Review Article

Color-Coded Segregation in Dental Waste Management: Global Evidence, Regional Practices, and the Bangladesh Perspective

Ahmed A[1], Mannan H[2], Lucky JS[3], Nuruzzaman K[4]

Abstract

Background: Evidence suggests that implementation of color-coded systems for waste segregation is an inexpensive and effective method for improving compliance and achieving sustainable waste management. This narrative review examines practices and experiences from other parts of the world to appreciate the challenges and leverage points in the context of waste management in Bangladesh.

Methods: A narrative review was performed in the period of January 2006 to January 2025, using PubMed and Google Scholar. The review incorporated literature in the areas of segregation of biomedical and dental waste, color-coded waste management systems, and compliance and adherence to waste management in low and middle-income countries (LMICs). The policy documents issued by the WHO, CDC, and national environmental authorities were also analyzed. Thematic analysis was utilized to examine the global waste management frameworks, practices in various regions, and the implementation shortcomings in Bangladesh.

Results: In high-income countries, compliance with color-coded segregation systems is nearly 90% owing to regulation, training, and digital monitoring for compliance. Whereas, LMICs and South Asia, compliance is only 60-80% because of poorly trained personnel and weak enforcement. The 2008 Medical Waste Management Rules in Bangladesh implemented color-coded segregation of waste (yellow, red, blue, and black bins), but compliance in dental practices still remains inconsistent.Staff training, standardized labeling, and monitoring, at the institutional level, have been shown to assist in compliance.

Conclusion: Evidence-sustainably supports the use of color-coded segregation for the effective management of dental waste. In the case of Bangladesh, implementation necessitates compulsory training and monitoring, incorporation into dental curricula, and enforcement of regulations. The use of the segregations as proposed by the WHO will enable safe dental practices while shielding health workers, the population, and the environment, thus enjoyed safe and sustainable systems.

Keyword: Biomedical waste management; Color-coded segregation; Dental waste; Infection control; Bangladesh; LMICs;

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1. Anam Ahmed, Associate Professor, Department of Dental Public Health, University Dental College, Dhaka.

2. Huda Mannan, Associate Professor (CC), Department of Pedodontics, University Dental College, Dhaka.

3. Jesmin Sultana Lucky, Associate Professor & Head, Dept. of Dental Public Health, Shaheed Suhrawardy Medical College, Dental Unit, Dhaka.

4. Khandakar Nuruzzaman, Assistant Professor, Department of Pedodontics, University Dental College, Dhaka.

*Corresponding Author

Dr. Anam Ahmed, Associate Professor, Department of Dental Public Health, University Dental College, Dhaka. Email: dph.udc@gmail.com, ORCID: https://orcid.org/0000-0002-7051-3990.

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1. Background

The management of biomedical waste (BMW) continues to pose global public health challenges. The COVID-19 pandemic's impact on healthcare waste management systems, particularly in low and middle-income countries, is particularly the pandemic's impact on the management systems in low and middle-income countries. In Bangladesh, urban hospitals particularly problematic with the inefficient management of BMW and having inadequate infrastructure and inadequate training identified as primary barriers [1,2]. Dental practices, as well as clinical, generate waste containing sharps, blood-soaked materials, chemicals, medications, and mercury-amalgams and are thus, potential environmental polluters and disease vectors. Waste management, segregation, and recycling in demolition clinics have been identified as important and urgent [3,4]. The segregation of waste is critical to preventing cross-contamination and strict, adequate waste treatment, as advocated by WHO, CDC, and stipulated in ICD-10-Coding guidelines and the India BMW Management Rules, 2016 [5]. In Bangladesh, insufficient regulatory oversight stems largely from weak enforcement of the 2008 Medical Waste Rules in private dental practices [6,7]. This review outlines obstacles and identifies solutions by proposing the implementation of the color-coded bin systems as evidence suggests provides effective management of dental waste.

2. Methods

This narrative review employed to evaluate literature pertaining to color-coded segregation systems in the management of dental waste. Comprehensive searches of peer reviewed articles were made in the PubMed and Google Scholar databases for the period of January 2006 to January 2025. There were also check citation and other relevant source that is relevant to objectives. Search terms included combinations of "color code," "color-coded bins," "biomedical waste segregation," "dental waste," "dentistry," "waste management," "infection control," and "healthcare waste." Boolean operators were used to streamline the searches and address pertinent literature in various sectors using "AND" and "OR." This review focused on KAP studies, implementation research, policy documents, and systematic reviews.

The review included studies in English and research conducted in South and Southeast Asia (as low and middle-income countries) concerning healthcare and dental waste segregation. Policy documents of WHO, CDC, and of the European Union, India and Bangladesh were also included. We excluded studies concerning non-healthcare wastes, duplicates, and segregation missing description. Data extraction employed structured sheets by region, type of waste, compliance, training, and policy. Thematic synthesis included global and regional along with the specific practices to Bangladesh. The quality of the practices was rated according to study design and transparency of reporting.

3. Overview of Biomedical Waste and Colour-Coding Systems

Biomedical waste (BMW) indicates waste which is a byproduct of healthcare delivery and includes laboratory and research activities which is bordered by pathological waste, waste which is hazardous and infectious, pharmaceutical and chemical waste, sharps, radioactive waste, and non-hazardous general waste [5]. Approximately 85% of healthcare waste is non-hazardous, however 15% is hazardous to human health and requires appropriate and safe disposal [8]. For the effective management of BMW, waste segregation is critical and occurs within the hierarchy of waste management which includes, prevention, segregation, collection, storage, transport, treatment, and disposal. Appropriate segregation reduces the infection risks waste costs, and eliminates the mixing of hazardous and non-hazardous waste [5]. The use of colour-coded bins streamlines and simplifies waste management and provides recognition facilitation for staff training [3].

For infected and pathological waste the WHO suggests the use of yellow containers, red for recyclables that are contaminated, blue/white for sharps, and backpage/ green for general waste [9]. In the 2016 regulations of Biomedical Waste Management, India classifies these wastes under four categories, yellow for infectious waste, red for contaminated plastics, blue/white for waste sharps and glassware, and black for general waste [5]. In Bangladesh, the Medical Waste Rules of 2008 classify waste with yellow for infected waste, red for sharps, blue for liquid waste, and black for general waste [6,7]. Reduction of infection risks, contamination of the environment, noncompliance issues, and costs associated with treatment are some of the benefits of making use of a properly integrated colour-coded system in a facility. Studies report a reduction of up to 30-50% of hazardous waste and segregation of waste results in positive economic and environmental benefits.

4. Dental Waste Management Practices: Global, Regional, and Bangladesh Context

4.1 Global Practices: Colour-Code Segregation

The World Health Organization outlines the importance of source segregation for safe healthcare waste

management. Colour-coded waste containers facilitate the handling and minimization of cross-contamination of waste [8,9]. High compliance using waste segregation systems has been shown in the developed systems. The United Kingdom's National Health Service (NHS) has a well-defined colour coding scheme where yellow bins are used for infectious waste, orange is used for alternative treatment infectious waste, purple is for cytotoxic waste and black is for general waste. In the United States, guidelines from the Centers for Disease Control and Prevention (CDC) and Occupational Safety and Health Administration (OSHA) recommend the use of red bags to be used regulated medical waste and sharps are to be placed in puncture resistant containers. European Union directives ensures these practices are consistent for all member states along with compliance to safety regulations [5.10,11,12]. Compliance with such practices is over 90% in well-resourced settings with regular training [5]. The proper segregation of waste enhances cost-effectiveness by 48%, achieved mainly by diminishing the volumes of hazardous clinical waste up to 71.2% and ascertaining proper disposal of hazardous waste. Real-time tracking of the generation, collection, and treatment of waste is facilitated by digital monitoring systems incorporating RFID tags and IoT sensors [13-19].

4.2 Regional Practices: Asia and Southeast Asia

Countries in South and South-East Asia face uneven challenges in terms of limited resources, rapid expansions in health care, and variations in the complexity of regulatory frameworks. Among the South-East Asian Association of Nations (ASEAN) countries, India has the most established regulatory regime. Under the provisions of the Biomedical Waste Management Rules 2016 and subsequent amendments of 2018, India imposes a color coded (yellow, red, blue/white, and black) and labeled classification and segregation system with prescribed treatments. Compliance and self-reported adherence to these rules varies between 60 to 85 percent [5]. A systematic review of Indian dental colleges found that 67% of participants incorrectly employed the color coded strategies indicating a lack of understanding of the rules [20]. Facilities that provide regular training, in most countries, are found to have higher compliance; trained health care workers were 4.33 times more likely to follow the prescribed waste management [21]. In Nepal, 91.8% of dental students expressed positive attitudes toward waste management, although over 50% could not state the government guidelines or appropriate techniques for disposal [22]. Other countries in the region, such as Pakistan, Sri Lanka, Thailand, and Malaysia, do have regulations but, as in the case of India, the lack of enforcement and compliance with the regulations are even more pronounced. General issues reported in compliance troubleshooting are limited funding, lack of training, treatment facility gaps, weak enforcement, low awareness levels, and waste management cultural practices.During the COVID-19 pandemic, the weaknesses in waste management systems were laid bare [19.23]. At the regional level, India established common biomedical waste management facilities (CBMWTFs). These facilities offer centralized services to broaden access to waste treatment, improve compliance with treatment standards, and facilitate training programs to enhance the understanding and practices related to waste management [21,23].

4.3. Bangladesh Perspective

Bangladesh adopted the Medical Waste (Management and Processing) Rules in 2008 by implementing waste segregation at the source through the use of color-coded bins. Yellow is designated for infectious/ anatomical waste, red for sharps, blue for liquid waste, and black is general non-hazardous waste.Nonetheless, under this advisory framework, there are still gaps in implementation. The oversight is exemplified further still in the limited research on dental waste. The inadequacies of waste segregation within the general healthcare system have been described in detail elsewhere. [1,9,24] Reasons identified include the insufficient provision of color-coded bins, inadequate training of staff, poor waste segregation, and low awareness of the healthcare workers and waste handlers [18]. Resource gaps, unregulated private dental facilities, additional gaps with no dental waste disposal guidelines, inadequate waste disposal and curriculum integration in dentistry, and lack of enforcement by the Department of Environment are all contributing barriers. Initiatives from large teaching hospitals and training from NGOs are emerging as good practices, but, as noted in the literature, they are uncoordinated on the national level [1,24].

The color-coding systems for dental and biomedical waste management as recommended by the WHO/ international guidelines, India (BMW Rules 2016/2018), and Bangladesh (MWM Rules 2008) [5,9-11,19,25-30]

Color	WHO / International Classification	India (BMW Rules 2016/2018)	Bangladesh (MWM Rules 2008)	Typical Contents (Medical + Dental)
Yellow	Infectious / pathological waste/ Sharp	Human and animal anatomical waste, soiled waste, expired medicines, chemical waste	Hazardous Anatomical, pathological, infectious / bio-hazardous waste	• Blood-soaked gauze, tissues, culture plates • Extracted teeth (without amalgam) • Cotton, gauze, bibs contaminated with blood/saliva • Impression materials with body fluids • Pathological waste from oral surgery
Red	Contaminated recyclable (infectious plastics)	Contaminated recyclable waste (tubing, catheters, gloves)	Contaminated, non-infectious, bio-hazardous, non-biohazardous waste	• Used suction tips, saliva ejectors, irrigation syringes (non-sharp) • Blood/saliva-contaminated gloves, plastic cups, suction tubing • Plastic impression trays
Blue / White (Translucent)	Sharps / glassware	White (Translucent): Sharps (needles, blades, files, wires); Blue: Glassware, vials, ampoules	Liquid infectious waste	• Needles, scalpel blades, endodontic files, orthodontic wires • Broken glass, ampoules, glass mixing slabs • Used burs and metallic fragments • Amalgam capsules (if not recycled separately)
Black / Green	General non-hazardous waste	Black: General waste (non-contaminated)	Black: GeneralNon-hazardous, non-infectious, biodegradable waste Green: recyclable General waste	• Paper, packaging, office waste, food waste • Non-contaminated plastics and disposables • Empty toothpaste/mouthwash containers
White / Rigid Container with Mercury Label (Dental-specific)	Hazardous chemical / amalgam waste	Not color-coded (hazardous waste, Schedule I)	Not color-coded (toxic waste category)	• Dental amalgam scrap, mercury-contaminated materials • Used amalgam capsules, separators, mercury spill kits • X-ray fixer, developer solutions (chemical waste) • Lead foils from radiographs

Brown	Chemical & pharmaceutical waste			• Laboratory chemicals such as reagents, film developers, disinfectants, and solvents; expired disinfectants; and waste containing high proportions of heavy metals such as batteries, broken thermometers and sphygmomanometers, and blood pressure gauges • Expired and surplus pharmaceuticals; waste containing and contaminated with pharmaceuticals.
Silver Labelled with radiation symbol	Radioactive waste		Silver: Radioactive waste	• Waste containing radioactive materials such as unused liquids from radiotherapy or untapped research, contaminated glassware, packs, or absorbent paper, patient urine, and excreta containing unsealed radionuclide waste and excreta of patients tested or treated with radionuclide, sealed sources, or other radionuclide.

Table 1: Comparison of dental waste color-coding systems across regions.

5. Evidence-based KAP on color-coded segregation in dental settings

Although the importance of color-coded bins for the safe segregation of dental waste is acknowledged, numerous countries still face challenges in knowledge and practice. Majority of dental professionals in India do not practice color coding and many do not know of the waste categories and protocols [10,20,31, 32]. These findings are similar to Iran [33], Pakistan [34], and Bangladesh [7,35-37]. Here, only a small percentage of clinics adhere to the recommended practices of waste segregation and most do not have disposal facilities and the requisite training. Concerning waste management practices, a survey noted half of needle disposal in India was done by breaking the needle and very few practitioners had access to needle burning devices [10,14,20,32]. This practice poses a high risk of sustaining a needlestick injury and the subsequent exposure to bloodborne pathogens [38]. In Ghana, while some waste handlers are able to articulate the types of waste they are handling, many are not able to match the waste to the right color-coded bin, which results in the mixing of infectious and general waste, and the unsafe handling of sharps [10]. Ethiopia and South Africa are not very different in this regard; only about half of healthcare workers or waste handlers in these countries are able to correctly segregate waste using color codes. Their knowledge is often limited to only a few waste types or colors (e.g. yellow and red for infectious waste) [10,39,40]. Even in the presence of knowledge, waste segregation practices are difficult to implement, largely due to inadequate containers, lack of personal protective equipment, inadequate training, and absence of standard operating procedures supervision [10,12,40]. Several studies indicate that targeted education, regular training, and clear labeling placed on containers increase adherence and appropriate disposal segregation [39,41-43].However, unsatisfactory enforcement and insufficient resources undermine the minimal progress [10,12,40]. Moreover, waste management continues to be insufficiently incorporated into the dentistry curriculum; in a recent survey, 56.8% of respondents in India described having lack of formal trainingregarding waste management [44,45].

6. Challenges and Barriers

Ineffective institutional, behavioral, and policy frameworks result in poorly managed dental waste in low- and middle-income countries. In particular, poor oversight results in high risks associated with waste segregation and disposal due to lack of funding, absence of incinerators, and missing color-coded bins [19,46]. Staff knowledge gaps and inadequate training continue to be process-related challenges, and barriers to the implementation of evidence-based practices are most frequently associated with gaps in staff awareness [47]. Weak policy enforcement, including the lack of systematic implementation and monitoring of waste disposal policies, results in governance challenges for both the public and the private sectors, which are

subsequently unaccountable for the safe disposal of dental waste [19,48]. Context-specific strategies to strengthen public and environmental health, which include investing in infrastructure, staff training, and more supportive policies, need to be adopted in order to remove these challenges [19,46,49].

7. Public Health and Environmental Implications

The absence of appropriately color-coded disposal systems increases inadequate separation of healthcare waste, thus exposing healthcare workers, patients, and surrounding communities to preventable risks like the transmission of infectious diseases (hepatitis B, hepatitis C, and HIV), and increases the risk of occupational exposure to sharps, and hazardous waste [1,10,49]. In Bangladesh, and many other low- and middle-income countries, unmanaged hazardous and infectious wastes, poor burning and dumping of wastes, and the subsequent emission of poisonous wastes, and microplastics creates respiratory diseases and wastes [1,50,51]. Environmental and public health are threatened by the environmental diffusion of antibiotic-resistant pathogens, and the leaching of waste associated toxic goods like mercury and harmful sulfides, and heavy metals associated with burning and dumping of wastes [50,52,53]. These problems persist because of poor training and resource allocation, inadequate infrastructures, and weak regulation. Conversely, integrating waste management into IPC as well as training other sectors shows improvement in compliance. Effective management of biomedical waste will ensure occupational and environmental safety, and the attainment of health-related Sustainable Development Goals, potable water, responsible consumption, and climate action [1,50,51].

8. Recommendations

Proper and safe management of biomedical waste management requires coordinated and consistent application of color-coded waste segregation according to WHO guidelines in low-resource settings. Standardized training and continuous education offered to healthcare workers increase knowledge and compliance, as seen with improvements in practices post-intervention. Policy-informed best practices stemming from regional partnerships that include knowledge exchange and shared databases can also be beneficial. India's color-coded waste management system can be a great starting point for standardization in Asia and Southeast Asia. In Bangladesh, further compliance can be achieved by standardizing the use of yellow, red, blue/white, and black bins in dental clinics, integrating waste management with dental education, and using local language visual aids. Sustainable frameworks can be maintained through routine audits and improvement of infrastructures which include color-coded bins and collaboratives of health services with dental schools. Collaborations with the WHO can help with the removal of bridging practices and the consolidation of partnerships for policy execution.

9. Conclusion

Evidence-based practices continue to promote cost-effective approaches to segregation and management of waste in the dental field through color-coded segregation. When color-coded segregation is implemented properly, it minimizes the risks of infection, protects the health of personnel, and mitigates the adverse environmental impacts. Bangladesh can gain insights from the waste management system of the World Health Organization which is an example in the region.Integrated approaches consisting of sound policy, appropriate facilities, training and supervision are also required for successful implementation as studies have shown improvements in performance after the imposition of such approaches. Standardized color-coding should be complemented by the integration of waste management into the curricula of dental education and licensing in Bangladesh, which should include regular training and enforcement at the operational level. The post-COVID-19 pandemic situation highlights the urgent need for resilient systems in waste management. Enhanced comprehensive systems for the management of biomedical waste ensures universal health coverage and protects the health of people and the environment.

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