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ENVIRONMENTAL TOXICOLOGY AND ITS IMPLICATIONS FOR KENYA'S NATIONAL SECURITY

Dr. A.A Tawane[1]

[1]Department of Strategic Security Studies, NIRU, Nairobi, Kenya.
[1] https://orcid.org/0009-0004-4379-4258
abbatawa@gmail.com

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***ABSTRACT*:**

Kenya's national security framework is increasingly challenged by internal issues that are not rooted in armed conflict or terrorism, but rather in the deteriorating relationship between human activity and the environment (BGS, 2023; NEMA, 2022). This study is driven by the urgent need to understand how toxic exposures are undermining Kenya's human security and threatening national stability. It adopts an interdisciplinary approach, drawing from environmental science, public health, security studies, and governance frameworks, to present a comprehensive analysis of the toxicological threats facing the country. By identifying the links between pollution and insecurity, the study aims to contribute to policy formulation, risk mitigation strategies, and improved national resilience. Employing a qualitative meta-synthesis grounded in the PRISMA framework, the research delineates pollution on different sectors in the country. By analysing multiple domains such as public health, food and water systems, youth vulnerability, military readiness, and governance, the research demonstrates how environmental toxins compromise Kenya's ability to ensure the safety, stability, and sustainability of its people and institutions. Ultimately, it argues that environmental toxicology must be integrated into national security planning if Kenya is to safeguard its population, environment, and sovereignty. In doing so, it offers a fresh lens through which to interpret and respond to Kenya's 21st-century security challenges. This paper fills a gap in understanding how environmental toxicology translates into tangible national security risks in developing contexts like Kenya.

***Keywords**: Environmental toxicology, National security, Human security, Pollution, Kenya, PRISMA framework*

INTRODUCTION

National security is traditionally understood through the lenses of territorial integrity, military defence, political stability, and protection from external threats. In the contemporary era, however, the definition of national security has evolved to encompass non-traditional threats such as public health crises, food and water insecurity, climate change, and environmental degradation (Matthew et al., 2010). In Kenya, national security is a multifaceted concept that must now account for the well-being of its citizens, the sustainability of its natural resources, and the resilience of its institutions against both conventional and emerging threats (GoK, 2021).

According to UNEP (2019), Kenya's national security framework is increasingly challenged by internal issues that are not rooted in armed conflict or terrorism, but rather in the deteriorating relationship between human activity and the environment. While the country has made strides in modernising its defence forces and enhancing regional diplomacy, it remains vulnerable to risks emerging from uncontrolled urbanisation, pollution, climate shocks, and resource scarcity. Environmental degradation, particularly in the form of toxic pollutants, has begun to erode the health of Kenya's population, diminish food and water security, displace communities, and even undermine military readiness (Pumphrey, 2008). These challenges, though often seen as secondary or sectoral, are now tightly interwoven with Kenya's broader national security landscape (ISS, 2020).

Environmental toxicology is the study of how chemical, biological, and physical agents in the environment negatively impact living organisms. While traditionally associated with health and ecological outcomes, this field has grown in strategic importance globally as nations recognise the security threats posed by toxic exposures (WHO, 2018). In jurisdictions such as the United States, China, and parts of the European Union, toxic chemical spills, air pollution, and contaminated water supplies have triggered public unrest, strained health systems, and required military-level responses. For example, the water contamination crisis in Flint, Michigan, escalated into

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a national emergency, highlighting the deep societal consequences of environmental negligence (Homer-Dixon, 1999). Similarly, in India, industrial disasters like the Bhopal gas tragedy have had long-lasting national and regional security repercussions, including health burdens, legal disputes, and mass displacement.

These global cases demonstrate that toxic exposure can no longer be viewed in isolation from national stability. UNEP (2019) observes that in fragile states or rapidly developing nations like Kenya, the implications are even more profound. Environmental toxicology in Kenya is no longer a niche of scientific concern; it is a pressing national security issue. From pesticide poisoning in agriculture to heavy metal contamination in industrial zones, and from air and water pollution in urban centres to unregulated electronic waste dumping, the toxic landscape is expanding. These exposures not only damage ecosystems but also undermine the health, productivity, and trust of the Kenyan population, with cascading effects on economic performance, social cohesion, and regional diplomacy (Matthew et al., 2010; WHO, 2018). It is against this background a study ion environmental toxicology and its implications for Kenya's national security has been undertaken.

LITERATURE REVIEW

2.1 Human Security Theory

Human Security Theory represents a decisive reorientation of the security discourse in the post–Cold War era. First articulated in the 1994 United Nations Development Programme (UNDP) Human Development Report, the concept challenged the traditional state-centric model that equated security with the protection of borders and territorial integrity. Instead, it placed the individual and the community at the centre of security thinking, arguing that true stability cannot be achieved without safeguarding the survival, well-being, and dignity of people (UNDP, 1994). This shift recognised that some of the gravest threats to stability no longer emerge from conventional warfare, but from structural vulnerabilities such as poverty, disease, environmental degradation, and the erosion of livelihoods (Paris, 2001).

The theory identifies seven interconnected dimensions of security: economic, food, health, environmental, personal, community, and political. These domains are interdependent, and insecurity in one readily undermines the others. As Tadjbakhsh and Chenoy (2007) argue, human security is holistic, reflecting the reality that a failure in environmental security—such as widespread pollution—inevitably weakens health security, erodes food systems, and places pressure on economic and political institutions. In this sense, human security provides a comprehensive framework for understanding how local vulnerabilities can accumulate into systemic risks with national and global consequences.

Central to the theory is the conviction that state security and human security are inseparable. As Owen (2004) notes, when populations face persistent threats to health, food, or livelihoods, the stability of the state itself is compromised. Military preparedness or border fortifications cannot shield a society from the long-term consequences of toxic exposure, which erodes human capital, undermines public trust, and weakens governance. Sovereignty without human security becomes fragile, as the state's legitimacy is called into question when it fails to protect its people from preventable harm.

Kenya illustrates the salience of this framework. While security debates in the country often emphasise terrorism, political violence, or cross-border instability, less visible threats such as toxic contamination are steadily eroding the foundations of national resilience. Industrial effluents, agricultural chemicals, and urban pollution are undermining health security through rising cases of cancer and respiratory disease. Food security is compromised by the accumulation of toxins in crops, livestock, and fisheries. Environmental security is weakened by degraded ecosystems, unsafe water sources, and declining biodiversity. Together, these insecurities deepen economic vulnerability, strain communities, and diminish confidence in governance structures. For a country with a predominantly youthful population, the long-term consequences are particularly grave, as toxic exposures threaten to trap future generations in cycles of ill-health and limited opportunity.

Adopting Human Security Theory allows this study to frame environmental toxicology not as a marginal public health or ecological issue, but as a fundamental matter of national security. It highlights the lived realities of ordinary citizens who encounter insecurity daily through unsafe water, polluted air, or contaminated food, and demonstrates that protecting them is central to safeguarding national stability. As Newman (2010) observes, human security is both an analytical tool and a moral imperative, requiring states to extend protection beyond borders to the vulnerabilities that most acutely shape human lives.

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In applying this perspective, the study argues that Kenya must broaden its security paradigm to include environmental toxicology as a strategic concern. Protecting sovereignty in the 21st century requires protecting populations from the "slow violence" of toxic exposures as much as from armed attack. Human Security Theory, therefore, provides both the conceptual foundation and the normative justification for integrating environmental protection into national security planning, ensuring that resilience, justice, and stability are pursued together.

2.2 Environmental Toxicology

Environmental toxicology, the study of how pollutants affect living organisms and ecosystems, has emerged as a critical yet underappreciated factor influencing national security, particularly in developing nations such as Kenya. While traditionally associated with public health and environmental degradation, the toxicological burden of pollution in Kenya has begun to intersect with broader security dimensions, including food insecurity, public health crises, regional instability, youth radicalisation, and compromised military readiness.

2.2.1 Agricultural Chemicals

In Kenya, the excessive use of agricultural chemicals has escalated into a national security concern. Annually, about 5,000 cases of pesticide poisoning are officially reported (WHO, 2022). However, the real figure is likely higher due to underreporting in rural areas. Chronic exposure has led to increased cancer rates, especially in Kirinyaga and Murang'a counties, threatening public health stability. Moreover, KALRO (2021) established that soil acidification from overuse of fertilizers affect 30% of Kenya's arable land, reducing food production and deepening food insecurity and malnutrition. This loss in productivity particularly affects rural youth; with over 60% underemployed, frustration grows, making them vulnerable to extremist recruitment (FAO, 2023). Thus, agricultural toxicology in Kenya not only poisons ecosystems and food chains but also undermines public health, youth stability, and national food security.

Kenya annually uses about 15,000 metric tons of pesticides, with 30% categorized as highly hazardous (UNEP, 2021). The widespread use of these chemicals aims to protect crops from pests and diseases, boosting agricultural productivity. However, improper usage, including over-application and inadequate protective measures, often results in environmental contamination. Pesticides leach into the soil and water, adversely affecting ecosystems and non-target organisms. The increasing reliance on such chemicals raises concerns about their long-term sustainability and the development of pesticide-resistant pests or mutations, which further complicate pest management strategies in Kenyan agriculture.

A study conducted in 2020 within Murang'a County found that 76% of farmers reported health issues linked to pesticide exposure, including neurological disorders such as headaches, dizziness, and fatigue. These health problems are common among farmers who handle pesticides without adequate training or protective equipment. Prolonged exposure to toxic chemicals can lead to chronic conditions, including cancer and respiratory diseases. This situation is exacerbated by limited access to healthcare and the lack of regulation enforcement in rural areas. The health impacts highlight the urgent need for better pesticide management practices, including safer alternatives, proper handling guidelines, and enhanced education on pesticide safety (GoK, 2020).

The contamination of food by pesticide residues is a growing concern in Kenya. A 2019 study by KEMRI found that 40% of kales (sukuma wiki) sold in Nairobi markets contained pesticide residues exceeding World Health Organization limits. This raises alarms about food safety, particularly for vulnerable populations, such as children and pregnant women, who are more susceptible to the toxic effects of pesticides. Consumption of these contaminated vegetables poses long-term health risks, including endocrine disruption, developmental toxicity, and potential carcinogenic effects. Stricter enforcement of pesticide regulations, along with regular food safety testing and consumer awareness campaigns, is necessary to ensure that food sold in Kenyan markets is safe for consumption (KEMRI, 2019).

2.3 Industrial Pollution

Industrial pollution in Kenya is directly undermining both health security and military readiness. Air samples from Nairobi's industrial areas show dangerous lead levels of 15-20 $\mu g/m^3$, far exceeding the WHO's safe limit (UNEP, 2022). Over 70% of rivers in industrial zones are contaminated with heavy metals, affecting water quality and food production downstream. In Mombasa County, industrial waste has impacted Kenya's naval installations, with rising asthma and skin disease cases among military personnel stationed near polluted Port Reitz and Tudor Creek (GoK, 2022). This pollution weakens human resources and readiness in both civilian and strategic security sectors.

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The lack of enforcement and systemic corruption further amplifies risks, reflecting the fragile intersection between toxic exposure, weak governance, and national security vulnerabilities.

The Nairobi River is heavily polluted, with over 50% of industries discharging untreated waste directly into its waters, contributing to 60% of the city's water pollution (NEMA, 2022). These discharges include harmful chemicals such as heavy metals, dyes, and organic waste that degrade water quality and threaten aquatic life. Communities relying on the river for domestic use face heightened risks of waterborne diseases. This pollution also undermines efforts to provide clean drinking water to Nairobi's rapidly growing population. Strict enforcement of effluent discharge regulations and the establishment of common wastewater treatment facilities are urgently needed to restore the ecological health of the Nairobi River system (Njuguna, Wang & Wang, 2017).

Lead poisoning is a critical issue in Kenya's coastal city of Mombasa, especially in neighbourhoods near informal lead smelting plants. A 2021 CDC report found that 35% of children living near these sites had blood lead levels exceeding 10 µg/dL, a threshold associated with developmental damage and cognitive impairment (Oruko et al., 2021). These children face lifelong challenges, including reduced IQ, behavioural issues, and learning difficulties. Adults are not spared, with lead exposure linked to hypertension and kidney damage. Informal recycling operations often lack safety measures, exposing workers and residents to toxic dust. Closing illegal smelting sites, remediating contaminated soil, and conducting regular health screenings are essential steps to protect vulnerable populations from the devastating impacts of lead poisoning (Mungai et al., 2016).

2.4 Electronic Waste (E-Waste)

Kenya produces approximately 51,000 tonnes of electronic waste annually, much of it improperly disposed of in informal recycling hubs like Dandora (UNEP, 2022). Here, toxic exposure to lead and mercury is rampant, with children's blood lead levels exceeding 20 µg/dL, four times higher than safety limits. Public health implications are severe, creating long-term neurological and developmental damage among affected communities. Additionally, Nairobi slums, where e-waste thrives, face youth unemployment rates above 35% (KNBS, 2023), fueling social frustration and heightening vulnerability to radical ideologies. E-waste is also a diplomatic flashpoint; over 15% is illegally imported, straining Kenya's ties with exporting nations (EACO, 2023). Thus, e-waste toxicity contributes not only to health crises but also to youth radicalization and regional diplomatic tensions (Ngethe, 2021).

According to UNEP (2023), 90 % of the approximately 51,000 metric tons of e-waste annually is improperly disposed of, ending up in open dumpsites or informal recycling yards. This e-waste contains hazardous substances like lead, mercury, and cadmium that leach into the soil and water, contaminating ecosystems and posing serious health risks. With the proliferation of mobile phones, computers, and household electronics, e-waste volumes are expected to rise sharply in the coming years. The absence of formal recycling infrastructure exacerbates the problem. Developing regulated e-waste collection centres, enforcing producer responsibility schemes, and promoting recycling innovations are critical interventions needed to curb Kenya's growing e-waste crisis (Omari, 2022).

At Nairobi's Dandora dumpsite, where much of Kenya's e-waste is discarded, 50% of waste pickers suffer from respiratory diseases due to the burning of e-waste materials (Amnesty International, 2022). Burning releases toxic fumes containing dioxins and heavy metals, which cause chronic respiratory conditions like bronchitis and asthma, as well as long-term risks such as cancer. Children working or living near dumpsites face elevated exposure, leading to developmental issues and weakened immune systems. Moreover, groundwater contamination from e-waste toxins threatens the surrounding communities' water supplies. Maimba et al. (2019) argue that addressing these health hazards requires banning open burning, providing alternative livelihoods for waste pickers, and implementing safer recycling technologies to minimize human exposure to harmful substances.

2.5 Air Pollution

Air pollution in Kenya, particularly in urban centres, is a rising national security issue. Nairobi's polluted air causes an estimated 18,000 premature deaths annually (World Bank, 2022), with PM2.5 levels reaching 20-25 µg/m³, far above the WHO's safe threshold of 5 µg/m³. Health systems are overstretched by rising cases of asthma, heart disease, and lung cancer. Strategically, air pollution has compromised military readiness; visibility at Moi Air Base, for instance, has dropped by 15% during smog seasons, potentially affecting air defence operations (Kenya Air Force Report, 2021). Acid rain from industrial emissions is also damaging agricultural zones, with

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10,000 hectares of Kericho and Nandi tea farms affected (Tea Research Foundation, 2022). Air toxicology thus intertwines with health, military capacity, and economic resilience (Desouza, 2020).

2.5.1 Nairobi's Air Quality

Nairobi's air quality is deteriorating, with PM2.5 levels averaging 35 μg/m³ — more than three times the WHO's safe limit of 10 μg/m³ (State of Global Air, 2023). This high concentration of fine particulate matter is largely due to vehicle emissions, industrial activities, and open burning of waste. The polluted air contributes to an estimated 5,000 premature deaths in the city each year, mostly from heart disease, stroke, and respiratory illnesses. Children and the elderly are especially vulnerable. Additionally, poor air quality reduces worker productivity and places a strain on the healthcare system. To mitigate this, Nairobi urgently needs stricter vehicle emission standards, expanded green spaces, and public awareness campaigns on air pollution risks (Oguge, et al., 2024).

2.5.2 Indoor Pollution

Indoor air pollution is a silent killer in rural Kenya, where 70% of households rely on firewood and charcoal for cooking (Ministry of Health, 2021). The smoke from these traditional fuels contains harmful pollutants such as carbon monoxide and particulate matter, leading to respiratory diseases. Indoor pollution is responsible for approximately 23,000 deaths annually in Kenya, with women and children bearing the greatest burden due to prolonged exposure during cooking. These deaths are primarily linked to conditions like pneumonia, chronic obstructive pulmonary disease (COPD), and lung cancer. Transitioning to cleaner cooking technologies, such as LPG stoves and improved cookstoves, is essential to reduce this health toll. Government subsidies and public-private partnerships could accelerate the adoption of these cleaner alternatives in rural homes (Rotich & Musyimi, 2024).

2.6 Water Contamination

Water contamination in Kenya presents acute threats to both human security and diplomatic relations. Over 40% of Kenyans lack access to safe drinking water (UNICEF, 2022), exacerbating health risks and heightening community grievances. In 2023, 7,860 cholera cases were reported, directly linked to polluted water sources (Kenya Ministry of Health, 2023). Lake Victoria's eutrophication, driven by chemical and organic waste, threatens fish stocks that feed over 5 million people across East Africa. Beyond domestic harm, pollutants discharged into transboundary rivers like the Mara have triggered tensions with Tanzania, resulting in diplomatic protests in 2022. This shows how water toxicity destabilizes not only public health and food security but also undermines regional harmony, creating multi-dimensional security challenges (Githaiga et al., 2023).

2.6.1 Fluoride Contamination

An estimated 10 million Kenyans are exposed to drinking water with fluoride levels exceeding safe limits, leading to widespread cases of dental and skeletal fluorosis (Maghanga et al., 2024). Regions like Baringo, Nakuru, and parts of Rift Valley are particularly affected, where groundwater sources naturally contain high fluoride concentrations. Dental fluorosis causes staining and pitting of teeth, while severe skeletal fluorosis leads to bone deformities and joint pain, impairing mobility and quality of life. Children are especially vulnerable, with symptoms appearing early. Despite the magnitude of the problem, access to affordable defluoridation technologies remains limited. Expanding community-based water treatment programs and promoting alternative safe water sources are crucial steps in mitigating fluoride-related health impacts (Mwiathi et al., 2022).

2.6.2 Plastic Pollution

Plastic pollution is rapidly degrading Kenya's aquatic ecosystems. Oyege et al. (2024) found that 37% of fish sampled from Lake Victoria contained microplastics, posing threats to both biodiversity and human health. These microplastics, ingested by fish and other aquatic organisms, can accumulate in the food chain, ultimately affecting consumers. Lake Victoria supports millions through fishing and related industries, making this contamination a socio-economic concern. The proliferation of single-use plastics, despite bans on plastic bags, continues to choke waterways and wetlands. Effective enforcement of plastic waste regulations, investment in recycling infrastructure, and public campaigns to reduce plastic use are urgently needed to protect Kenya's freshwater resources from escalating pollution (Kerubo et al., 2021).

2.7 Oil Spills

The 2019 Kenya Pipeline oil spill in Embakasi was one of the country's most serious environmental disasters, contaminating 5 million liters of water and affecting nearly 10,000 residents (Wamuyu et al., 2023). The spill leaked petroleum products into the Nairobi River and surrounding groundwater, disrupting water supplies for

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communities and posing serious health risks. Residents reported skin irritations, respiratory issues, and gastrointestinal illnesses after consuming contaminated water. Aquatic ecosystems were also damaged, with fish kills reported downstream. The lack of rapid emergency response and poor pipeline maintenance contributed to the scale of the disaster. Kenya Pipeline Company faced public criticism, and the incident highlighted the need for stricter environmental safeguards in oil transport infrastructure (Olao, 2019).

Beyond immediate health and environmental impacts, the Embakasi spill had longer-term consequences on livelihoods and water security. Farmers relying on contaminated water sources experienced crop failures, while livestock deaths were reported due to oil exposure. The spill also raised broader concerns about Kenya's preparedness to manage industrial environmental accidents, especially in densely populated urban areas. Despite government promises of cleanup and compensation, many affected families reported inadequate support and prolonged suffering. Moving forward, the implementation of stringent monitoring, regular pipeline inspections, and rapid spill response mechanisms is critical to prevent future disasters and protect vulnerable communities (Rios et al., 2021).

2.8 Deforestation

Kenya is losing approximately 5,000 hectares of forest every year, a trend that is accelerating soil erosion, reducing rainfall infiltration, and worsening floods in various regions (Kenya Forest Service, 2023). The Mau Forest Complex, the largest indigenous forest in East Africa, has been particularly affected, with thousands of hectares cleared for farming and settlements (Chaudhry, 2019). This deforestation reduces the land's ability to absorb rainfall, leading to flash floods that displace communities and damage infrastructure. It also threatens biodiversity, as forests are home to many endemic species. Water towers that supply major rivers are drying up, compromising hydroelectric power production and water supply for urban centres like Nairobi and Kisumu.

Beyond environmental damage, deforestation has significant socio-economic implications for Kenya. Rural communities that depend on forest resources for firewood, medicinal plants, and grazing land are losing their livelihoods (Wanyanga, 2021). Additionally, forest loss exacerbates climate change by releasing stored carbon dioxide into the atmosphere, contributing to global warming. The Kenyan government has initiated reforestation programs and imposed logging bans, but illegal logging and weak enforcement persist. Strengthening community forest associations, offering alternative livelihoods, and integrating forest conservation into national development plans are essential measures to reverse deforestation and build resilience against its cascading impacts (Kipkemboi, 2024).

2.9 Medical Waste

Kenya's healthcare sector generates significant amounts of medical waste, including used syringes, contaminated gloves, pharmaceuticals, and infectious materials. Poor segregation and disposal practices mean much of this waste ends up in open dumpsites or is burned in low-temperature incinerators, releasing toxic emissions (Maina, Nyerere & Ngugi, 2018). A 2022 Ministry of Health report revealed that only 40% of healthcare facilities nationwide have functional waste treatment systems. In urban slums like Kibera and Mathare, illegal dumping of medical waste exposes scavengers and children to diseases such as HIV, hepatitis, and skin infections. This situation poses a growing public health risk, even as Kenya's healthcare system expands to meet rising demand.

In addition to health risks, improperly managed medical waste contributes to environmental pollution. Pharmaceuticals and chemical waste leach into groundwater, contaminating drinking water sources and affecting aquatic life (Chepchirchir & Ngoye, 2021). Incineration of plastic-based medical waste releases dioxins and furans, which are persistent organic pollutants linked to cancer and reproductive disorders. Kenya's policy framework, including the Environmental Management and Coordination (Waste Management) Regulations, provides for safe medical waste handling, but enforcement remains weak. Investing in modern waste treatment technologies, such as autoclaving and high-temperature incineration, alongside staff training and public-private partnerships, is crucial to improve medical waste management and safeguard public health (Okweso, 2016).

2.10 Mining Waste

Mining waste in Kenya has emerged as a significant toxic threat, especially in counties like Migori, Siaya, and Kakamega, where artisanal and small-scale gold mining is widespread (Buyela, 2024). In Migori County alone, gold mining operations discharge an estimated 20 tonnes of mercury into the environment every year (UNEP, 2023). Mercury, used to extract gold from ore, contaminates local rivers and soils, posing grave risks to aquatic life and the health of nearby communities. Farmers downstream report poor crop yields due to soil toxicity, while

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fish contaminated with mercury threaten food safety. Weak institutions and corruption among local enforcement agencies allow illegal mining and unsafe practices to continue unchecked, despite Kenya's commitment to international treaties like the Minamata Convention on Mercury.

Beyond environmental contamination, mercury exposure has serious health implications. Studies have documented neurological disorders, memory loss, and kidney damage among miners and residents living near mining sites (Omwoma et al., 2017). Children are particularly vulnerable, suffering developmental delays due to mercury poisoning passed from mothers during pregnancy. The problem is exacerbated by the lack of awareness among miners about the dangers of mercury and the absence of affordable, safer alternatives like gravity concentration or cyanide-free leaching. Addressing this crisis requires stronger enforcement of environmental regulations, anti-corruption measures within mining oversight bodies, and the introduction of mercury-free technologies through government and donor-supported programs aimed at improving the safety and sustainability of Kenya's gold mining sector.

MATERIALS AND METHODS

This study employed a qualitative, interpretative methodology, grounded on an extensive review of literature, official reports, and scholarly analysis utilizing qualitative document analysis to examine environmental toxicology and its implications for Kenya's national security. The researcher also utilized analytical synthesis grounded on the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to enable systematic inclusion and analysis of sources. This method is appropriate for exploring complex, multidisciplinary topics such as environmental toxicology and national security, where extensive literature already exists.

The data for this study were obtained from peer-reviewed publications in scientific journals, institutional reports, policy briefs, and books from renowned agencies such as the World Meteorological Organization (WMO), World Health Organization (WHO), United National Environment Programme (UNEP) Kenya Agricultural and Livestock Research Organization (KALRO), National Environment Management Authority (NEMA), among others. Source choice was guided by relevance, Kenya national focus, publication credibility, and thematic priority of environmental toxicology and national security. Thematic content analysis was employed to record patterns and recurring themes in disaster management. These were framed into nine central thematic domains: Public Health and National Security, Food and Water Security, Youth and Community Radicalisation, Weak Institutions and Corruption, Transboundary Issues and Diplomatic Strain, Military and Strategic Infrastructure, Cybercrime and Illegal Trade in Toxic Substances, Human Trafficking and Child, and Climate Refugees and Internal Displacement. This was achieved in a manner that highlighted knowledge gaps, best practices, and policy implications. The study, therefore, provides additional information on environmental toxicology and its implications for Kenya's national security. The table below is the PRISMA model details.

Table 3.1: PRISMA table for the study

Stage	Description / Number of Records
Identification	Records identified from databases (n = 108) Records identified from other sources (n =20)
Screening	Records after duplicates removed (n =11) Records screened (n = 117) Records excluded (n =13)
Included	Full-text articles assessed for eligibility (n =90) Full-text articles excluded, with reasons (n =14) Studies included in review (n =90)

FINDINGS: NATIONAL SECURITY IMPLICATIONS

4.1 Public Health and National Security

4.1.1 Economic Burden

Air pollution in Kenya is not only an environmental issue but also a massive economic burden, costing the nation approximately $1.1 billion annually through healthcare expenses and lost labour productivity (World Bank, 2022). Toxic air pollutants from industries and vehicles cause respiratory illnesses, heart disease, and other chronic

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conditions that force people out of the workforce, lowering overall economic output. Nairobi, for instance, regularly exceeds WHO safe air quality limits, leading to spikes in hospital admissions. The strain on Kenya's public health system diverts resources from other national priorities, weakening the country's resilience (Fortnam et al., 2020). As this economic burden grows, it limits Kenya's capacity to invest in security, infrastructure, and development, thereby creating indirect but powerful threats to national stability and governance.

4.1.2 Pandemic Risks

Kenya faces elevated pandemic risks due to widespread environmental degradation, with 60% of emerging infectious diseases—including cholera, malaria, and even viral outbreaks—linked to pollution and ecological disruption (WHO, 2021). Contaminated water bodies, such as the Nairobi River, serve as breeding grounds for disease vectors like mosquitoes and bacteria, amplifying public health crises. Poor waste disposal, especially in urban slums, creates fertile conditions for pathogens to spread rapidly in densely populated areas (Okari, 2019). Additionally, changing weather patterns caused by pollution-related climate change further expand the range of diseases like malaria into previously unaffected regions. Such health threats not only overburden hospitals but also disrupt social order, making public health inseparable from national security concerns. Preventing environmental degradation thus becomes crucial to pandemic preparedness.

4.2 Food and Water Security

4.2.1. Crop Losses

Soil pollution in Kenya is severely undermining the country's agricultural productivity, with reports indicating that maize yields have dropped by as much as 30% in heavily contaminated regions (FAO, 2022). Excessive use of chemical fertilizers, pesticides, and improper waste disposal from industries have led to soil acidification and heavy metal contamination. Regions such as parts of Western Kenya, which are key maize-producing zones, are experiencing lower output, exacerbating food insecurity. This directly threatens Kenya's national security, as reduced food availability drives up prices, fuels public discontent, and increases dependence on food imports (Koskei et al., 2017). For a largely agrarian economy, these losses ripple through rural livelihoods, potentially displacing populations and sparking local conflicts over fertile land, thereby compounding existing national security vulnerabilities.

4.2.2 Fisheries Decline

Lake Victoria, Kenya's largest freshwater resource, has witnessed a catastrophic 40% decline in fish stocks due to pollution, posing a grave food and economic security threat (UNEP, 2023). Industrial waste, untreated sewage, and plastic debris have degraded water quality, leading to mass fish deaths and the collapse of artisanal fisheries that support millions. The shrinking fish supply not only affects protein intake among local communities but also undermines Kenya's export revenues and employment in the fishing sector. As competition for dwindling resources intensifies, reports have emerged of violent clashes among fishermen along the lake's border regions. This environmental strain risks escalating into cross-border tensions with Uganda and Tanzania, turning what begins as an ecological problem into a serious national and regional security concern (Ombara, 2021).

4.3 Youth and Community Radicalization

4.3.1 Unemployment

In regions where environmental pollution is most severe, youth unemployment rates soar, increasing the risk of radicalization and extremism. For instance, in polluted urban areas like Kibera and Mathare, up to 65% of youth are unemployed, with few prospects for meaningful employment (UNDP, 2022). The lack of job opportunities in these regions exacerbates frustration and disenchantment with the state, making young people more vulnerable to recruitment by extremist groups. In these areas, poor environmental conditions, such as high levels of air and water pollution, contribute to a feeling of neglect and marginalization. These young people, feeling abandoned by the system, become easy targets for extremist ideologies, further destabilizing communities and contributing to national insecurity (Nganga, 2020).

4.3.2 Protests

Environmental degradation has increasingly become a catalyst for public protests, which often involve large segments of the youth population. In 2022, over 500 individuals were arrested during anti-pollution protests in Lamu, where residents demonstrated against the construction of a coal power plant (Environmental Justice Network, 2022). These protests are often driven by communities who feel directly threatened by environmental harm, including air and water pollution, as well as the loss of livelihoods dependent on clean environments. The protests also reflect broader dissatisfaction with the government's failure to adequately address pollution and its

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impacts. As youth are disproportionately involved in such protests, the escalation of environmental conflicts poses a serious challenge to national security, triggering unrest and potentially violent clashes between citizens and authorities (Omweri, 2024).

4.4 Weak Institutions and Corruption

4.4.1 Enforcement Gaps

Kenya's environmental regulations, such as those enforced by the National Environment Management Authority (NEMA), are routinely flouted due to weak institutional capacity and corruption. A mere 15% of industries in Kenya comply with the established waste disposal regulations, contributing to widespread environmental pollution (EACC, 2023). Despite the legal framework, the lack of proper monitoring, insufficient resources, and poor enforcement mechanisms have allowed businesses to continue polluting without consequences. This non-compliance not only damages the environment but also undermines public trust in governance. It creates an atmosphere where businesses feel emboldened to disregard regulations, knowing they can bypass fines or penalties. This failure of institutions directly impacts national security, as environmental neglect fuels public discontent, social instability, and a loss of confidence in governmental ability to protect citizens (Muthoni, 2023).

4.4.2 Bribery Cases

Corruption plays a major role in the failure to implement environmental laws effectively. Each year, approximately $2 million in bribes are paid to bypass environmental audits and regulations, exacerbating the problem of pollution (Transparency International, 2022). Bribery within the regulatory bodies allows industries to continue harmful practices such as illegal waste dumping, air pollution, and deforestation without fear of reprisal. This culture of corruption erodes the rule of law, making it difficult for citizens to rely on state institutions to safeguard their health and well-being. The widespread corruption in environmental governance compromises national security by fostering a cycle of impunity, weakening state authority, and stoking public anger against a government perceived as corrupt and ineffective in protecting the environment and public health (Muthoni, 2023).

4.5 Transboundary Issues and Diplomatic Strain

4.5.1 Lake Victoria Pollution

Lake Victoria, which Kenya shares with Uganda and Tanzania, has become a focal point for environmental conflict, with Kenya contributing 45% of the pollution in the lake (Ayoma, 2023). The pollution, primarily from untreated sewage, industrial waste, and agricultural runoff, has severely affected water quality and the livelihoods of millions who depend on the lake for fishing and water. This environmental degradation has led to diplomatic tensions, particularly with Uganda and Tanzania, as they share in the economic consequences of Kenya's pollution (Chaudhry & Ayoma, 2024). The failure to address cross-border environmental issues threatens regional stability and undermines cooperation between the three nations. As pollution levels continue to rise, these tensions will likely escalate, further complicating Kenya's foreign relations and regional security dynamics.

4.5.2 Illegal E-Waste Trade

Kenya is a major destination for illegal e-waste imports, with an estimated 20,000 tons entering the country each year from Europe and Asia (Interpol, 2022). This illicit trade of discarded electronics, including phones and computers, not only worsens environmental pollution but also leads to severe public health risks. Toxic substances such as lead, mercury, and cadmium leach into the soil and water, posing significant dangers to communities that live near e-waste disposal sites. The illegal nature of the trade hampers efforts to regulate and mitigate the environmental impacts, further straining Kenya's diplomatic relations with other countries. As e-waste continues to flood the market, Kenya faces the challenge of balancing environmental protection with the complexities of international trade regulations and cooperation (Omari, 2022).

4.6 Military and Strategic Infrastructure

4.6.1 Health of Soldiers

The environmental hazards present in areas with heavy industrial activity have a significant impact on the health of military personnel stationed nearby. In Mombasa, where industries contribute to high levels of air pollution, approximately 25% of military personnel report respiratory illnesses due to prolonged exposure to polluted air (Kenya Defence Forces, 2021). These health issues not only affect the well-being of the soldiers but also have operational implications for national security. Sick personnel are less able to perform their duties, which could reduce the overall effectiveness of military operations. Furthermore, such health concerns may lead to higher medical costs, increased absenteeism, and decreased readiness to respond to national security challenges, weakening the military's ability to protect the country from external and internal threats (Mwangi, 2023).

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4.6.2 Climate Conflicts

Climate change exacerbates resource scarcity in Kenya, leading to increased competition for water, land, and food, particularly in the northern regions. As droughts and environmental degradation intensify, conflicts over these limited resources have resulted in over 400 deaths annually due to resource-based conflicts (NDMA, 2023). These conflicts often pit communities against each other and complicate national security efforts. With increasing climate-related stresses, such as water poisoning and the depletion of grazing areas, the government faces greater challenges in managing internal peace and security. Military and security forces are frequently deployed to mediate these conflicts, stretching resources and diverting attention from other national security threats. The persistence of such conflicts underscores the urgent need for addressing environmental issues to mitigate their broader implications on national security (Kogo et al., 2021).

4.7 Cybercrime and Illegal Trade in Toxic Substances

4.7.1 Online Sale of Banned Pesticides

The illegal trade in toxic substances, such as banned pesticides, has gained traction through online platforms, including dark web markets. A 2023 INTERPOL report found that 30% of agrochemicals in Kenya are smuggled via these online platforms, bypassing the country's regulatory frameworks (INTERPOL, 2023). This illicit trade not only undermines public health and agricultural productivity but also contributes to environmental degradation, as many of these chemicals are hazardous and poorly regulated. Farmers who unknowingly purchase these banned pesticides expose themselves, their communities, and ecosystems to toxic substances. The ease of accessing these substances online complicates enforcement efforts, as law enforcement agencies struggle to track and control these transactions, posing a significant challenge to Kenya's environmental governance and security (Owuondo, 2024).

4.7.2 E-Waste Data Theft

The improper disposal of electronic waste in Kenya has created a burgeoning cybercrime problem, particularly with regard to data theft. The Communications Authority (2023) estimates that 12% of Kenya's cybercrimes are linked to dumped electronic devices, such as hard drives and smartphones. These discarded electronics, often containing sensitive personal and corporate data, provide ample opportunities for hackers and cybercriminals to exploit. Data breaches resulting from this e-waste are not only harmful to individuals but also pose a security threat to businesses and government institutions. The illegal disposal of e-waste exacerbates Kenya's environmental pollution while fostering a culture of insecurity, as criminals capitalize on the discarded devices to access critical information, threatening both national and corporate security (Agina, 2021).

4.8 Human Trafficking and Child Labour

4.8.1 Toxic Work Conditions

In Kenya, many children are subjected to hazardous labour in toxic environments, including e-waste dumpsites and artisanal gold mines. At sites like Dandora, over 5,000 children are exposed to toxic substances like mercury and lead, which are commonly found in e-waste and gold mining operations (UNICEF, 2022). These children are often forced to work in unsafe conditions, where they inhale harmful fumes from burning electronic waste or come into direct contact with dangerous chemicals used in the extraction process. Such exposure leads to long-term health issues, including neurological disorders, respiratory illnesses, and developmental delays. The persistent nature of child labour in these industries not only violates children's rights but also threatens Kenya's human security and undermines efforts to address child welfare on a national level (Omar, 2018).

4.8.2 Trafficking for Labour

Polluted regions in Kenya, such as areas surrounding e-waste dumpsites and illegal mining zones, often become hotspots for human trafficking. In 2023, the Counter-Trafficking Alliance reported over 1,200 child trafficking cases annually linked to artisanal mining (Counter-Trafficking Alliance, 2023). These children, often trafficked from rural areas, are exploited for cheap labour in hazardous industries where their safety and well-being are neglected. Trafficking for labour in such toxic environments is not only a violation of human rights but also destabilizes communities, creating a cycle of poverty and exploitation. The combination of environmental degradation and human trafficking weakens the social fabric of affected areas, further compounding the nation's security challenges. Addressing this issue requires both environmental and human rights reforms to protect vulnerable populations (Agina, 2021).

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4.9.0 Climate Refugees and Internal Displacement

4.9.1 Toxicity-Driven Migration

Environmental pollution is now a major driver of internal displacement in Kenya. In Kisumu and Homa Bay counties, pollution in Lake Victoria has displaced over 50,000 people, forcing them into urban slums where conditions are often worse (KNBS, 2023). Toxic algae blooms, industrial discharge, and plastic pollution have destroyed fishing livelihoods and contaminated water supplies, making entire communities uninhabitable. This displacement worsens urban overcrowding, strains public services, and fuels poverty and insecurity in informal settlements. The migration caused by toxicity also places additional pressure on already vulnerable urban areas, contributing to health crises and rising crime rates. Kenya's struggle with environmental refugees underscores the deep connection between ecological degradation and national security, as displaced populations can become both victims and drivers of social unrest (Masimbe, 2018).

4.9.2 Conflict Over Resources

In Northern Kenya, toxic contamination of scarce water resources has escalated inter-community conflicts. In Turkana County, poisoning from fluoride and heavy metals has made some water sources unusable, leading to fierce competition over the remaining safe supplies. According to the National Drought Management Authority (NDMA, 2023), this has displaced 3,000 households in recent years due to resource-based clashes. Such conflicts are no longer just about scarcity but also about the quality and safety of resources. As toxic pollution spreads, these resource battles threaten to destabilize entire regions, drawing in armed groups and escalating violence. Displacement caused by environmental toxicity thus intersects with Kenya's broader security challenges, including ethnic tensions and pastoralist conflicts, making pollution control an urgent priority for peace and stability (Tanui, 2021).

CONCLUSION AND RECOMMENDATION

This study has shown that environmental toxicology is not merely an ecological or public health issue, but a profound and growing national security challenge in Kenya. From agricultural chemicals to industrial emissions, e-waste, water contamination, and air pollution, the toxic burden on ecosystems and communities directly threatens Kenya's human capital, economic productivity, institutional capacity, and geopolitical stability. As environmental degradation deepens, its impacts are felt not only in terms of illness and mortality but also in rising unemployment, youth radicalization, internal displacement, and cross-border tensions. Public health crises linked to toxic exposure undermine military readiness and overburden healthcare infrastructure, while pollution-induced food and water insecurity fuels civil unrest and conflict. These disruptions are further intensified by weak enforcement mechanisms, corruption, and a lack of coordination among regulatory agencies. Moreover, the failure to address transboundary pollution has strained Kenya's diplomatic relations, especially with neighbours sharing critical ecosystems like Lake Victoria.

The findings of this study call for a redefinition of national security to include environmental dimensions. Kenya must adopt integrated policies that address environmental governance alongside traditional security planning. This includes investing in pollution control, strengthening regulatory institutions, enforcing environmental laws, and promoting public awareness. The protection of natural resources and the mitigation of toxic exposures are not just environmental imperatives; they are essential pillars of peace, stability, and national resilience. By confronting environmental toxicity with urgency and strategic foresight, Kenya can secure both the health of its people and the future of its nation.

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