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Sustainable layered double hydroxide foils: Calcium hydroxide and alternative magnesium sources for rapid point-of-use water disinfection in rural and disaster settings

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ABSTRACT

Access to safe drinking water remains a critical global challenge, particularly in developing regions and during post-disaster emergencies where conventional water treatment infrastructure is often compromised. This study presents a novel, sustainable, and highly effective point-of-use (POU) water disinfection method utilizing layered double hydroxide (LDH) foils. We addressed key limitations of powdered LDHs by immobilizing them onto aluminum foil, enabling easy application and separation from treated water. A significant innovation lies in replacing hazardous NaOH with safer, more accessible calcium hydroxide ($Ca(OH)_2$) for LDH synthesis, coupled with the exploration of alternative magnesium (Mg) sources like $MgCl_2$, $Mg(NO_3)_2$, and $Mg(OH)_2$, which are commonly available as agricultural fertilizers, enhancing local applicability. The synthesized LDH foils underwent characterization using x-ray diffraction (XRD), confirming successful LDH phase formation. Disinfection efficacy was rigorously evaluated against *Escherichia coli* (*E. coli*) as a model pathogen. Results demonstrate remarkable removal efficiency: LDH foils prepared with $MgCl_2$, $Mg(NO_3)_2$, and $Mg(OH)_2$, and seawater achieved near-complete *E. coli* elimination (< 1 CFU/mL) within 3 hours, while $Mg(OH)_2$-derived foils also showed significant reduction. This efficient and rapid destruction of pathogens, together with ease of application and green synthesis, positions LDH foils as a possible solution to enhance drinking water resilience within rural communities and in disaster relief efforts. Regeneration protocols will be optimized and performance verified within real-world water matrices in the near future.

Keywords: LDH foil, water disinfection, point-of-use (POU), disaster emergency, water resilience, *E. coli* removal.

INTRODUCTION

Access to safe and affordable drinking water remains a fundamental human right as well as a fundamental goal of the sustainable development goals (SDGs), particularly SDG 6, on Clean Water and Sanitation (Arora and Mishra, 2022). Due to sustained global efforts, an estimated 2 billion people in the world lack safely managed drinking water services, and 703 million people continue to lack a basic drinking water service, with the majority relying on sources that are contaminated (WHO, 2024). Bacterial, viral, and parasitic microorganism contamination of water by pathogenic microorganisms is the prime cause of waterborne diseases and a major cause of morbidity and mortality, particularly among susceptible populations like children and the elderly (da Silva et al., 2023; Natishah et al., 2025; Shayo et al., 2023; Wysowska et al., 2024). In many instances, such problems are compounded by inadequate infrastructure, limited resources, and limited access to efficient water treatment technologies (Dickin and Gabrielsson, 2023).

The urgency of this global issue is then exacerbated in areas of disaster risk. Earthquakes, floods, and landslides are becoming the norm of regular occurrence, frequently destroying critical water infrastructure, and wreaking large-scale contamination of water sources and isolating communities from access to safe drinking water (Bata et al., 2022; Pagano et al., 2017; Zamani et al., 2022). Flash floods, also in the process of increasing in magnitude and frequency, have a propensity to deprive affected groups of access to safe water, posing a heightened risk of outbreaks of waterborne diseases (Wang et al., 2023). In such dire circumstances, rapid deployment of effective and operational emergency interventions is of utmost priority to prevent disease outbreaks and safeguard public health.

Point-of-Use (POU) water treatment technologies are key to the provision of safe drinking water to communities not served with piped centralized water supplies (Ihsan and Derosya, 2024). Conventional POU interventions, such as boiling, chlorination, filtration, and SODIS, have been widely accepted; however, all of these interventions have inherent limitations, i.e., energy consumption for boiling, potential taste and odor issues with chlorination, and time-consuming procedures with SODIS, which collectively underscore the need for better, more efficient, user-friendly, and sustainable POU technologies.

Layered double hydroxides (LDHs), also known as hydrotalcite-like materials, have emerged as promising materials for water remediation due to their superior adsorption characteristics for a broad range of contaminants, including heavy metals (Fan et al., 2023), dyes (Bobde et al., 2023), and notably, pathogenic microorganisms like viruses and bacteria (Forano et al., 2018). Their efficiency as adsorbents is due to their unique anionic clay structure, which facilitates strong interactions with pathogens through diverse mechanisms like electrostatic attraction, ion exchange, hydrogen bonding, and polar interactions (Wang et al., 2023). LDHs are also typically non-toxic with a record of safety, having been utilized in a myriad of pharmaceutical applications (Luo et al., 2025; Rybka and Matusik, 2025), thus rendering them highly suitable for the treatment of drinking water.

Despite the immense potential of LDHs as adsorbents of pathogens, their application in large-scale POU water treatment has been deterred by their ubiquitous powdered nature. The fine particulate nature of powdered LDHs poses considerable challenges in separating them from treated water, often requiring additional filtration steps that complicate their use, particularly in emergency or low-resource settings. To overcome this critical limitation, recent advancements have focused on immobilizing LDHs onto solid substrates (Ihsan et al., 2025). Our previous work, along with others, has successfully demonstrated the fabrication of LDH-foils, where LDH nanostructures are directly grown or integrated onto aluminum foil (Ihsan et al., 2023; Johan et al., 2023). This innovative fabrication technique eliminates the handling difficulties associated with powdered LDHs, allowing for easy application and subsequent removal of the foil sheet after water treatment.

While previous studies have successfully synthesized LDH-foils using methods involving sodium hydroxide (NaOH) and seawater, these approaches present practical challenges for broader implementation. The use of NaOH, a strong caustic agent, raises safety concerns in handling and disposal, particularly in decentralized or community-based applications. Moreover, the reliance on seawater as a magnesium (Mg) source limits applicability to coastal regions, posing a significant hurdle for inland or non-coastal areas, especially during emergency relief efforts when access to specific resources is constrained.

This research directly addresses these critical gaps by introducing a novel and more sustainable approach to LDH-foil synthesis. Our innovation primarily involves the strategic replacement of NaOH with calcium hydroxide ($Ca(OH)_2$) as a safer, more readily available, and cost-effective alkaline reagent for LDH formation. $Ca(OH)_2$ is less hazardous to handle and widely accessible, making the synthesis process more sustainable and amenable for community-level production (Chang et al., 2017). Furthermore, we thoroughly explore alternative magnesium sources beyond seawater, specifically investigating the use of $Mg(NO_3)_2$ and $MgCl_2$. Significantly, both compounds are commonly utilized as agricultural fertilizers (Zhang et al., 2020), which not only ensures their accessibility and affordability in diverse geographical locations, including non-coastal rural areas, but also aligns with principles of resourcefulness. We also consider magnesium hydroxide ($Mg(OH)_2$) as a viable Mg source. Crucially, this study explicitly integrates the development of LDH-foils within the context of post-disaster emergencies, focusing on delivering a POU disinfection solution that is rapid, simple to deploy, and resilient to damaged infrastructure.

Building upon this compelling need and the identified innovative pathways, this study aims to enhance community drinking water resilience, particularly in disaster-prone areas such as West Sumatra, through the development of an innovative and applicable LDH-foil POU disinfection method. Specifically, our research objectives are to optimize the effectiveness of pathogen adsorption and the sustainability of LDH-foils by modifying their synthesis method using $Ca(OH)_2$ as a safer alternative to NaOH. We also aim to explore the utilization of more accessible and economical alternative Mg sources, including seawater, $Mg(OH)_2$, $MgCl_2$, and $Mg(NO_3)_2$, for LDH-foil fabrication. Concurrently, this research will investigate the influence of $Ca(OH)_2$ on the physicochemical characteristics and pathogen adsorption capabilities of the synthesized LDH-foils, and evaluate the potential of seawater and $Mg(OH)_2$ as specific alternative Mg sources in the context of drinking water disinfection. Ultimately, the goal is to optimize the overall fabrication and application methods of these LDH-foils to enhance their effectiveness, efficiency, and ease of use for drinking water disinfection in rural areas and during critical post-disaster emergency conditions.

MATERIALS AND METHODS

All chemical reagents used in this study were of analytical grade and purchased from Merck KGaA, Germany. Commercial aluminum foil (Best Fresh, Yumico, Indonesia) with a thickness of 0.014 mm was used as the substrate for LDH growth. Magnesium (Mg) solutions were prepared using 0.05 M magnesium chloride ($MgCl_2$), 0.05 M magnesium nitrate ($Mg(NO_3)_2$) and seawater from Muaro Lasak Beach, Padang, West Sumatra, Indonesia, as alternative Mg sources. This specific concentration of 0.05 M was chosen to mimic the approximate concentration of magnesium naturally present in seawater (Johan et al., 2023). Alkaline solutions included 0.02 M calcium hydroxide ($Ca(OH)_2$) and 1 M Sodium Carbonate (Na_2CO_3).

Synthesis of LDH foils

The LDH foils were synthesized through a two-step immersion method. Commercial aluminum foil was cut into 25 cm² pieces (specifically, 5×5 cm squares) and thoroughly cleaned to remove any surface impurities. This was followed by the pretreatment step, where each foil piece was immersed in 50 mL of 0.02 M $Ca(OH)_2$ solution for 1 minute at room temperature. Following the pretreatment, the primary treatment was conducted. The pre-treated foils were then immersed in 100 mL of various Mg solutions for 24 hours at room temperature (approximately 25 °C) without agitation. Two main types of Mg solutions were utilized:

- Mg solutions with Na_2CO_3 – for this approach, Mg solutions were prepared from 0.05 M $MgCl_2$ or 0.05 M $Mg(NO_3)_2$, or natural seawater. The pH of these Mg solutions was carefully adjusted to 10 by the addition of 1 M Na_2CO_3.
- saturated $Mg(OH)_2$ solution – a saturated solution of $Mg(OH)_2$ was also used directly as a Mg source without further pH adjustment, as it inherently provides the necessary alkalinity.

After the 24-hour immersion period, all synthesized LDH foils were thoroughly rinsed with distilled water to remove any loosely adhered particles and unreacted reagents, and then allowed to air-dry naturally. The resulting LDH foils were visually characterized and designated based on their synthesis conditions, as detailed in Table 1.

Characterization of LDH foils

The successful formation of the LDH phase on the aluminum foil substrate was confirmed using powder XRD. XRD analysis was performed on a Bruker D8 Advance instrument, employing CuKα radiation at 40 kV and 40 mA. Diffraction patterns were recorded across a 2θ range from approximately 5° to 60° to identify the characteristic peaks corresponding to LDH structures and the aluminum foil substrate.

Disinfection experiment

The disinfection efficacy of the synthesized LDH foils was evaluated using *Escherichia coli* (*E. coli*) as a model pathogenic bacterium. All experimental equipment and solutions, with the exception of the *E. coli* culture, were sterilized by autoclaving at 121 °C for 20 minutes prior to use. A pure culture of *E. coli* was prepared by incubating trypticase soy broth (TSB) medium at 37 °C until the viable count reached approximately 2×10^8 CFU/

mL. This was further diluted with distilled water to achieve a starting concentration of 100000 CFU/mL. Finally, 1 mL of this suspension was mixed with 99 mL of distilled water in a 250 mL bottle to provide a test solution with the target initial concentration of *E. coli* being 1000 CFU/mL.

For the experiments concerning adsorption, every 250 mL bottle with 100 mL of *E. coli* test solution was either used as a blank control or received one 25 cm² LDH foil. After this addition, bottles were agitated on a reciprocal shaker at 80 rpm and were held at 25 °C for 24 hours.

To monitor the decrease in bacterial concentration, samples from every bottle were collected at pre-determined time intervals: 0, 1, 3, and 24 hours. Viable counts of *E. coli* from the samples were enumerated by the standard plate dilution method with lysogeny broth (LB) agar as the growth medium. Colonies were counted after appropriate incubation, and the results were expressed as Colony Forming Units per milliliter (CFU/mL). All disinfection experiments were performed in triplicates to ensure reproducibility and statistical reliability.

RESULTS AND DISCUSSIONS

Synthesis and visual characteristics of LDH foils

The LDH foils were successfully synthesized on aluminum foil substrates through a two-step immersion method, involving a $Ca(OH)_2$ pretreatment followed by immersion in various Mg solutions. Table 1 summarizes the synthesis parameters for each LDH foil sample, along with their final pH values and visual appearances. As observed in Table 1, the pH values after synthesis ranged from 10.03 to 10.54, indicating an alkaline environment conducive to LDH formation (Fukugaichi et al., 2022). The visual appearance of the synthesized foils, depicted in Figure 1, varied significantly depending on the Mg source and the presence of Na_2CO_3 as a co-reagent. Sample 1, prepared using seawater and Na_2CO_3, exhibited a distinct dark brown color, likely attributable to impurities or organic matter present in the natural seawater. Sample 2, synthesized with $Mg(OH)_2$, showed a light gray-brown hue. In contrast, Samples 3 and 4, which utilized synthetic Mg salts ($MgCl_2$ and $Mg(NO_3)_2$ respectively) with Na_2CO_3, presented a more uniform light silver appearance. This lighter, more consistent coloration suggests a purer LDH layer, potentially indicating better crystallization or fewer co-precipitated impurities compared to the seawater-derived sample. The various visual aspects, particularly color and surface homogeneity, can be related to the purity and morphology of synthesized LDH phases, which can influence their reactivity and adsorption behavior.

Crucially, the qualitative observation of powder remnants on the foil surfaces after synthesis and washing provides useful information regarding the adhesion and stability of the formed LDH layer. Samples 1 and 2 had "no powders" remaining on the surface after processing, indicating that the LDH was greatly incorporated with the aluminum foil substrate. This tight binding is one of the advantages for POU applications, since it effectively minimizes the risk of release of particulate matter into the treated water, a major practical disadvantage of powdered adsorbents. Samples 3 and 4, while having excellent visual uniformity, contained "too few powders," which could be brushed off with only a gentle swipe. This suggests a slightly less persistent adhesion than for Samples 1 and 2, but much better than for standard powdered adsorbents. These

Table 1. Synthesis parameters and visual characteristics of LDH foil samples

No sample	Pretreatment	Reagent	Mg solutions	pH final	Powder assessment	Color
1	0.02M $Ca(OH)_2$ 50 mL (1 min)	1M Na_2CO_3 1 mL	Seawater 100 mL (24 hours)	10.54	No powders	Dark brown
2	0.02M $Ca(OH)_2$ 50 mL (1 min)	---	$Mg(OH)_2$ 100 mL (24 hour)	10.43	No powders	Light gray brown
3	0.02M $Ca(OH)_2$ 50 mL (1 min)	1M Na_2CO_3 1 mL	0.05M $MgCl_2$ 100 mL (24 hours)	10.03	Too few powders, just light swipe to remove	Light silver
4	0.02M $Ca(OH)_2$ 50 mL (1 min)	1M Na_2CO_3 1 mL	0.05M $Mg(NO_3)_2$ 100 mL (24 hours)	10.06	Too few powders, just light swipe to remove	Light silver

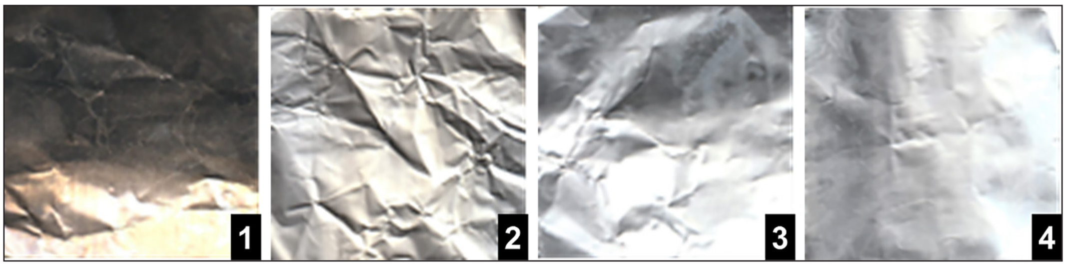

Figure 1. Visual appearance of LDH foil samples corresponding to Sample No. 1–4 in Table 1

observations are important for assessing the field usability and ease of use of the LDH foils with a clean and efficient treatment process, free of secondary contamination or the need for involved separation processes. The differences in powder formation are likely due to small variations in the LDH nucleation and growth kinetics on the aluminum substrate, depending on the provided Mg precursor and alkaline reagent combination. This characterization confirms the usefulness of $Ca(OH)_2$ as a pretreating agent and various Mg sources, including $MgCl_2$, $Mg(NO_3)_2$, seawater, and $Mg(OH)_2$, for successful LDH formation on aluminum foil.

XRD characterization of LDH foils

X-ray diffraction (XRD) analysis was performed to confirm the formation of layered double hydroxide (LDH) phases on the aluminum foil and to investigate the crystallographic structure of the synthesized materials. The XRD patterns for the pristine aluminum foil and the four synthesized LDH foil samples (Nos. 1–4) are presented in Figure 2.

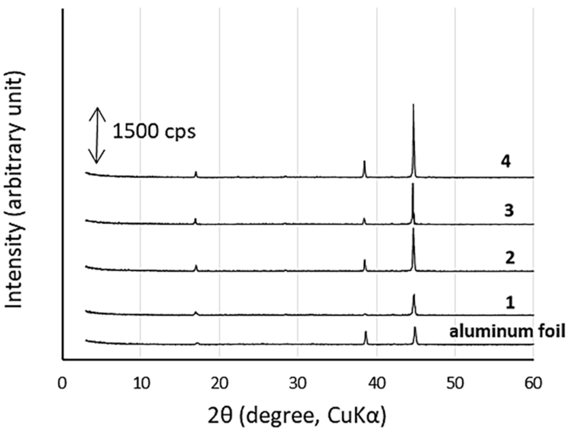

Figure 2. XRD patterns of pristine aluminum foil and synthesized LDH foil samples

The pristine aluminum foil exhibited sharp characteristic peaks corresponding to its crystalline structure, primarily at approximately 38.5°, 44.7°, and 65.1° 2θ, which are typical reflections of metallic aluminum. Upon synthesis, the XRD patterns of all LDH foil samples showed significant changes. Most notably, new diffraction peaks emerged at low 2θ angles, namely at approximately 11.3° (corresponding to the (003) plane) and 22.7° (for the (006) plane), which are characteristic reflections of the hydrotalcite-like layered structure. While these characteristic LDH peaks, particularly at 11−12° (003) and 22−23° (006), were observed in all the samples prepared, their intensities were found to be relatively broad and less intense compared to highly crystalline LDH materials reported in the literature (Bukhtiyarova, 2019; Hobbs et al., 2018).

This broadening and lower intensity of LDH diffraction peaks typically reflect a lower degree of crystallinity, smaller crystallite sizes, or the existence of structural disorder such as stacking faults in LDH layers. These are not typical characteristics of LDH materials prepared by in-situ growth methods or at ambient temperatures, where crystal growth kinetics may be slower and less perfect crystalline domains. Despite these observations, the clear visibility of these specific LDH reflections incontrovertibly confirms the successful development of the desired layered double hydroxide phases on the aluminum foil substrate under all synthesis conditions experimented with. This verifies the efficiency of our enhanced synthesis approach through $Ca(OH)_2$ pretreatment and various alternative Mg sources. The preservation of the pointed aluminum peaks also indicates that the LDH layer is deposited on the surface without fully consuming or significantly altering the initial aluminum substrate, which is desirable for maintaining the mechanical strength of the foil intact in POU applications. The ability to create active LDH layers in such circumstances, even with possibly reduced crystallinity, is particularly significant given the practical advantages of using safer and more readily available precursors in decentralized water treatment.

Disinfection efficiency of LDH foils against *E. coli*

The primary objective of this study was to evaluate the pathogen removal efficiency of the synthesized LDH foils, specifically their ability to eliminate *Escherichia coli* (*E. coli*) from contaminated water. The results of the *E. coli* disinfection experiments are presented in Figure 3, showing the viable *E. coli* count (CFU/mL) over a 24-hour period for the control (blank) and all four LDH foil samples. As depicted in Figure 3, the blank control sample showed minimal reduction in *E. coli* count over 24 hours, maintaining a concentration around 10^3 CFU/mL, indicating the inherent stability of *E. coli* in distilled water without treatment. In stark contrast, all LDH foil samples demonstrated remarkable efficiency in reducing *E. coli* populations.

1. Rapid reduction – for Sample 1 (seawater + Na_2CO_3), Sample 3 ($MgCl_2$ + Na_2CO_3), and Sample 4 ($Mg(NO_3)_2$ + Na_2CO_3), a rapid decrease in *E. coli* viable counts was observed within the first few hours. Specifically, Sample 3 and Sample 4 achieved near-complete elimination of *E. coli* (reaching below detectable limits, typically 1 CFU/mL) within 3 hours. Sample 1 also showed significant reduction, dropping to approximately 1 CFU/mL within 3 hours. This indicates that LDH foils fabricated with synthetic Mg salts and seawater, in conjunction with Na_2CO_3, are highly effective at rapid *E. coli* removal.

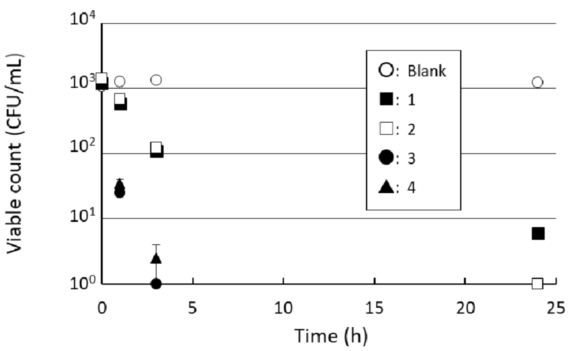

Figure 3. Disinfection efficiency of LDH foil samples against *E. coli* over 24 hours

2. Performance comparison – Sample 2, synthesized using $Mg(OH)_2$, showed a slower but consistent reduction. While it achieved a significant decrease, it took approximately 24 hours to reach a very low *E. coli* count (around 1 CFU/mL). The observed Sample 2 kinetics disparity with other samples (1, 3, 4) may be due to variations in the morphology, exposed surface area, or charge density of $Mg(OH)_2$-derived LDH compared to other Mg precursors. $Mg(OH)_2$, for instance, may lead to a denser LDH material or fewer accessible active sites for bacterial contact (Ihsan et al., 2024). The superior performance of Samples 3 and 4 (using $MgCl_2$ and $Mg(NO_3)_2$) highlights their potential as highly efficient alternatives to seawater-derived LDHs, particularly given their higher purity and consistency observed visually. The comparable efficiency of Sample 1 (seawater) suggests that naturally occurring Mg in seawater, when combined with an alkali, can also effectively form active LDH layers.
3. Optimal adsorption time – the results clearly indicate that an adsorption time of 3 hours is sufficient for Samples 1, 3, and 4 to achieve a substantial reduction in *E. coli* viable counts to levels below 10 CFU/mL, often reaching below 1 CFU/mL, meeting stringent drinking water quality standards. For Sample 2, a longer contact time, up to 24 hours, is required for optimal disinfection. This finding has deployment practicality in that, depending on the urgency and contact time available, one can choose specific LDH foil formulations. That such high removal efficiencies are achievable with minimal contact time testifies to the potency of LDH foils as an effective and viable POU solution.

The higher disinfection activity of LDH foils is due to a synergistic interplay of mechanisms based mainly on their inherent structural properties. The positively charged Mg-Al LDH sheets electrostatically interact with the negatively charged bacterial cell membrane of *E. coli* strongly (Forano et al., 2018; Remesh et al., 2023; Wilhelm et al., 2021). This preliminary attraction leads to the physical adsorption of bacterial cells on the LDH surface. Subsequent interactions can lead to the disruption of bacterial cell membranes, possibly by contact or discharge of highly localized hydroxyl ions due to the alkalinity created during LDH production, leading to oxidative stress and inactivation or lysis of bacteria. While our study did not incorporate advanced microscopy like SEM to view the interaction between bacteria, previous studies on LDH-pathogen interaction justify these proposed mechanisms (Ihsan et al., 2025). Successful formation of the layered structure, as evidenced by XRD, provides the right framework for such surface-mediated and charge-induced interactions. Furthermore, the high surface area provided by the LDH nanostructures, even when immobilized on a foil, reduces the contact points for the removal of bacteria compared to bulk materials.

Implications for sustainable water disinfection and applicability in emergency settings

This study's findings hold significant implications for developing sustainable and applicable POU water disinfection solutions, particularly for rural and disaster-stricken communities. The successful synthesis of active LDH foils using $Ca(OH)_2$ as an alkaline reagent marks a crucial advancement. Compared to NaOH, $Ca(OH)_2$ is inherently safer to handle, more readily available as a common agricultural lime, and generally more economical (Chang et al., 2017). This shift in precursor chemistry significantly enhances the sustainability and feasibility of local production, reducing reliance on hazardous chemicals and complex supply chains.

Moreover, the exploration and validation of alternative magnesium sources such as $MgCl_2$, $Mg(NO_3)_2$, and $Mg(OH)_2$ are highly impactful. The fact that $MgCl_2$ and $Mg(NO_3)_2$ are widely used as agricultural fertilizers (Zhang et al., 2020) ensures their broad accessibility and affordability, especially in inland regions where seawater is not an option. This resourcefulness enhances the independence of communities in producing these disinfection devices. The demonstrated effectiveness of LDH foils produced using these diverse locally accessible Mg sources presents alternatives that are flexible to the particular regional availability of resources.

The problem with removing powdered adsorbents from treated water using LDH-foils, which grow directly onto aluminum foils, is that immersion retrieval and utilization are too simple. It mimics the ease of use ideal for point-of-use methods. Such ease of use is critical in emergencies where speed, low training requirements, and durable, easy-to-understand devices are vital. Quickly using a straightforward sheet for water disinfection instead of complex filtration or sedimentation systems provides far greater benefits than conventional powdered adsorbents or other more complex point-of-use systems. Compared to other commonly used POU methods like boiling (energy-intensive), chlorination (taste/odor issues, dependence on chemical supply), or filtration (clogging, maintenance), LDH foils have the advantages of being easy, energy-sparing, and perhaps even greater shelf-life and reusability, and thus are highly suited for both everyday rural use and emergency disaster relief.

While the current work was concerned primarily with the first synthesis and disinfection activity, future research directions are crucial for the full utilization of the potential of these LDH foils. Additional investigation of the regeneration and reusability of the LDH foils will be undertaken to establish their long-term sustainability and economic feasibility. This will involve the development of optimum regeneration protocols via the application of safe and accessible reagents. Furthermore, monitoring of their performance with more extensive testing on real water samples (river water, well water, etc.) and with a variety of pathogenic microorganisms beyond *E. coli* will be important to ascertain their performance under differing environmental conditions (Zimmer & Dorea, 2023). Optimization of the processes for possible larger-scale production and exploration of the integration of these foils into simple, portable water treatment units for rapid deployment in response to emergencies are important avenues for further research.

CONCLUSIONS

This study successfully demonstrated the new and eco-friendly synthesis of layered double hydroxide foils and evaluated their performance as a POU water disinfectant against *Escherichia coli*. The key findings confirm the successful synthesis of LDH phases on aluminum foil substrates with various synthesis conditions, as deduced from XRD analysis. This work is a significant enhancement using $Ca(OH)_2$ as a safer, easier-to-source, and cheaper alkaline reagent instead of traditional NaOH for LDH synthesis. Furthermore, we were also able to successfully explore and prove the use of other sources of magnesium (Mg), including $MgCl_2$, $Mg(NO_3)_2$, $Mg(OH)_2$, and even seawater. The strategic application of these Mg sources, particularly those readily available as agricultural fertilizers, greatly enhances the local applicability and feasibility of this method, especially for non-coastal or resource-limited communities.

Most significantly, the synthesized LDH foils exhibited great efficiency in removing *E. coli* from contaminated water. $MgCl_2$, $Mg(NO_3)_2$, and $Mg(OH)_2$-based preparations, as well as seawater, exhibited rapid and near-complete annihilation of *E. coli* within just 3 hours, demonstrating their huge potential for instant disinfection applications. While the $Mg(OH)_2$-based LDH foil was slightly slower, it also showed significant disinfection over a longer contact time. The LDH in foil sheet form overcomes the limitations of powdered adsorbents, offering unparalleled ease of application and removal from water after treatment, an attribute critical in POU systems.

In conclusion, this research significantly contributes to the improvement of sustainable and effective measures for safe drinking water provision. The LDH foils formed by the synthesized method using environment-friendly synthesis paths and proven effectiveness in the removal of pathogens offer a hopeful, simple-to-apply, and robust method well-suited for rural communities and in challenging post-disaster conditions, thereby enhancing global water resilience. Future work will focus on further advancing regeneration and reusability protocols for increasing regeneration to further establish the long-term feasibility and cost-effectiveness of such new LDH foils.

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