



Gadolinium Pollution - A future forward perspective on human and environmental impact

Makayla R. Long, Nir A. Dayan, Meicai Xu, Wei Liao, Assaf A. Gilad, Mark DeLano

Introduction

Since 1988, gadolinium-based contrast agents (GBCAs) have been used in more than 300 million procedures worldwide to improve image contrast in Magnetic Resonance Imaging (MRIs)¹. The composition of GBCAs have been improved to be more stable, but many have **raised concern that dissociated gadolinium may have potentially extreme adverse effects on humans, animals, and our environment**. For example, it is known that GBCAs are primarily excreted through urine and enter the sewage system, but levels of gadolinium are not monitored at wastewater treatment plants as standard practice. GBCAs are highly soluble and stable, and thus are not effectively removed by conventional water treatment processes. This leads to GBCA accumulation in surface water and even drinking water supplies^{2,3}. Mentioned here is a single source and example of gadolinium pollution, which presents the opportunity to investigate a broader perspective and current known understanding of gadolinium pollution.

As the utility and demand for gadolinium in MRI applications continues to grow, we encourage greater collective effort amongst scientists, physicians, and researchers to understand the full scope of gadolinium's effect on human health and the environment. **This review seeks to consolidate the current known understanding of gadolinium pollution, raise awareness about gadolinium pollution, and to advocate for meaningful interventions via interdisciplinary research.**

Methods

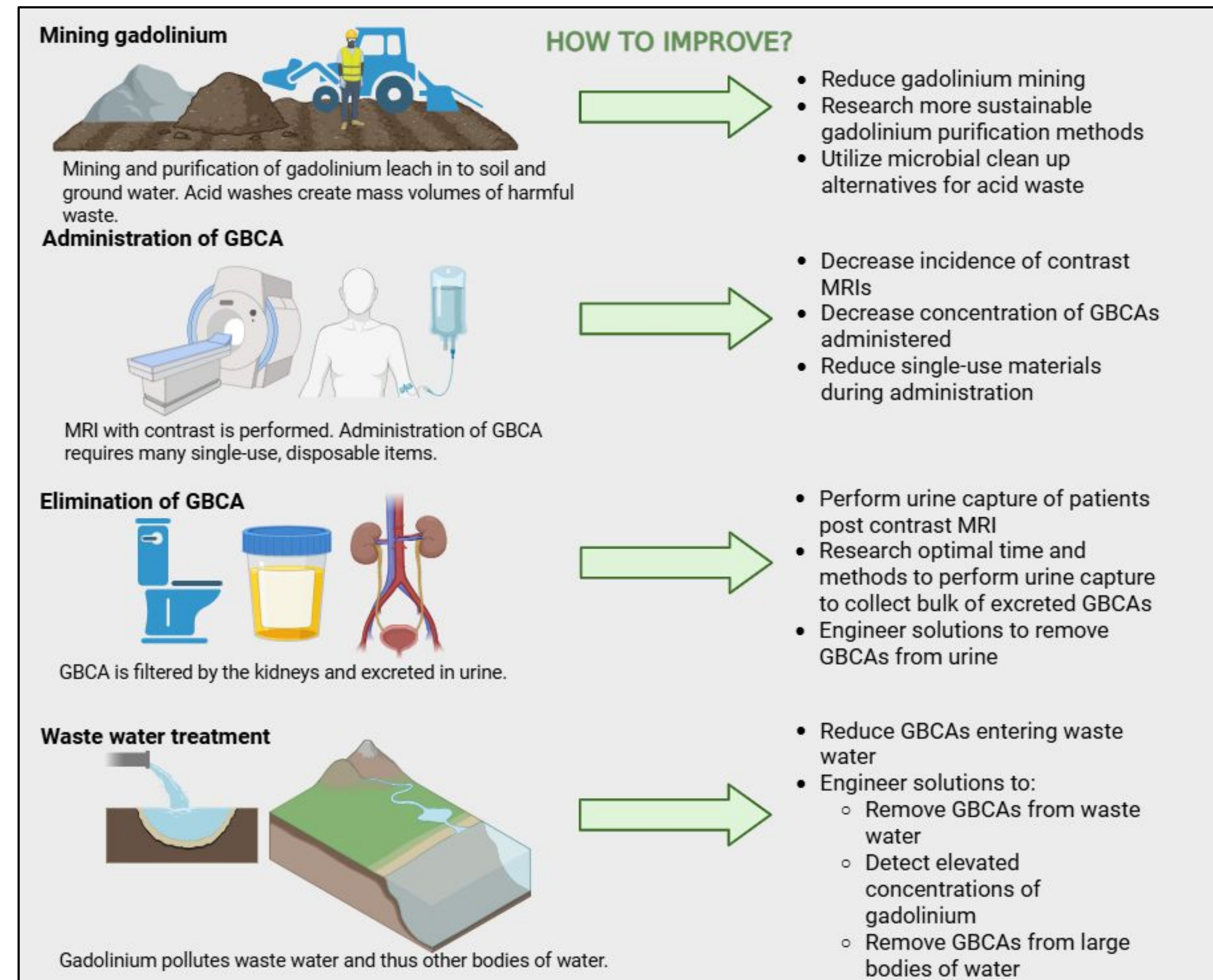
This manuscript is a review article of the current literature as pertains to gadolinium impact on human and environmental health. This review was conducted using an unstructured, narrative approach to explore current perspectives, data, and understanding of gadolinium pollution. Relevant literature was identified through searches of major academic databases including PubMed, Google Scholar, and MSU Libraries. Articles were selected based on their relevance, contribution to the field, and accessibility, with an emphasis on peer-reviewed publications. The review aimed to provide a broad overview of key developments, emerging trends, and ongoing debates within the topic area, without employing formal inclusion or exclusion criteria.

Acknowledgements

Thank you to Dr. Assaf Gilad and Dr. Mark DeLano for their mentorship and guidance.

Thank you to all faculty and staff at MSU CHM who continue to invest in my knowledge and growth.

Results



Conclusions

GBCAs have been a pivotal component of MR imaging technology and advancement for diagnoses and guiding treatment, however there is growing evidence to support human and environmental contamination.

- Radiologists must explore dose reduction and use of higher relaxivity contrast agents^{4,5}
- To date, GBCAs and gadolinium are not classified as toxic waste materials
- To date, no technology exists to remove gadolinium or recycle it from water

Future directions:

- Research the long-term implications of GBCAs
- Engineer techniques for gadolinium acquisition from water, including the use of microorganisms
- Push the boundaries of limiting GBCAs without compromising image quality and patient treatment

References

1. Lohrke J, Frenzel T, Endrikat J, et al. 25 Years of Contrast-Enhanced MRI: Developments, Current Challenges and Future Perspectives. *Adv Ther.* 2016;33(1):1-28. doi:10.1007/s12325-015-0275-4
2. Brünjes R, Hofmann T. Anthropogenic gadolinium in freshwater and drinking water systems. *Water Res* 2020;182:115966
3. Bordeneuve-Pérès A, Barrat JA, Bayon G, Rouget ML, Tripiet R, Salem DB. Unveiling rare earth elements in beers:evidence for gadolinium contamination. *Food Chem* 2025;493(Pt 3):145953
4. Scarciglia A, Papi C, Romiti C, Leone A, Di Gregorio E, Ferrauto G. Gadolinium-Based Contrast Agents (GBCAs) for MRI: A Benefit-Risk Balance Analysis from a Chemical, Biomedical and Environmental Point of View. Volume 9. *Global Challenges: Wiley*; 2025
5. Loevner LA, Kolumban B, Hutóczki G, Dziadziuszko K, Bereczki D, Bago A, Pichiechio A. Efficacy and Safety of Gadopichol for Contrast-Enhanced MRI of the Central Nervous System: The PICTURE Randomized Clinical Trial. *Invest Radiol* 2023;58(5):307-313.