid rain simulation miniature.

Figure 1. Acid Rain Simulation Miniature

Discussion

The development of a recycled material-based acid rain simulation miniature demonstrates the potential of utilizing simple materials to create effective learning media. The successful visualization of the acid rain process in this miniature aligns with the principles of contextual learning proposed by E. B. Johnson, (2002), wherein physical representations can aid in understanding abstract concepts in science education.

Choosing recycled materials as the primary construction resource not only supports environmental sustainability but also adds value in terms of accessibility and ease of replication. The use of cardboard for constructing the factory and vehicle models illustrates that simple materials can be effectively employed to create adequate visual representations (Sankey, 2003). This supports the findings of Wardani et al. (2019) regarding the importance of developing economical and easily reproducible learning media.

The technical aspects of the miniature showcase several advantages in visualizing the acid rain process. The placement of emission sources, including factories and motor vehicles, provides a comprehensive overview of the primary contributors to air pollution. The inclusion of chemical labels (SO2, NOx, CO2) aids in identifying specific pollutants involved in acid rain formation, aligning with chemistry education concepts that emphasize understanding molecular transformations (Claesgens et al., 2009; Kozma & Russell, 2005; Sevian & Talanquer, 2014; Wu et al., 2001).

The visualization of atmospheric processes through the representation of clouds and rain droplets offers a sequential depiction of the transformation of pollutants into acid precipitation. The use of distinct colors for the miniature components (green for vegetation, blue for water, white for clouds) helps differentiate the elements involved in the process. This supports the visual design principles in education highlighted by Carter (2003), Hidayat et al. (2021), Kimball (2013), Øygardslia et al. (2020), Yeh & Cheng (2010), Yong et al. (2016), emphasizing the importance of contrast and differentiation in learning media.

Integrating ecosystems through representations of trees and a fish pond provides context regarding the impact of acid rain on the environment. This representation aids in building a holistic understanding of the cause-and-effect relationships between human activities, air pollution, and environmental degradation. This approach aligns with the principles of education for sustainable development, which emphasize understanding the interconnections among environmental aspects (Agbedahin, 2019; Annan-Diab & Molinari, 2017; Blewitt, 2012; Di Biase et al., 2022; Kioupi & Voulvoulis, 2019; Mensah, 2019; Nilsson et al., 2018; Sharma, 2023).

However, the development of this miniature also faced several technical challenges. The use of recycled materials necessitated specific techniques in processing to achieve sturdy and durable structures. Additionally, visualizing microscopic chemical processes on a macro scale required simplifications that must maintain conceptual accuracy. These challenges may serve as considerations for further development in creating more refined learning media.

The success of this miniature development indicates that an exploratory approach to creating learning media can yield creative solutions for visualizing complex chemistry concepts. The use of recycled materials not only supports sustainability but also demonstrates that effective learning media can be developed with limited resources.

Conclusions

The development of a recycled material-based acid rain simulation miniature has successfully produced an effective learning medium to visualize the complex processes involved in acid rain formation. Through an exploratory approach and the utilization of recycled materials, this research not only provides a creative solution for chemistry education but also supports environmental sustainability principles. The successful visualization of key components, such as emission sources, atmospheric transformations, and environmental impacts, combined with the use of appropriate chemical labels, demonstrates that complex learning media can be developed with limited resources without compromising educational value and conceptual accuracy.

Conflict of Interest: The authors declare that there are no conflicts of interest concerning the publication of this article.

References

Abbasi, T., Poornima, P., Kannadasan, T., & Abbasi, S. A. (2013). Acid rain: past, present, and future. *International Journal of Environmental Engineering*, *5*(3), 229–272.

Abdinejad, M., Talaie, B., Qorbani, H. S., & Dalili, S. (2021). Student perceptions using augmented reality and 3d visualization technologies in chemistry education. *Journal of Science Education and Technology*, *30*, 87–96.

Agbedahin, A. V. (2019). Sustainable development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, efficacy, eminence, and future. *Sustainable Development*, *27*(4), 669–680.

Anjum, S. (2015). Al-Razi: A Distinguished Physician of the Medieval History: A Review of his Method and Influence. *Revelation and Science*, *5*(2).

Annan-Diab, F., & Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *The International Journal of Management Education*, *15*(2), 73–83.

Armstrong, J. S. (1970). How to avoid exploratory research. *Journal of Advertising Research*, *10*(4), 27–30.

Bhargava, S., & Bhargava, S. (2013). Ecological consequences of the acid rain. *IOSR J. Appl. Chem*, *5*, 19–24.

Bhatti, N., Streets, D. G., & Foell, W. K. (1992). Acid rain in Asia. *Environmental Management*, *16*, 541–562.

Blewitt, J. (2012). *Understanding sustainable development*. Routledge.

Bricker, O. P., & Rice, K. C. (1993). Acid rain. *Annual Review Of Earth And Planetary Sciences, Volume 21, Pp. 151-174.*, *21*, 151–174.

Burmeister, M., & Eilks, I. (2012). An example of learning about plastics and their evaluation as a contribution to Education for Sustainable Development in secondary school chemistry teaching. *Chemistry Education Research and Practice*, *13*(2), 93–102.

Carter, R. (2003). Teaching visual design principles for computer science students. *Computer Science Education*, *13*(1), 67–90.

Chen, X., & Achal, V. (2020). Effect of simulated acid rain on the stability of calcium carbonate immobilized by microbial carbonate precipitation. *Journal of Environmental Management*, *264*, 110419.

Claesgens, J., Scalise, K., Wilson, M., & Stacy, A. (2009). Mapping student understanding in chemistry: The perspectives of chemists. *Science Education*, *93*(1), 56–85.

Cooper, D., & Higgins, S. (2015). The effectiveness of online instructional videos in the acquisition and demonstration of cognitive, affective and psychomotor rehabilitation skills. *British Journal of Educational Technology*, *46*(4), 768–779.

Dai, Z., Liu, X., Wu, J., & Xu, J. (2013). Impacts of simulated acid rain on recalcitrance of two different soils. *Environmental Science and Pollution Research*, *20*, 4216–4224.

Di Biase, R., Malatesta, S., & Schmidt di Friedberg, M. (2022). Promoting education for sustainable development in the Maldives: Exploring the link between theory and practice. *Prospects*, *52*(3), 529–544.

Diatta, J., Youssef, N., Tylman, O., Grzebisz, W., Markert, B., Drobek, L., Wünschmann, S., Bebek, M., Mitko, K., & Lejwoda, P. (2021). Acid rain induced leakage of Ca, Mg, Zn, Fe from plant photosynthetic organs–Testing for deciduous and dicotyledons. *Ecological Indicators*, *121*, 107210.

Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to 'seeing'how science works. *International Journal of Stem Education*, *2*, 1–13.

Fei, J., Ma, J., Yang, J., Liang, Y., Ke, Y., Yao, L., Li, Y., Liu, D., & Min, X. (2020). Effect of simulated acid rain on stability of arsenic calcium residue in residue field. *Environmental Geochemistry and Health*, *42*, 769–780.

Ferenbaugh, R. W. (1976). Effects of simulated acid rain on Phaseolus vulgaris L.(Fabaceae). *American Journal of Botany*, *63*(3), 283–288.

Grennfelt, P., Engleryd, A., Forsius, M., Hov, Ø., Rodhe, H., & Cowling, E. (2020). Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio*, *49*, 849–864.

Hidayat, A., Rahman, N. F., & Suharto, B. (2021). Media pembelajaran inovatif dalam pendidikan sains: Kajian pengembangan dan implementasi. *Jurnal Pendidikan dan Pembelajaran Sains*, 4(2), 45-58.

Ifegbesan, A. P., Ogunyemi, B., & Rampedi, I. T. (2017). Students' attitudes to solid waste management in a Nigerian university: Implications for campus-based sustainability education. *International Journal of Sustainability in Higher Education*, *18*(7), 1244–1262.

Irwin, J. G., & Williams, M. L. (1988). Acid rain: chemistry and transport. *Environmental Pollution*, *50*(1–2), 29–59.

Johnson, D. W., Turner, J., & Kelly, J. M. (1982). The effects of acid rain on forest nutrient status. *Water Resources Research*, *18*(3), 449–461.

Johnson, E. B. (2002). *Contextual teaching and learning: What it is and why it's here to stay*. Corwin Press.

Kimball, M. A. (2013). Visual design principles: An empirical study of design lore. *Journal of Technical Writing and Communication*, *43*(1), 3–41.

Kioupi, V., & Voulvoulis, N. (2019). Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes. *Sustainability*, *11*(21), 6104.

Kozma, R., & Russell, J. (2005). Students becoming chemists: Developing representational competence. *Visualization in Science Education*, *1*, 121–146.

Krug, E. C., & Frink, C. R. (1983). Acid rain on acid soil: a new perspective. *Science*, *221*(4610), 520–525.

Larssen, T., Lydersen, E., Tang, D., He, Y., Gao, J., Liu, H., Duan, L., Seip, H. M., Vogt, R. D., & Mulder, J. (2006). *Acid rain in China*. ACS Publications.

Li, X., Wang, Y., Zhang, Y., Wang, Y., & Pei, C. (2021). Response of soil chemical properties and enzyme activity of four species in the Three Gorges Reservoir area to simulated acid rain. *Ecotoxicology and Environmental Safety*, *208*, 111457.

Likens, G. E., & Bormann, F. H. (1974). Acid rain: a serious regional environmental problem. *Science*, *184*(4142), 1176–1179.

Likens, G. E., Bormann, F. H., & Johnson, N. M. (1972). Acid rain. *Environment: Science and Policy for Sustainable Development*, *14*(2), 33–40.

Liu, M., Huang, X., Song, Y., Tang, J., Cao, J., Zhang, X., Zhang, Q., Wang, S., Xu, T., & Kang, L. (2019). Ammonia emission control in China would mitigate haze pollution and nitrogen deposition, but worsen acid rain. *Proceedings of the National Academy of Sciences*, *116*(16), 7760–7765.

Liu, Z., Li, D., Zhang, J., Saleem, M., Zhang, Y., Ma, R., He, Y., Yang, J., Xiang, H., & Wei, H. (2020). Effect of simulated acid rain on soil CO2, CH4 and N2O emissions and microbial communities in an agricultural soil. *Geoderma*, *366*, 114222.

Lu, C., Wang, W., Zhou, Q., Wei, S., & Wang, C. (2020). Mechanical behavior degradation of recycled aggregate concrete after simulated acid rain spraying. *Journal of Cleaner Production*, *262*, 121237.

Lu, C., Zhou, Q., Wang, W., Wei, S., & Wang, C. (2021). Freeze-thaw resistance of recycled aggregate concrete damaged by simulated acid rain. *Journal of Cleaner Production*, *280*, 124396.

Mahdikhani, M., Bamshad, O., & Shirvani, M. F. (2018). Mechanical properties and durability of concrete specimens containing nano silica in sulfuric acid rain condition. *Construction and Building Materials*, *167*, 929–935.

Maler, K.-G. (1989). The acid rain game. In *Studies in Environmental Science* (Vol. 36, pp. 231–252). Elsevier.

Marfu'ah, S., & Anwar, S. (2018). How to develop SETS-based colloidal system teaching materials? *International Conference on Mathematics and Science Education of Universitas Pendidikan Indonesia*, *3*, 298–303.

Marfu'ah, S., Anwar, S., & Hendrawan, H. (2022). Pengembangan Bahan Ajar Sistem Koloid Menggunakan Metode Four Steps Teaching Material Development. *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, *6*(3), 715–727.

Marfu'ah, S., Anwar, S., & Hendrawan, H. (2023). *KOLOID: PRINSIP, METODE & APLIKASI*. CV. DOTPLUS Publisher. https://books.google.co.id/books?id=otHJEAAAQBAJ

Marfu'ah, S., & Meristin, A. (2022). Lembar Kerja Laboratorium Berbasis Proyek Pembuatan Koloid dengan Pemanfaatan Daun Cincau Perdu (Premna Oblongifolia). *Orbital: Jurnal Pendidikan Kimia*, *6*(2), 160–170. https://doi.org/10.19109/ojpk.v6i2.15015

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1), 1653531.

Menz, F. C., & Seip, H. M. (2004). Acid rain in Europe and the United States: an update. *Environmental Science & Policy*, *7*(4), 253–265.

Mohnen, V. A. (1988). The challenge of acid rain. *Scientific American*, *259*(2), 30–39.

Nilsson, M., Chisholm, E., Griggs, D., Howden-Chapman, P., McCollum, D., Messerli, P., Neumann, B., Stevance, A.-S., Visbeck, M., & Stafford-Smith, M. (2018). Mapping interactions between the sustainable development goals: lessons learned and ways forward. *Sustainability Science*, *13*, 1489–1503.

Olympiou, G., & Zacharia, Z. C. (2012). Blending physical and virtual manipulatives: An effort to improve students' conceptual understanding through science laboratory experimentation. *Science Education*, *96*(1), 21–47.

Olympiou, G., Zacharias, Z., & Dejong, T. (2013). Making the invisible visible: Enhancing students' conceptual understanding by introducing representations of abstract objects in a simulation. *Instructional Science*, *41*, 575–596.

Øygardslia, K., Weitze, C. L., & Shin, J. (2020). *The educational potential of visual novel games: Principles for design*.

Rahman, F., Khalil, M., & Jumadi, J. (2020). Pengembangan model fisik dalam pembelajaran sains: Analisis dampak terhadap pemahaman konseptual dan keterampilan berpikir kritis. *Journal of Science Education Research*, 3(1), 12-25.

Reis, S., Grennfelt, P., Klimont, Z., Amann, M., ApSimon, H., Hettelingh, J.-P., Holland, M., LeGall, A.-C., Maas, R., & Posch, M. (2012). From acid rain to climate change. *Science*, *338*(6111), 1153–1154.

Sankey, M. D. (2003). Visual and multiple representation in learning materials: an issue of literacy. *Create. Ed 2003: ELearning for the Creative Industries*.

Septiani, A. N. S. I., & Rejekiningsih, T. (2020). Development of Interactive Multimedia Learning Courseware to Strengthen Students' Character. *European Journal of Educational Research*, *9*(3), 1267–1280.

Sevian, H., & Talanquer, V. (2014). Rethinking chemistry: A learning progression on chemical thinking. *Chemistry Education Research and Practice*, *15*(1), 10–23.

Sharma, S. (2023). Towards Sustainable Education: Integrating Environmental and Social Responsibility into the Curriculum. *International Scientific Journal for Research*, *5*(5), 1–10.

Singh, A., & Agrawal, M. (2007). Acid rain and its ecological consequences. *Journal of Environmental Biology*, *29*(1), 15.

Underdal, A., & Hanf, K. (2019). *International environmental agreements and domestic politics: The case of acid rain*. Routledge.

Wang, T.-L., & Tseng, Y.-K. (2018). The comparative effectiveness of physical, virtual, and virtual-physical manipulatives on third-grade students' science achievement and conceptual understanding of evaporation and condensation. *International Journal of Science and Mathematics Education*, *16*, 203–219.

Wardani, S., Nurhayati, S., & Safitri, A. (2019). Efektivitas media pembelajaran konvensional dan digital dalam pembelajaran kimia: Studi meta-analisis. *Jurnal Inovasi Pendidikan Kimia*, 13(2), 2401-2413.

Wettestad, J. (2018). *Clearing the air: European advances in tackling acid rain and atmospheric pollution*. Routledge.

Wu, H., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(7), 821–842.

Yeh, H.-T., & Cheng, Y.-C. (2010). The influence of the instruction of visual design principles on improving pre-service teachers' visual literacy. *Computers & Education*, *54*(1), 244–252.

Yin, M., Sun, J., Chen, Y., Wang, J., Shang, J., Belshaw, N., Shen, C., Liu, J., Li, H., & Linghu, W. (2019). Mechanism of uranium release from uranium mill tailings under long-term exposure to simulated acid rain: Geochemical evidence and environmental implication. *Environmental Pollution*, *244*, 174–181.

Yong, Y.-P., Jantan, A. H., Abdullah, R. H., & Kamaruddin, A. (2016). The impact of visual design principles on classical aesthetic design for a web-based educational platform. *International Journal of Technology Enhanced Learning*, *8*(3–4), 318–339.

Zhang, L., Pan, Y., Xu, K., Bi, L., Chen, M., & Han, B. (2022). Corrosion behavior of concrete fabricated with lithium slag as corrosion inhibitor under simulated acid rain corrosion action. *Journal of Cleaner Production*, *377*, 134300.

Zuin, V. G., Eilks, I., Elschami, M., & Kümmerer, K. (2021). Education in green chemistry and in sustainable chemistry: perspectives towards sustainability. *Green Chemistry*, *23*(4), 1594–1608.

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