Journal of Communicable Diseases
Volume 57, Issue 3 - 2025, Pg. No. 166-173
Peer Reviewed & Open Access Journal

Review Article

Promotion of Biosafety Principles as a Culture Among Children to Prevent Communicable Diseases

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DOI: https://doi.org/10.24321/0019.5138.202583

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How to cite this article:
Sinha S, Gupta G, Tolani H. Promotion of Biosafety Principles as a Culture Among Children to Prevent Communicable Diseases. J Commun Dis. 2025;57(3):166-173.

Date of Submission: 2025-07-10
Date of Acceptance: 2025-07-22

A B S T R A C T

Biosafety, once limited to research and clinical settings, has evolved into a cornerstone of modern public health. The COVID-19 pandemic has emphasised the urgent need for a biosafety-conscious society to survive. This paper explores the necessity of cultivating a culture of biosafety among children, evaluates the roles of educational institutions, families, and communities, and discusses practical and policy-based recommendations for instilling biosafety in childhood development. This paper argues for the early inculcation of biosafety principles in children as a foundational public health strategy to prevent communicable diseases, including public health literacy. Through a review of literature and behavioural theories, the study highlights how schools, parents, and communities can collaboratively foster a culture of biosafety among young populations. The paper draws from global frameworks, behavioural science, and real-world interventions to propose a holistic, scalable approach to biosafety literacy. The work further addresses the challenges faced in this mission and proposes actionable strategies for integrating biosafety education into daily life and curricula.

Keywords: Biosafety, Community, Communicable Disease, Family, Health Literacy, Parents, School Curriculum

Introduction

Biosafety refers to containment principles, technologies, and practices implemented to prevent unintentional exposure to pathogens or their accidental release[1](WHO, 2020). Although its origin is rooted in laboratory practices to safeguard researchers and staff, biosafety has gained new significance in everyday life as people worldwide are affected by infectious disease outbreaks, environmental risks, and biological threats.[2] So, the scope of biosafety has been extended to include hygienic behaviours, vaccination literacy, environmental sanitation, and antimicrobial stewardship.[3]

Health is increasingly recognised as a collective responsibility in the modern world, and education plays a pivotal role in disseminating essential knowledge and empowering individuals and communities to respond to health challenges. Instilling biosafety values in children can be a long-term investment in public health, which can provide

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a good return by reducing disease burden due to communicable diseases. The World Bank[4] thinks that early health education significantly reduces the economic burden of diseases. As childhood is considered the formative years of habit formation, biosafety education from early childhood not only improves current well-being but also ensures a resilient population equipped to manage future crises out of communicable diseases.[5,6] If biosafety education can be supported with infrastructural provision, an appropriate school curriculum, parental modelling, and community norms, it can develop a child into a future health warrior both at the individual and community levels (Fig. 1).

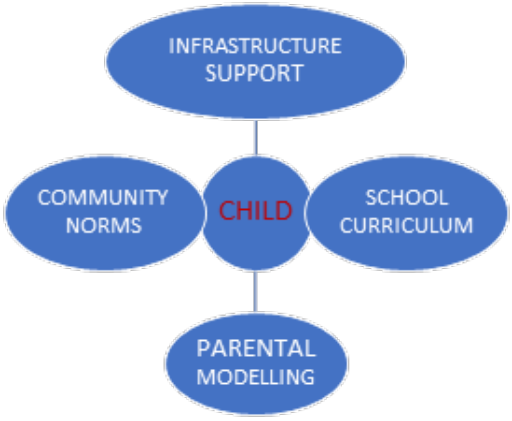

Figure 1.Conceptual Model / Framework

Burden of Communicable Diseases

Despite major advances in medical science, communicable diseases continue to be a leading cause of death and disability globally, especially in low- and middle-income countries. The World Health Organisation (WHO) reports that over 7 million people die annually from infectious diseases, many of which are preventable.[7] Children are being disproportionately affected. In 2021 alone, over 5 million children under the age of five died due to preventable illnesses like pneumonia, diarrhoea, and malaria.[7] Emerging zoonotic threats such as Ebola, Zika, and COVID-19 and their mitigation have further pointed out the urgent need for behavioural change and community education for better preparedness. Diseases such as rabies, Nipah virus, and avian influenza, along with the suspected zoonotic origin of COVID-19, pose the threat of animal-to-human transmission. Moreover, indirect transmission through fomites—such as shared toys, towels, and doorknobs—also causes disease spread. The SARS-CoV-2 virus, for example, can survive on surfaces for hours or even days.[8] In Southeast Asia, over 60% of global dengue cases occur, with India being the most affected; India also has the world's highest tuberculosis burden at nearly 2.8 million cases annually.[9,10,11]

Many of these diseases—such as diarrhoeal infections, respiratory illnesses, hepatitis, and vector-borne diseases—can be prevented through simple and affordable biosafety practices. Diarrhoeal diseases, causing about 1.5 million deaths annually among children under five, result mainly from faecal-oral transmission through unsafe water, poor sanitation, and inadequate hand hygiene.[9,12] The practice of handwashing alone can reduce diarrhoeal risk by 30–40%.[13] Acute respiratory infections, responsible for over 2.5 million global deaths annually, are generally spread through droplets, aerosols, and direct contact. During the COVID-19 pandemic, mask-wearing and hand hygiene proved effective non-pharmaceutical interventions.[14,15] Hepatitis A and E are linked to contaminated food and water, whereas hepatitis B and C are spread through blood-borne routes such as unsafe injections—yet these can be prevented through sanitation, vaccination, and biosafety protocols.[16] Meanwhile, malaria killed more than 600,000 people in 2022, and dengue continues to infect over 100 million people each year, though active community programmes to remove mosquito breeding sites have shown promising results.[17,18] Despite public health efforts, gaps in grassroots health education persist, and most infections still spread due to factors that can be prevented. These factors attract attention to the necessity of education and to strengthening biosafety practices worldwide.

Rationale for Prioritising Children

Children as Disease Vectors and Victims

Children are often considered as the passive recipients of infection; they can serve as vectors, especially in environments with close-contact dynamics such as schools and daycares.[19] Children are frequently asymptomatic carriers of infections, which acts as a constraint for disease control without foundational knowledge of biosafety practices.[20] Research by Aiello et al.[21] highlighted that the hand hygiene practices in school settings could reduce absenteeism by up to 50%. Therefore, these biosafety practices have both direct and indirect benefits towards community health.

Neurodevelopment and Habit Formation

Neuroscientific evidence supports the view that foundational behaviour patterns are encoded during early childhood.[22] Psychological studies also show that behaviours established before the age of 10 years are less likely to change later in life.[23] The capacity to assimilate norms such as regular handwashing and personal hygiene is strongest during the preoperational and concrete operational cognitive stages.[5] These behaviours become part of a child's routine when they are consistently modelled and reinforced.[24] Behavioural modelling in early years has long-run health impacts, influencing hygiene, dietary, and environmental practices.[25]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202583

Role of Education

Curriculum Integration and Cross-Disciplinary Learning

Integrating biosafety into the curriculum helps children develop knowledge, attitude and practice towards it. Cross-disciplinary approaches are very effective to enhance learning—for instance, combining biology with storytelling (language arts) or measuring microbial growth in mathematics lessons.[26] Countries like Japan and Finland have already embedded hygiene education into primary health curricula.[27,28] School-based health programmes have been shown to significantly reduce respiratory and gastrointestinal ailments through hygiene training.[13] Integration of health education with the STEM curriculum can enhance both academic outcomes and health literacy.[29]This can be done in a graded manner for different age levels (Fig.2).

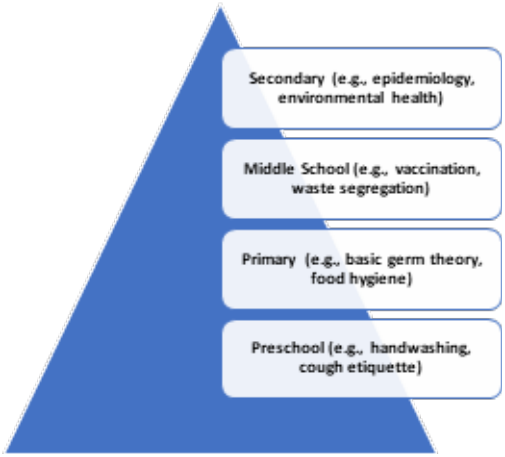

Figure 2.Age-wise Biosafety Education Ladder Diagram

Practical Engagement through Active Learning

Children engage more deeply with biosafety principles when activities involve inquiry-based and experiential methods. Games such as "Germ Detectives" or classroom experiments using Glow Germ kits help visualise microbial presence.[30] Service-learning projects—such as organising school health campaigns—reinforce biosafety practices while constructing civic responsibility.[31] Active learning methods (e.g., storytelling, simulation) improve the capacity to retain and encourage socio-emotional skills relevant to community health behaviours.[32] Longitudinal studies confirm that biosafety-related habits formed in school (e.g., use of sanitisers) continue into adolescence and adulthood.[33] Digital gamification and behavioural nudges (e.g., colourful reminders, mascots) boost biosafety engagement in school environments.[34]

School Infrastructure as Behaviour Shapers

The school environment itself is an important factor in build biosafety behavior. Functional handwashing stations, visible health promotion posters, and the presence of school nurses are linked to increased hygiene adherence.[35] Investments in Water, Sanitation, and Hygiene (WASH) infrastructure are critical in both high-income and low-resource settings.[36]

The Home and Community Ecosystem

Family as the First Line of Influence

It is widely acknowledged that family is the first school from which children learn their first lessons. Parental modelling has long been effective in shaping early health behaviours in children.[37,25] Studies suggest that common biosafety behaviours, such as mask usage and regular handwashing, are more effectively adopted by children when these behaviours are reinforced at home from early years.[38] Parental engagement plays a vital role in the credibility of school-based programmes and wellbeing.[39] Studies show that children of parents with high health literacy demonstrate significantly better hygiene and nutritional behaviours.[40]

Community-Level Health Literacy and Social Norms

Communities contribute to the collective health mindset. The theory of planned behaviour emphasises that subjective norms influence individual health choices.[41] When biosafety becomes a visible community value—through signage, campaigns, or communal health stations—it normalises protective behaviours.[42] Faith leaders, community health workers, and youth groups are instrumental in promoting biosafety messages.[43] Community-level trust in public health measures is strongly correlated with child biosafety behaviours (e.g., mask usage, school attendance during outbreaks).[44] Faith-based organisations and local NGOs can act as trusted intermediaries in health communication, especially in low-trust environments.[45]

Challenges to Biosafety Adoption

Socioeconomic Inequalities and Access

Poverty and inadequate infrastructure worsen inequality in biosafety literacy and practices among children.[46] Global disparities in access to soap, clean water, personal protective equipment (PPE), and sanitation persist as a barrier to universal biosafety.[47] In India, for instance, only 58% of rural schools had functioning handwashing facilities as of 2020.[48] Equitable resource allocation is essential for promoting inclusive biosafety practices. A 2021 UNICEF-WHO report indicated that 43% of schools worldwide lack basic hygiene services, which is a drawback in biosafety implementation.[47] Another setback is the cultural resistance to biosafety practices, which are often based on misinfor-

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202583

mation and myths related to health issues, necessitating culturally competent public health education.[49]

Behavioural Fatigue and Low Risk Perception: Behavioural fatigue takes place when people, particularly children, become desensitised to prolonged health measures to which they are previously unaccustomed .[50] If the perceived threat is low or abstract in nature—like microscopic germs which cannot be seen apparently—the compliance to health practices drops. Making risk visible through stories, simulations, and real-world case studies improves engagement.[51,52] The Health Belief Model and Protection Motivation Theory explain how perceived severity and susceptibility affect hygiene-related behaviours in children and adolescents.[53,54]

Recommendations for Multilevel Implementation

Enhancing Risk Literacy

Knowing the routes of biohazard transmission is the basis of risk literacy. Teaching children how pathogens spread, survive, and give rise to disease gives meaning to safety practices and risk mitigation methods.[55] Animation, models, and mobile learning tools can translate complex biological concepts into child-friendly formats.[56]Risk Perception: Making the Invisible Visible

Risk perception refers to how individuals understand and evaluate potential hazards. In the case of biological risks, threats are often invisible (e.g., viruses, bacteria), making them abstract and easy to underestimate. Biosafety education provides the cognitive tools to conceptualise and assimilate the techniques and practices to confront these threats. During COVID-19, populations with higher biosafety literacy were more likely to perceive asymptomatic transmission as a real risk and adopt mask-wearing and hand hygiene accordingly.[52] Educating individuals about droplet transmission, surface contamination, and viral persistence helps convert abstract risk into a tangible understanding.[55] This heightened awareness enhances vigilance and preparedness. “Risk perception is a precursor to risk-mitigating behaviour. Educating the public on the nature of biological threats improves their ability to make informed decisions under uncertainty”.[51] Risk Mitigation: Encouraging Preventive Behaviour

Once risks are identified and recognised, the next step is risk mitigation, which includes taking specific actions to reduce those risks. Biosafety education emphasises strategies such as hand hygiene, disinfection, safe food handling, responsible disposal of biological waste, etc. In schools where handwashing was taught along with germ theory, infection rates declined, and students developed long-term hygiene habits.[57] The adherence to hand hygiene and mask-wearing significantly reduces the spread of the respiratory illness.[15] The scientific explanation of the nature and behaviour of microbes increases the credibility of recommending measures against them. Knowing that viruses can survive on surfaces for hours makes individuals more likely to clean frequently touched surfaces.[55] “Knowledge of the science behind disease transmission leads to higher adoption of risk-reducing practices, such as mask-wearing and physical distancing”.[44] Biosafety education plays a crucial role in empowering children to comprehend the significance of vaccines, understand their schedules, and grasp the concept of herd immunity. When students are informed about these topics, they often act as health advocates within their families and communities, contributing to increased vaccine acceptance and uptake.[58,59] Additionally, educating children on the importance of completing prescribed antibiotic courses—and the dangers of self-medication—can contribute significantly to curbing the spread of antimicrobial resistance, particularly in TB and respiratory infections.[60,14]

Encouraging Protective Practices through Reinforcement

Reinforcing biosafety behaviours among children using reward systems, praise, and gamified tracking improves adherence.[23] Peer recognition systems, such as “Hygiene Hero” awards, can further enhance motivation and create school-wide norms.[61]

Practice: Sustaining Safe Behaviours as Norms

The third pillar of biosafety education is practice—the sustained application of learnt concepts as new behaviours. Biosafety education must extend beyond cognitive understanding and encompass the domains of social behaviour and habit formation. For example, the UNICEF WASH in School programme highlighted that providing handwashing infrastructure and education led to lower absenteeism due to illness and better hygiene practices even outside school.[61] Behavioural reinforcement through repetition, peer modelling, and institutional cues (e.g., handwashing stations, posters) creates social norms that support long-term adherence to what has been learnt. This aligns with Bandura’s social cognitive theory, which posits that people learn and sustain behaviours by observing others and receiving positive feedback. “Social learning and early reinforcement of protective behaviours lead to normalised health practices across populations”.[24]

Creating Supportive Environments: Behavioural science confirms that social cues, repetition, and environmental nudges can create new habits[62]. Biosafety posters, hygiene mascots, and daily routines like “sanitation circle time” reinforce positive behaviours in primary schools.[63] Empowering children as health ambassadors leads to broader community behaviour change, especially in rural and under-resourced settings.[15] Interventions based on the “child-as-change-agent” model are effective in catalysing health improvements in families and neighborhoods[64] (Fig.3).

ISSN: 0019-5138
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Figure 3.“Child as Change Agent” Cycle Flowchart

School-Based Interventions: A Sustainable Approach

School-based interventions include

- **Curriculum Integration:** Incorporating biosafety education into existing subjects like science and health education and environmental education.
- **Workshops and Seminars:** Organising regular biosafety workshops, where students can learn about hygiene, disease transmission, and preventive measures through hands-on activities.
- **Environmental Cues:** Providing visual cues, such as posters and stickers, to remind children of important practices like handwashing and mask-wearing.
- **Partnerships:** Partnering with public health organisations to offer free vaccinations, hygiene kits, and educational materials.

Parental and Community Involvement

To reinforce biosafety principles at home and in the community:

- **Parental Modelling:** Parents should model biosafety behaviours at home, such as hand hygiene and regular cleaning.
- **Community Engagement:** Communities should organise public health campaigns to raise awareness about biosafety practices, ensuring they are culturally sensitive and accessible.
- **Resource Provisioning:** Local governments and NGOs should provide resources, such as free hygiene products, to families in need.

Global Frameworks Supporting School Biosafety

UN Sustainable Development Goals (SDGs)3,4 and 6 are aligned to biosafety education, as they focus on Good Health and Well-being, Quality Education, and Clean Water and Sanitation, respectively. WHO’s Health Promoting Schools (HPS) is also a global initiative to integrate health into every aspect of school life. UNICEF’s WASH in Schools (WinS) focuses on water, sanitation, and hygiene infrastructure and education in school environments.

Conclusion

Promoting biosafety literacy in children can lay the foundation for sustainable public health. While challenges like socioeconomic disparities and behaviour resistance exist, multilevel interventions involving schools, homes, and communities can overcome these barriers. Educating children through engaging pedagogical methods, reinforcing behaviours through parental modelling and peer learning, and building supportive infrastructures can result in a culture where biosafety is second nature. A biosafety-educated generation will not only better navigate future pandemics but also actively participate in shaping healthier and more resilient societies. Through this model we can establish biosafety practices as a healthy culture for the future and can change the perspective of public health literacy on a mass scale and can prevent the burden of communicable diseases to a large extent (Fig. 4).

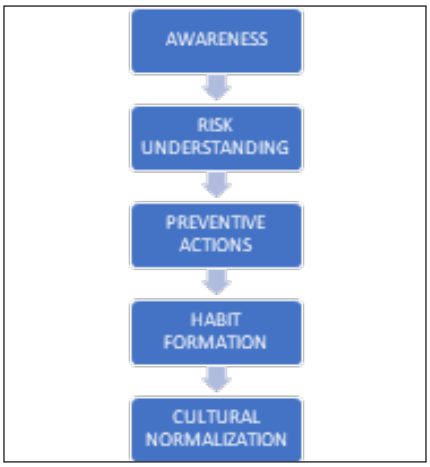

Figure 4.Behavioural Change

Acknowledgement: The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest: None

Source of Funding: None

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: None

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