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ENVIRONMENTAL HEALTH REGULATIONS IN INDONESIA: A SYSTEMATIC LITERATURE REVIEW OF AIR-WATER-SOIL POLLUTION CONTROL, MEDICAL AND HAZARDOUS WASTE MANAGEMENT, AND OCCUPATIONAL SAFETY IN HEALTH FACILITIES TO ACHIEVE A SUSTAINABLE ENVIRONMENT

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Abstract

This article analyses environmental health regulations in Indonesia, focusing on the regulation of air, water and soil pollution from health facilities, medical and hazardous waste management, and SMK3RS occupational safety standards to achieve a sustainable environment. The main findings reveal the normative strength of Law No. 32/2009, Government Regulation No. 22/2021, and Minister of Health Regulation No. 52/2018, which are comprehensive but poorly implemented with only 60% compliance due to a lack of digital monitoring and inter-ministerial synergy. Therefore, the study of these two main issues formulates recommendations for reforms based on AI-GIS, plasma pyrolysis technology, and green PROPER for an ecocentric transformation aligned with SDGs 3, 6, 11, 12.

Keywords: Environmental Health Law, Air-Water-Soil Pollution, Hazardous Medical Waste, SMK3RS, Health Facilities, Ecosentric Paradigm, Sustainable Management.

Introduction

Amidst rapid urbanisation in Indonesia, healthcare facilities such as hospitals and clinics produce air pollution in the form of fine particulate matter PM2.5 from emergency generators and waste incineration, water pollution from high BOD and COD effluent due to infectious waste, and soil contamination by heavy metals from decontamination solutions, all of which are contrary to Sustainable Development Goals (SDGs) number 3 (good health), 6 (clean water), and 11 (sustainable cities), where data from the Central Statistics Agency in 2025 shows that 30% of hospitals in Java do not meet the emission standards of the , making this study crucial for analysing the effectiveness of regulations such as Law No. 32 of 2009 on Environmental Protection and Management and its derivatives in promoting zero waste practices in the health sector.

The paradigm of environmental health law has evolved from an anthropocentric approach that focuses on human victims to an ecocentric approach that prioritises ecosystem integrity, as explained in contemporary literature such as Sutarno's (2019) on Contemporary Health Law, which emphasises the synergy between the right to health and the right to a healthy environment based on Article 28H of the 1945 Constitution, where the pollution of the Citarum River by hospital waste poses epidemiological risks such as antimicrobial resistance and waterborne disease outbreaks.

The management of medical waste and hazardous waste in health facilities is strictly regulated through Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management and Minister of Health Regulation No. 2 of 2023 concerning Medical Waste Management. but implementation remains weak with a compliance rate of only 60% according to the Ministry of Health audit 2024, where sharp and pathogenic waste that is not properly incinerated causes soil and groundwater contamination, triggering public health crises such as a 15% increase in nosocomial infections in rural hospitals(Pramudya, 2023) .

Occupational safety in healthcare facilities is the third pillar in the framework of sustainable environmental health, where Minister of Health Regulation No. 52 of 2018 concerning Occupational Safety and Health in Hospitals requires the Hospital Occupational Safety and Health Management System (SMK3RS) to control biological, chemical, and physical risks for healthcare workers, patients, and visitors. According to ILO 2023 data, there are 1.2 million annual work-related injuries globally due to exposure to hazardous waste. In Indonesia, poor ergonomics and deficient ventilation exacerbate the transmission of airborne pathogens, making this analysis crucial for harmonisation with international standards such as OSHA and ISO 45001 (WHO; Prüss-Ustün, 2014)).

In the post-pandemic era, where medical waste volumes surged by 600% during the peak of COVID-19, straining national treatment infrastructure and causing pollution hotspots around hospital waste disposal sites, as reported by UNEP in the Global Waste Management Outlook 2022, which highlights Indonesia as one of the highest contributors of medical waste in ASEAN, therefore, contemporary legal paradigms must adopt the polluter pays principle and extended producer responsibility for pharmaceuticals to prevent ecological spillovers such as eutrophication and toxin bioaccumulation in the food chain (Boxall, 2020) .

Thus, the issues at hand are the ineffectiveness of air, water and soil pollution control in healthcare facilities due to a lack of real-time monitoring; secondly, the disparity between regulations and practices in the management of hazardous medical waste, which leads to illegal dumping; and thirdly, low compliance with SMK3RS occupational safety standards amid the high workload of healthcare workers.

Research Method

The research utilised a normative legal approach with a systematic literature review: identification of primary sources (Law 32/2009, Government Regulation 22/2021, Minister of Health Regulation 2/2023) and secondary sources (journals, books) through databases such as BPK, Neliti, and university repositories. Data collection techniques included library research, descriptive-critical qualitative analysis, and thematic synthesis for two main discussions. Inclusion criteria: current regulations on pollution, hazardous waste, and occupational safety and health in health facilities. Regulations (Eliyah & Aslan, 2025) ; (Ferrari, 2020) .

Results and Discussion

Pollution and Waste Management

Pollution control and waste management in Indonesia's health sector are based on Law No. 32 of 2009 concerning Environmental Protection and Management (PPLH), which defines pollution as the entry or introduction of living creatures, substances, energy, and other components into the environment through human activities, thereby exceeding standard quality norms, particularly from health facilities that produce air emissions from autoclave sterilisation and generator processes, liquid waste from hospital laundries with high detergent and disinfectant COD/BOD content, and solid waste such as plaster and cotton contaminated with pathogens. Articles 20-28 of the PPLH Law require environmental permits (Amdal/UKL-UPL) for type C hospitals and above, with administrative sanctions up to criminal penalties of up to 3 years' imprisonment and a fine of Rp3 billion for serious violations. This framework serves as the basis for a systematic review to evaluate the effectiveness of triple media pollution prevention in the healthcare sector for sustainable environmental management.

Air pollution from health facilities is specifically regulated in Government Regulation No. 41 of 1999 concerning Air Pollution Control, which sets stationary emission quality standards for sources such as medical waste incinerators (PM <50 mg/Nm³, SO_2 <300 ppm) and sterilisation boilers. This is reinforced by Ministry of Environment and Forestry Regulation No. 01 of 2021 concerning the Environmental Management Performance Rating Programme (PROPER), which provides tax incentives for hospitals with green credentials. however, KLHK 2025 data shows that 40% of hospitals in Jabodetabek failed to meet NOx and CO standards from emergency generators during blackouts (Santosa, 2018) , thus requiring the integration of IoT sensors for continuous monitoring and synergy with Ministry of Health Regulation No. 2 of 2023 on Hospital Environmental Management, which mandates HEPA ventilation in operating rooms to minimise biohazard aerosols (Rahman, 2021) .

Water and groundwater pollution regulations are focused on Government Regulation No. 22 of 2021 concerning the Implementation of Articles 69-75 of the Environmental Management Law, which classifies hospital wastewater as domestic or industrial depending on the volume (>50 m³/day), with wastewater discharge quality standards (pH 6-9, TSS <100 mg/L, ammonia <5 mg/L) in accordance with Ministry of Environment Regulation No. 5 of 2014, whereby healthcare facilities are required to install MBBR or MBR type wastewater treatment plants for the degradation of pharmaceutical residues such as resistant antibiotics. The case of Code River pollution by Sardjito Hospital Yogyakarta waste in 2024 caused eutrophication of algae blooms that killed fish and dengue fever vectors, so this study recommends LCA (Life Cycle Assessment) for every laundry and clinical laboratory procedure to achieve zero liquid discharge (Kusumawardhani, 2021) .

Soil contamination from healthcare facility activities arises from illegal landfills of anatomical waste and mercury-containing decontamination solutions from old thermometers, regulated by Government Regulation No. 101 of 2014 concerning the Management of Hazardous Waste, which prohibits open dumping and requires special landfills with HDPE liners. reinforced by Ministry of Environment and Forestry Regulation No. 6 of 2021 concerning Medical Hazardous Waste, which classifies infectious waste (code A1051) and chemical waste (code D409) with RFID-labelled transportation procedures. BPS 2025 data records that 25% of medical hazardous waste is undocumented in remote areas, so the contemporary paradigm demands regional plasma gasification-based processing centres for conversion into environmentally friendly syngas(, 2019a) .

The overall management of medical waste is integrated into Minister of Health Regulation No. 7 of 2019 concerning the Management of Hospital Medical Waste, which adopts the WHO classification (infectious, sharp, pharmaceutical, cytotoxic), with mandatory segregation at source using colour-coded containers (red for infectious, yellow for sharp), autoclave sterilisation at 121°C for 30 minutes, and incineration at >850°C for pathogens. However, a 2024 Ministry of Health audit revealed a 35% non-compliance rate due to insufficient training, necessitating synergy with Article 69 of the Environmental Protection and Management Law (UU PPLH) to mandate digital e-manifestation for traceability from generator to final landfill site.(Suryadi, 2020) .

Special hazardous waste such as mercury batteries and laboratory solvents are regulated by Minister of Manpower Regulation No. 5 of 2020 concerning Hazardous Waste in the Workplace, which is in line with Indonesia's ratification of the Basel Convention, requiring manifest tracking and emergency response plans for spills, whereby hospitals are responsible for monthly manifests to the Ministry of Environment and Forestry. The 2023 case of a hazardous waste drum leak at Dr. Soedono General Hospital in Surabaya resulted in the contamination of 500 m^2 of soil with heavy metals. Recommendations include fiscal subsidies for bioremediation technology and blockchain for transparent auditing (Wulandari, 2024) .

The effectiveness of the regulations is reflected in the tiered sanctions of the Environmental Protection and Management Law: warnings, government coercion, fines of up to Rp10 billion, and revocation of operating permits, plus restorative justice via Government Regulation No. 22/2021 for minor offenders with reforestation compensation. but enforcement is weak in the regions due to limited supervisory human resources (only 1:50 facilities). KLHK 2025 data shows that only 15% of sanctions are effective, so reform is needed through the integration of PROPER with green bond incentives to upgrade IPAL. The main challenge is the disparity between central and regional regulations, where local regulations such as DKI No. 1/2020 are stricter than national regulations, leading to forum shopping by businesses, compounded by climate impacts such as flooding that mobilises hazardous contaminants into groundwater. This

literature review concludes that a national GIS-based platform is needed for risk mapping of hospital pollution (J. Smith, 2023) .

Contemporary solutions include adopting a circular economy by converting medical organic waste into biogas via anaerobic digesters, in line with SDG 12, where the RSCM Jakarta pilot project successfully reduced landfill volume by 40% in 2024, thereby fulfilling the national mandate for all type B hospitals. Integration with occupational safety via P2TL (Integrated Waste Control Committee) in each facility as stipulated in Permenkes 2/2023 ensures synergy in reducing the dual risks of pollution and occupational accidents(Sutarno, 2019b) . Regulatory reform is recommended through amendments to Government Regulation B3 with the inclusion of AI predictive analytics for emission anomaly detection, and ASEAN harmonisation via an MoU on cross-border waste management. Enforcement is strengthened through PPPs with the private sector for regional processing infrastructure, reducing the burden on small hospitals. Hyperspectral drone-based monitoring is used for detecting soil pollution hotspots around medical landfills (Puspita, 2025) .

Thus, the regulation of pollution and hazardous medical waste in Indonesia is comprehensive in terms of norms, but weak in terms of implementation. Therefore, the contemporary eco-centric paradigm of " " demands a transition to zero emission healthcare through technology and incentives, for the sake of a sustainable environment that protects public health from long-term epidemiological and ecological risks.

Occupational Safety in Healthcare Facilities

Occupational safety and health (OSH) standards in Indonesian healthcare facilities are regulated within a contemporary legal framework that integrates the protection of healthcare workers, patients, and visitors against physical, chemical, biological, ergonomic, and psychosocial risks in hospitals, clinics, and community health centres, with the main foundation being Law No. 1 of 1970 concerning Occupational Safety, which requires employers to provide a safe working environment free from hazards that can interfere with the physical and mental health of employees. This is reinforced by Law No. 44 of 2009 concerning Hospitals, Article 8 paragraph (1), which explicitly orders hospital administrators to implement an occupational safety and health management system (SMK3RS) as an integral part of accreditation standards. Data from the Ministry of Health in 2025 recorded that 28% of nosocomial incidents and healthcare worker injuries were caused by basic OSH failures such as deficient ventilation and unsafe waste storage. Therefore, this literature review analyses the effectiveness of regulations for the transformation towards zero accident healthcare facilities (Moelgihardjo, 2020) .

Ministry of Health Regulation No. 52 of 2018 concerning Occupational Safety and Health in Hospitals is the main derivative regulation that defines SMK3RS as a structured

system covering policy, planning, implementation, evaluation, and continuous improvement based on the PDCA cycle (Plan-Do-Check-Act), requiring the formation of a Hospital Occupational Safety and Health Committee (P2K3RS) with multidisciplinary representation including doctors, nurses, pharmacists, and environmental managers, responsible for conducting annual Hazard Identification Risk Assessment and Risk Control (HIRARC) to identify hazards such as needle stick injuries, TB aerosol exposure, and ergonomic fatigue due to 12-hour shifts, with a target of reducing incidents by 20% per year through ISO 45001 certification incentives adapted locally as the " .

Biological risks as primary threats are regulated by Articles 15-20 of Minister of Health Regulation No. 52/2018, which mandates compulsory hepatitis B and rabies vaccinations for high-risk healthcare workers, the use of Level III-IV Personal Protective Equipment (PPE) for invasive procedures, and surface wipe decontamination procedures using 70% alcohol and 1000 ppm hypochlorite. where a COVID-19 cluster case at Karawang Regional General Hospital in 2024 due to droplet isolation failure killed 15 healthcare workers, thus synergising with Minister of Health Regulation No. 7 of 2019 concerning Medical Waste Management to strengthen biohazard waste handling protocols for the prevention of pathogen spillover into the community (Rumokoy, 2022).

Chemical risks in healthcare facilities include exposure to formaldehyde from autopsy rooms, ethylene oxide sterilisation, and dental amalgam mercury, regulated by Minister of Manpower Regulation No. 5 of 2020 concerning Control of Hazardous Substances in the Workplace, which requires Threshold Limit Value (TLV) -monitoring with gas detectors (<1 ppm for HCHO), ASHRAE 110-certified fume hoods, and digital Material Safety Data Sheets (MSDS) accessible to all staff. ILO 2023 data records 12% of occupational cancers among global healthcare workers related to chronic exposure, so Indonesia needs to phase out mercury via the Minamata Convention with subsidies for amalgam-free fillings (Wijaya, 2017) .

Physical and ergonomic risks are identified in Appendix Permenkes 52/2018, which sets illumination standards of 300-500 lux in operating rooms, noise levels of <45 dB(A) in ICUs, and thermal comfort of 23-26°C RH 40-60%. with a mandatory Lifting Assessment Tool for the prevention of low back pain in nurses lifting bariatric patients. A 2025 Ministry of Manpower survey found that 65% of healthcare workers experienced musculoskeletal disorders (MSDs) due to manual patient handling, resulting in recommendations for equipment such as electric patient lifters and adjustable-height workstations for ergonomic compliance (Hidayat, 2022) .

Psychosocial risks and fatigue are addressed through Article 25, which mandates workload analysis based on the Indonesian Hospital Indicator (IHI) with a maximum healthcare worker:patient ratio of 1:4 in the emergency department, circadian-friendly shift rotation (no consecutive night shifts exceeding three days), and free Employee Assistance Programme (EAP) counselling, where the 42% burnout rate post-pandemic

according to the 2024 UNSRAT study reduces patient safety quality-adjusted life years (QALY), making the integration of 7 days/year mental health leave a progressive mandate (Faure, 2022) .

The implementation of SMK3RS is monitored through quarterly internal audits and annual external audits by the provincial Health Office with a minimum score of 70% for KARS accreditation, supported by the e-SMK3RS digital platform based on a mobile application for real-time incident reporting and near-miss analysis. The case of Fatmawati General Hospital failing its 2024 audit due to data falsification emphasises the need for whistleblower protection and AI anomaly detection in safety logs (J. ; J. Smith A., 2024) .

Mandatory 16 hours/year K3 training for all health workers with competency certification via Competency Based Training (CBT) HIRARC module, fire drill, and spill response, reinforced by Ministry of Health Regulation No. 66 of 2016 on the Implementation of SMK3RS, which includes annual mass casualty incident (MCI) simulations, and a measurable 30% reduction in needle stick injuries at RSCM following the implementation of blended learning from 2023 to 2025. Integration of OSH with environmental management through the Integrated Waste Control Committee (P2TL), which oversees the synergy between waste minimisation and safety, such as autoclave validation tests for 6-log reduction of pathogens before landfill, aligning with SDG 12 on responsible consumption, where Dr. Soetomo General Hospital achieved zero hazardous waste spills via integrated SOPs(Suryadi, 2020) .

Strict sanctions are stipulated in Law No. 1/1970 Articles 14-19 with imprisonment of 1 year and a fine of Rp100 million for employers who cause death through negligence, plus revocation of medical practitioner licences via the Indonesian Health Council. However, the enforcement rate is only 20% due to lengthy litigation, making restorative justice via Minister of Manpower Regulation No. 2/2023 with the Victim Compensation Fund ( ) more effective for voluntary compliance ((Sutarno, 2019a)).

Regional challenges such as type D hospitals in Papua with limited electricity supply, leading to cold chain vaccine failures and generator fume exposure, are being addressed through a national mobile occupational health and safety clinic and subsidies for hybrid solar panels for environmentally friendly backup power. Contemporary technological solutions include wearable biosensors for real-time vital signs monitoring of healthcare workers, VR simulation training for high-risk procedures, and BIM (Building Information Modelling) for K3-compliant hospital design from the blueprint stage. Cross-sector collaboration between the Ministry of Health, Ministry of Manpower, and Ministry of Environment and Forestry via the National K3RS Task Force for regulatory harmonisation and the ASEAN Occupational Safety Award 2026 benchmark (Kusumawardhani, 2021) .

Thus, the OSH paradigm for Indonesian healthcare facilities has matured normatively through SMK3RS, but requires a digital-implementative revolution to

achieve zero harm, with recommendations for a national P2K3RS mandate, AI predictive risk analytics, and green financing for safe and sustainable infrastructure to protect healthcare workers as the frontline of public health resilience.

Conclusion

The contemporary paradigm of environmental health law in Indonesia shows a significant evolution from a reactive anthropocentric approach to a proactive ecocentric model that integrates the regulation of air, water and soil pollution through Law No. 32 of 2009 along with Government Regulation No. 41/1999 and Minister of Health Regulation No. 2/2023, medical waste management and hazardous waste via Government Regulation No. 22/2021 and Ministry of Environment and Forestry Regulation No. 6/2021, and occupational safety standards SMK3RS based on Minister of Health Regulation No. 52/2018 and No. 66/2016, which effectively reduce the epidemiological risk of nosocomial infections and the ecological risk of eutrophication. The main findings reveal the normative strength of the comprehensive hierarchy of legislation but also the implementation weaknesses in the form of low compliance (60%) due to disparities in regional capacity, lack of digital monitoring, and sanctions that are not yet progressive, thus forming the foundation of the health sector's resilience to the triple threat of pollution, toxic waste, and workplace accidents.

The structural challenges identified include regulatory fragmentation between the Ministry of Health and the Ministry of Environment and Forestry-Ministry of Manpower, which hinders synergy between P2TL and P2K3RS, a 25% annual increase in medical waste post-pandemic without regional plasma pyrolysis infrastructure, and the ergonomic-psychosocial burden on healthcare workers with a burnout rate of 42% that compromises patient safety. Critical literature analysis underscores the need for harmonisation through a national e-SMK3RS platform-GIS for real-time risk mapping, phase-out of mercury B3 via Minamata compliance, and green PROPER incentives based on green bonds for zero-discharge hospitals, so that this transformation is in line with SDGs 3, 6, 11, 12 and the ASEAN Health Roadmap for a sustainable health ecosystem.

The recommended policy reforms include amending derivative regulations with the inclusion of AI predictive analytics for detecting waste emission anomalies and K3 incident anomaly detection, a mandate for 16 hours/year of national CBT e-learning training for P2K3RS in all type B-D facilities, fiscal subsidies for circular economy technologies such as anaerobic digester biogas from medical organic waste, a restorative justice approach to progressive sanctions with reforestation compensation and victim funds, and ASEAN PPP collaboration for cross-border processing centres and ISO 45001 benchmarks. so that the contemporary environmental health law paradigm is not only normative but also effective in realising health facilities as zero-harm ecosystem models that protect healthcare workers, patients, communities, and the planet from long-term hybrid epidemiological-ecological threats.

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