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The Ecological Cost of Post-Disaster Reconstruction: Environmental and Health Risks Associated with Temporary Concrete Plants and the Search for Sustainable Solutions

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Abstract

Post-disaster reconstruction processes generate extraordinary demand for construction materials, often requiring the rapid deployment of temporary industrial production systems. Among these, concrete plants represent critical logistical infrastructure but also significant sources of environmental pressure and public health risk. This study examines the ecological and health implications associated with temporary concrete production facilities operating in accelerated post-disaster rebuilding environments. Focusing on reconstruction conditions observed following the 2023 Kahramanmaraş earthquake sequence in southern Türkiye, the research applies a qualitative documentary-based environmental assessment framework integrating institutional reports, regulatory publications, reconstruction documentation, and established environmental engineering impact pathways. The analysis identifies key environmental exposure mechanisms, including particulate emissions, transport-related dust dispersion, slurry discharge risks, noise pollution, and intensive water and energy consumption, all of which collectively generate cumulative ecological and public health pressures in already fragile post-disaster landscapes. The findings demonstrate that reconstruction speed, regulatory flexibility, and emergency industrial siting practices can structurally amplify environmental risks unless supported by integrated governance controls. The study proposes a sustainability-oriented reconstruction management framework emphasizing strengthened environmental assessment procedures, controlled industrial siting, adoption of green production technologies, circular material recovery strategies, and community-level monitoring mechanisms. By conceptualizing temporary concrete production systems as environmental governance nodes rather than purely technical facilities, the research contributes a transferable analytical framework for managing ecological risks in large-scale disaster reconstruction contexts worldwide. Rather than interpreting post-disaster concrete production as a purely technical construction necessity, this study conceptualizes temporary concrete plants as critical environmental governance nodes and provides a transferable analytical framework for managing ecological and public health risks in accelerated reconstruction systems worldwide.

Keywords: post-disaster reconstruction; concrete plants; environmental impact; public health; sustainability; circular economy; Turkey

1. Introduction

Post-disaster reconstruction is widely regarded as a cornerstone of social resilience and economic recovery; however, the environmental burden associated with the production and deployment of construction materials in such contexts is frequently underestimated [1]. Among these materials, concrete represents the dominant structural component of rapid rebuilding programs, and the sudden surge in demand typically leads to the intensive installation of temporary concrete production plants. As observed in Türkiye following the 2023 Kahramanmaraş earthquakes, the expansion of concrete production capacity is therefore not merely a technical response to construction needs but also a critical operational issue with direct implications for environmental sustainability, public health, and regional land-use management.

Post-earthquake reconstruction in southern Türkiye has unfolded within an environmentally sensitive regional landscape characterized by protected natural areas, wetlands, forest ecosystems, wildlife conservation zones, and major river basins. Pre-disaster environmental assessments had already identified several affected provinces as experiencing significant pollution pressures, including air-quality degradation linked to industrial activity, localized water contamination risks, and solid-waste management challenges. Although comprehensive quantitative ecosystem-impact measurements following the earthquake remain limited, the scale of structural collapse and debris generation inevitably creates risks for soil stability, hydrological systems, and ecological functions such as water retention and carbon storage. Moreover, the vast volume of demolition waste generated by the disaster—containing hazardous construction materials including chemical insulation compounds, plastic derivatives, and asbestos—substantially increases environmental management complexity during the reconstruction phase. These baseline ecological vulnerabilities underscore the need to evaluate not only the speed of rebuilding but also the environmental operational footprint of emergency construction infrastructure, particularly rapidly deployed concrete production facilities. Recent independent environmental monitoring initiatives conducted in the earthquake region have also documented a rapid expansion of ready-mixed concrete production facilities following the 2023 disaster, accompanied by growing concerns regarding sustained particulate emissions and localized air-quality deterioration during the reconstruction period. Such observations further underline the necessity of examining reconstruction-related industrial infrastructure as a key environmental management issue rather than a purely logistical necessity [37].

The urgency of restoring housing and infrastructure in disaster-affected regions frequently creates institutional pressure to prioritize reconstruction speed over environmental safeguards [2]. While such prioritization may be unavoidable in the short term, it risks generating long-term ecological degradation, public-health exposure, and regulatory management challenges that may ultimately undermine the sustainability of the recovery process itself. Accordingly, this study examines the environmental and health risks associated with temporary post-disaster concrete plants and proposes policy and operational management strategies for more sustainable reconstruction practices. Specifically, the study addresses the following research questions:

(1) What multidimensional environmental impacts emerge from temporary concrete plants established during post-disaster reconstruction?

(2) Which regulatory, spatial, and operational policy mechanisms can mitigate these risks while maintaining reconstruction efficiency?

Although the empirical observations discussed in this research are informed by reconstruction dynamics following the 2023 Kahramanmaraş earthquakes, the analytical framework developed here is not restricted to a single geographic case. Large-scale reconstruction environments worldwide typically share comparable logistical pressures, emergency regulatory relaxations, and accelerated construction-material demand [36]. The environmental risk patterns examined in this study are therefore treated as structurally transferable to broader post-disaster rebuilding contexts, supporting the generalizability of the proposed management framework.

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2. Methodology

2.1. Research Design

This study applies a qualitative environmental risk assessment framework to evaluate the environmental and public-health implications of temporary concrete production facilities established during post-disaster reconstruction. The methodological approach is designed to identify systemic environmental exposure pathways emerging from accelerated rebuilding logistics rather than to quantify emissions from a single production facility. Such system-oriented qualitative assessment approaches are widely used in disaster-environment research where reconstruction speed, temporary infrastructure deployment, and regulatory flexibility create complex operational conditions. Similar environmental evaluation frameworks emphasizing lifecycle-oriented assessment and early-stage environmental consideration are increasingly recommended in construction sustainability research [36].

2.2. Temporal Scope of Analysis

The analytical period covers the primary emergency and early reconstruction phases following the February 2023 Kahramanmaraş earthquake sequence and extends through the active rebuilding period between 2023 and 2025. This timeframe corresponds to the period during which large-scale debris removal, emergency housing construction, permanent residential rebuilding, and temporary industrial material-production installations were documented across multiple affected provinces. National reconstruction scale, structural damage distribution, and debris magnitude were verified using official governmental recovery documentation and national disaster assessment reports.

2.3. Geographical Scope

The geographical scope includes major reconstruction zones within the earthquake-affected region of southern Türkiye where intensive rebuilding activity and temporary construction-material production systems were publicly documented (Figure 1) The analysis particularly considers reconstruction dynamics across provinces including Kahramanmaraş, Hatay, Adıyaman, Gaziantep, and Malatya, which experienced severe structural destruction and accelerated rebuilding timelines requiring large-scale concrete supply capacity. These provinces represent high-intensity reconstruction environments characterized by extensive demolition waste, compressed rebuilding schedules, emergency regulatory procedures, and rapid deployment of temporary industrial infrastructure. The geographical focus of the analysis covers the primary earthquake-affected reconstruction corridor in southern Türkiye, where large-scale structural damage and accelerated rebuilding activities were documented (Figure 1).

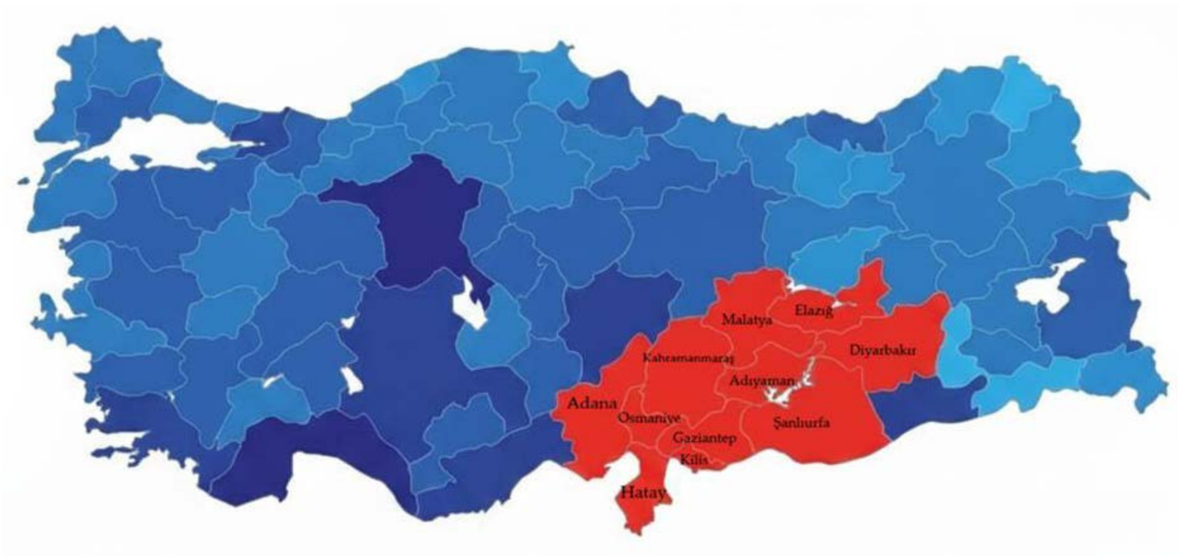

Figure 1. Earthquake-affected reconstruction region in southern Türkiye considered within the geographical scope of this study. Highlighted provinces represent high-intensity rebuilding zones following the February 2023 earthquake sequence.

2.4. Data Sources and Documentary Evidence

The analysis is based on triangulated documentary evidence derived from multiple independent institutional and academic sources, including:

- official governmental earthquake assessment and reconstruction reports
- publications from the Ministry of Environment, Urbanization and Climate Change
- national disaster-management documentation and recovery statistics
- publicly released environmental monitoring statements and regulatory summaries
- municipal reconstruction announcements and infrastructure updates
- peer-reviewed environmental engineering and environmental health literature

Key macro-scale reconstruction indicators, including destruction scale and debris volume estimates, were verified using official national earthquake recovery documentation (e.g., national reconstruction assessment reports issued in 2023).

The documentary evidence reviewed in this study includes officially published post-earthquake reconstruction and environmental assessment materials released by national institutions, including the February 2023 earthquake impact and recovery assessment published by the Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, national reconstruction evaluation documentation issued through the Presidency of Strategy and Budget of the Republic of Türkiye, publicly available disaster coordination briefings, and institutional environmental management publications addressing debris handling, reconstruction logistics, and environmental monitoring procedures during the 2023–2025 rebuilding period. These institutional publications were examined alongside regulatory documents, publicly released monitoring summaries, and peer-reviewed environmental health literature in order to identify recurring operational environmental exposure pathways associated with temporary concrete production systems.

2.5. Environmental Risk Identification Procedure

Documented reconstruction logistics, institutional environmental risk statements, and publicly reported operational characteristics of temporary construction infrastructure were systematically reviewed in order to identify recurring environmental exposure pathways associated with emergency concrete production systems.

Particular analytical attention was given to:

- particulate emissions from cement transfer and aggregate handling
- airborne dust dispersion generated by heavy vehicle circulation
- uncontrolled aggregate storage and site layout compression
- slurry discharge and sediment runoff risks
- temporary land-use allocation practices near residential zones
- cumulative pollution pressures emerging during high-demand reconstruction phases

Rather than relying on isolated anecdotal observations, these risk pathways were interpreted through established environmental impact assessment principles, construction sustainability frameworks, and emission pathway models widely recognized in environmental engineering research.

2.6. Analytical Strategy and Reliability

To ensure methodological robustness despite the operational constraints typical of post-disaster environments, the study adopts a documentary triangulation strategy integrating multiple independent evidence streams.

Post-disaster reconstruction zones frequently involve:

- restricted industrial site accessibility
- rapidly changing construction logistics
- temporary regulatory relaxations
- heterogeneous inspection capacity

These conditions often limit the feasibility of standardized long-duration environmental measurement campaigns. Accordingly, environmental risk identification is based on converging institutional documentation, regulatory publications, reconstruction logistics reports, and established engineering emission models.

This triangulated qualitative assessment approach enables both:

- contextual realism grounded in documented reconstruction operations
- theoretical generalizability across comparable global post-disaster rebuilding contexts

By combining institutional documentation, operational reconstruction evidence, and peer-reviewed environmental risk frameworks, the study ensures methodological transparency, analytical defensibility, and structural transferability of findings.

3. Results

3.1. Earthquake Damage and Reconstruction Demand

The scale of structural destruction following the 2023 Kahramanmaraş earthquakes created an unprecedented reconstruction demand across the affected region. Official assessments reported more than 35,000 collapsed buildings, alongside nearly 180,000 heavily damaged and over 40,000 moderately damaged structures requiring demolition and rebuilding. In total, reconstruction-related intervention was projected for over 800,000 independent housing and commercial units. The total volume of construction and demolition debris generated by the disaster was estimated at approximately 100–120 million cubic meters. Such extensive structural loss inevitably produced extraordinary demand for construction materials, particularly concrete, thereby accelerating the rapid establishment of temporary concrete production facilities throughout the reconstruction zone [34].

3.2. The Increased Role of Concrete Plants After Disasters and

Administrative Weaknesses

Disasters necessitate extraordinary construction activity due to the destruction they cause to the building stock. In this process, concrete stands out as an indispensable material due to its advantages in cost, accessibility, and mechanical durability [3]. However, the prioritization of "speed" over all else in an environment of urgent need leads to the unplanned and intensive deployment of temporary concrete plants. This situation brings with it a series of administrative weaknesses.

The "emergency" exceptions in Environmental Impact Assessment (EIA) regulations can become almost a general rule in disaster areas, resulting in the substantial omission of strategic site selection, public health risk assessment, and ecological footprint analyses required for plant installation. Numerous temporary concrete production facilities were established throughout the reconstruction region in order to meet the urgent material demand generated by large-scale post-disaster rebuilding activities [4].

The weakening of inspection mechanisms constitutes another critical problem. The chaotic environment in disaster areas exceeds the capacity of environmental inspection teams, and plant operations continue without effective oversight. This enables widespread violations such as filter systems not functioning properly, non-compliance with wastewater management, and exceeding noise limit values. For instance, closed aggregate storage and advanced dust collection systems, which are mandatory for stationary plants, are not used in many temporary plants on grounds of extra cost and time savings. Consequently, an uncontrolled pollution burden on the environment and public health emerges. Released fine dust (PM10) and particulate matter capable of reaching the lungs

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through respiration (PM2.5) spread over wide areas with the wind, reducing air quality to critical levels [5]. Carcinogenic particles such as silica dust from aggregate crushing-screening processes further aggravate this risk. Studies indicate that such plants significantly reduce air quality, especially in urban areas, and increase the long-term risk of respiratory diseases [6]. Furthermore, continuous noise from 24/7 operation cycles functions as an additional psycho-social stressor for a population already traumatized by the earthquake [7]. Elevated particulate matter concentrations have been reported across multiple monitoring stations in the earthquake-affected reconstruction region, indicating sustained airborne pollution pressures during the rebuilding period. As illustrated in Figure 2, PM10 averages in several provincial monitoring locations exceed recommended annual guideline thresholds, highlighting the persistence of post-disaster particulate exposure risks.

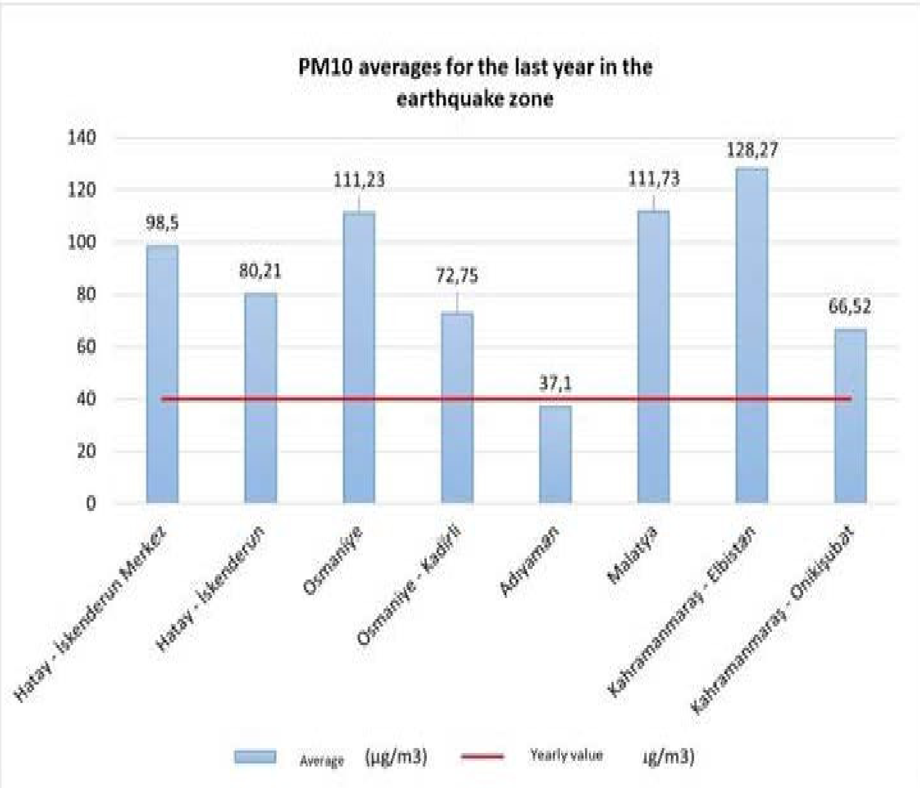

Figure 2. Source: Adapted from publicly reported regional air-quality monitoring data (2023–2024)[37].

From an operational engineering perspective, environmental risks associated with temporary concrete plants are not inevitable consequences of reconstruction speed but largely reflect insufficient implementation of standard mitigation systems. Established industrial control practices—including enclosed aggregate storage units, multi-stage baghouse filtration, automated water-spray dust suppression networks, sedimentation basins for slurry wastewater treatment, and controlled truck-washing platforms—are widely available and technically feasible even within temporary plant configurations. Their systematic integration into emergency construction planning protocols would substantially reduce airborne particulate emissions, wastewater alkalinity discharge, and soil contamination risks without significantly delaying production capacity.

Table 1. Environmental Risk Categories Associated with Temporary Concrete Production Facilities in Post-Disaster Reconstruction Contexts.

Environmental Component	Primary Risk Source	Typical Operational Cause	Potential Impact	Mitigation Measures
Air Quality	Cement dust emission	Aggregate handling, truck loading, mixer discharge	Respiratory exposure, PM concentration increase	Enclosed storage, baghouse filters, water spray systems
Soil Quality	Alkaline slurry discharge	Mixer washout, uncontrolled wastewater release	Soil pH alteration, vegetation damage	Sedimentation basins, controlled wash platforms
Water Resources	Runoff contamination	Improper slurry disposal, open drainage	Surface water turbidity, ecosystem disruption	Wastewater treatment pits, controlled drainage systems
Noise Environment	Heavy truck circulation	Continuous material transport and mixing operations	Community disturbance, chronic exposure risks	Time-restricted logistics, buffer zone planning
Landscape Integrity	Rapid temporary siting	Emergency land allocation without environmental zoning	Visual degradation, land-use conflicts	Temporary zoning control and monitored plant placement

3.3. Multidimensional Environmental Impacts

3.3.1. Air Pollution: Particulate Matter Emissions and Dispersion

The most evident impact of concrete production on air quality is particulate matter (PM) emissions. Significant amounts of fine dust are released during cement production, aggregate (sand, gravel) storage, crushing-screening, and transportation processes. While PM10 particles can accumulate in the upper respiratory tract, the more hazardous PM2.5 and finer particles (<1.0 µm) can penetrate directly into the alveoli and potentially enter systemic circulation [8]. Supporting these concerns, field-based environmental monitoring conducted in Antakya in January 2025 detected average PM10 concentrations exceeding both national regulatory thresholds and World Health Organization guideline values, suggesting that intensive reconstruction logistics and nearby concrete production activities may significantly contribute to elevated airborne particulate exposure in disaster-affected urban zones [37].Crystalline silica dust (SiO_2) released during aggregate processing is classified by the International Agency for Research on Cancer (IARC) as "Carcinogenic to Humans" (Group 1), and long-term exposure can lead to irreversible lung diseases such as silicosis [9]. These particles, transported by wind, not only reduce air quality in residential areas but also clog leaf stomata, reducing photosynthetic efficiency in plants, and adversely affect soil microbiota [10].

3.3.2. Water Pollution: Chemical Contamination and Resource

Consumption

Plant operations entail not only pollution but also intensive resource consumption. Water used for concrete mixing and equipment cleaning becomes wastewater with high levels of suspended solids and high pH values (12-13 levels) [11]. This high alkalinity, when directly discharged into water sources (streams, rivers, groundwater), increases biochemical oxygen demand (BOD), potentially suffocating aquatic life and causing mass mortality of pH-sensitive species. Additionally, heavy metals (such as chromium, cadmium, lead) that leach into or are washed from concrete mixtures risk bioaccumulation in aquatic ecosystems and entry into the food chain [12].

3.3.3. Soil Pollution and Physical Degradation

Dust emissions are transported through the air and accumulate on surrounding soil surfaces. This accumulation alters the physicochemical properties of soil; it reduces porosity and water infiltration capacity, impairing soil fertility and structure [13]. Fine particles accumulating particularly on agricultural lands can lead to loss of permeability and desertification. The alkaline conditions created by wastewater raise soil pH, inhibiting the uptake of nutrients (phosphorus, iron, zinc, manganese, etc.) and causing nutrient deficiency and phytotoxicity in plants [14].

3.3.4. Noise Pollution: Physiological and Psychological Effects

Continuous operation cycles create persistent noise pollution from aggregate crushers, mixers, and transport vehicles. This noise is not merely an environmental problem but a proven public health risk. The World Health Organization (WHO) states that long-term exposure to noise above 55 dB increases the risk of cardiovascular disease [15]. In disaster areas, where these levels are significantly exceeded, it becomes a triggering factor for hypertension, ischemic heart disease, and sleep disorders. Particularly for individuals experiencing post-traumatic stress disorder, continuous noise functions as a chronic stressor that delays psychological recovery [16].

3.3.5. Cross-Ecosystem Interactions (Cumulative Impact)

These effects are not independent of each other. Airborne particles eventually mix into water and soil systems. Water pollution affects soil quality and groundwater reserves. This cumulative and mutually reinforcing effect creates long-lasting, difficult-to-repair pressure on local ecosystems already vulnerable after disasters [17]. The potential threat posed by plants established after the 2023 Kahramanmaraş earthquakes to the region's agricultural productivity and water resources is a concrete manifestation of this multidimensional impact.

3.4. Direct and Indirect Effects on Public Health

The pollution caused by concrete plants creates multi-layered effects on public health, both direct (acute) and indirect (chronic and social). These effects further disadvantage the health status of a population already fragile after disaster, undermining society's overall recovery capacity [18].

3.4.1. Direct Physiological Effects: Respiratory and Cardiovascular

Systems

Particulate matter (PM) exposure constitutes the most evident and well-documented direct health risk. Chronic PM2.5 exposure penetrates deep into the alveoli, triggering a systemic inflammatory response. This not only increases the prevalence and severity of respiratory diseases such as asthma, bronchitis, and COPD [19] but can also lead to irreversible deterioration in respiratory functions. Exposure to crystalline silica (SiO_2) from aggregate processing is a direct causal factor for fibrotic lung diseases such as silicosis and is classified as a Group 1 human carcinogen by IARC [9].

These physiological effects are not limited to the respiratory system. Systemic inflammation accelerates endothelial dysfunction and atherosclerosis, targeting the cardiovascular system as well. Increased diesel exhaust emissions and continuous noise pollution from plants elevate sympathetic nervous system activity and stress hormone (cortisol) levels, significantly increasing the risk of hypertension, ischemic heart disease, and myocardial infarction [20]. Noise-induced sleep disruption leads to disturbances in glucocorticoid rhythm, further exacerbating these cardiometabolic risks.

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3.4.2. Indirect Effects: Psychosocial and Socio-Economic Burdens

Health effects extend beyond pathophysiology, leaving deep marks on individuals' mental health and social welfare. Field studies reveal that in areas near concrete plants—particularly among individuals living within a 500-meter impact radius—general quality of life and mental health indicators significantly decline [21]. Exposure to continuous noise, dust, and heavy vehicle traffic leads to learned helplessness and environmental stress. This exacerbates conditions commonly seen after disasters, such as Post-Traumatic Stress Disorder (PTSD), depression, and anxiety, disrupting the psychological recovery process [22].

Another dimension of indirect effects is socio-economic. Decreased agricultural productivity due to air pollution and water contamination threatens local livelihoods, bringing food security problems [23]. The increased burden of respiratory and cardiovascular diseases raises healthcare expenditures at both individual and societal levels and reduces labor productivity. This further complicates the recovery of a local economy already shaken by disaster [24]. The effects of concrete plants on public health transcend being a simple matter of environmental pollution, becoming a structural obstacle to post-disaster social resilience. This compound risk, emerging at the intersection of physical illness, psychological trauma, and socio-economic decline, clearly demonstrates that public health interventions in disaster areas must be addressed integratively with environmental and social policies, not merely medical ones.

4. Discussion

The findings of this study should be interpreted not solely as a localized environmental observation but as an illustration of structural governance challenges inherent to accelerated reconstruction systems. Post-disaster rebuilding environments typically operate under compressed timelines, regulatory flexibility, and extraordinary material demand, conditions that collectively reshape industrial siting practices and environmental oversight capacity. Within this systemic context, temporary concrete production facilities function as critical logistical nodes whose environmental performance directly influences both ecological recovery trajectories and long-term public health stability.

Our findings reveal a fundamental tension in post-disaster reconstruction: the imperative for rapid rebuilding conflicts with the need for environmental protection and public health preservation. This tension is particularly acute in the case of concrete plants, which, while essential for reconstruction, generate significant negative externalities that are often overlooked in emergency situations. To analytically operationalize this governance tension across reconstruction timelines, the rebuilding process may be structured into sequential operational phases characterized by distinct material demand intensity, temporary plant density, and environmental monitoring capacity, as summarized in Table 2.

Table 2. Reconstruction Phases and Corresponding Environmental Risk Intensities.

Reconstruction Phase	Concrete Demand Level	Temporary Plant Density	Environmental Monitoring Capacity	Expected Environmental Risk Level
Emergency Response Phase	Extremely high	Very high	Low	Critical
Early Reconstruction Phase	High	High	Medium	High
Stabilization Phase	Moderate	Moderate	Improved	Medium
Long-Term Urban Redevelopment	Normalized	Low	Institutionalized	Controlled

The administrative weaknesses identified in this study—particularly the circumvention of EIA procedures and weakened inspection mechanisms—are consistent with broader critiques of disaster

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governance [25]. When "emergency" exceptions become the norm, they create pathways for environmental degradation that may have long-lasting consequences. The situation observed in Kahramanmaraş is not unique to Turkey; similar patterns have been documented following earthquakes in Haiti [26], Nepal [27], and Indonesia [28], suggesting a systemic problem in post-disaster reconstruction governance. Institutional reconstruction assessments further indicate that numerous temporary concrete plant projects approved in the earthquake region during the 2023–2025 rebuilding period received expedited environmental clearance decisions categorized as "EIA not required", highlighting structural challenges in maintaining standard environmental screening procedures under emergency reconstruction pressures [37]

From an engineering and built-environment management perspective, the environmental risks observed in rapid reconstruction contexts are not solely regulatory issues but also design and operational control challenges. Temporary concrete production systems require structured dust suppression mechanisms, controlled aggregate storage layouts, sedimentation management for slurry discharge, and monitored transport logistics in order to minimize airborne particulate release and soil contamination. Incorporating such technical mitigation measures into emergency construction planning frameworks would significantly reduce the ecological footprint of accelerated rebuilding operations while maintaining production efficiency.

The multidimensional environmental impacts documented here—affecting air, water, soil, and acoustic environments—create cumulative pressures on ecosystems that are already stressed by the disaster itself. This compound effect is particularly concerning because it may undermine the very goal of sustainable reconstruction. As Berke and Campanella [29] argue, true recovery requires not only rebuilding physical structures but also restoring and enhancing environmental quality and community well-being.

The public health consequences identified in this study deserve particular attention. The direct physiological effects—respiratory and cardiovascular diseases—are well-documented in the environmental health literature [30]. However, the indirect psychosocial and socio-economic effects are often underestimated in post-disaster planning. Our findings suggest that the pollution from concrete plants creates an additional burden on populations already coping with trauma, potentially slowing psychological recovery and exacerbating existing mental health conditions. This aligns with emerging research on "compound disasters" and the importance of addressing multiple stressors in post-disaster contexts [31].

The policy recommendations developed in this study—strategic site selection with expedited but comprehensive EIA, mandatory green technologies, promotion of circular economy approaches, and community participation—represent a balanced approach that acknowledges the urgency of reconstruction while safeguarding environmental and public health. These recommendations align with broader calls for "building back better" [32] and the principles of sustainable development [33,35].

Environmental governance considerations further indicate that post-disaster reconstruction must extend beyond rapid structural replacement and incorporate ecosystem recovery strategies. Evidence from the affected earthquake region demonstrates that large-scale demolition debris may contain hazardous construction materials, including asbestos-based insulation, chemical compounds, and plastic derivatives, which pose risks to soil systems, surface waters, and groundwater reserves if not properly managed. Effective environmental management therefore requires a phased intervention framework. In the short term, priority actions include the identification of hazardous debris zones, monitoring of contaminated surface and groundwater systems, and the secure disposal of construction waste outside agricultural land and drinking-water catchments. Medium-term recovery strategies should focus on stabilizing erosion-prone slopes, rehabilitating damaged wetlands and protected ecosystems, strengthening land-use restrictions around vulnerable water resources, and promoting large-scale recycling of demolition materials. In the long term, reconstruction policies should explicitly integrate ecosystem restoration into rebuilding programs, including habitat recovery initiatives, biodiversity protection measures, and landscape-scale

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environmental monitoring systems. Such integration ensures that reconstruction activities do not merely restore built infrastructure but also enhance ecological resilience and environmental sustainability in disaster-affected regions.

5. Conclusions

Post-disaster reconstruction inevitably requires large-scale material production, and temporary concrete plants therefore become operationally indispensable components of recovery systems. However, the findings of this study demonstrate that the environmental and public-health risks associated with these facilities represent not incidental side effects but structural governance challenges embedded within accelerated rebuilding processes. When reconstruction systems prioritize speed without integrating environmental safeguards, cumulative impacts on air quality, water systems, soil integrity, and community well-being may significantly undermine long-term recovery outcomes.

Accordingly, sustainable post-disaster reconstruction must extend beyond resilient building design and urban planning to include the environmental governance of industrial supply infrastructures. Temporary concrete production facilities should therefore be treated not merely as logistical necessities but as strategic environmental management units requiring structured siting controls, emission-reduction technologies, and continuous monitoring frameworks. Embedding such safeguards within emergency construction governance systems represents a critical step toward aligning rapid rebuilding objectives with long-term ecological resilience and public-health protection.

5.1. Policy and Implementation Recommendations

Based on our findings, we propose the following recommendations for policymakers, disaster management agencies, and reconstruction planners:

Strategic Site Selection and Expedited EIA: A rapid but comprehensive Environmental Impact Assessment (EIA) protocol, specifically designed for post-disaster situations, should be implemented. This protocol must absolutely determine the distance of temporary plants from residential areas, agricultural lands, and water resources, and mandate their establishment in designated industrial zones away from these areas. Pre-identified sites for temporary industrial activities should be incorporated into disaster preparedness plans.

Green Technology and Inspection Mandate: The use of state-of-the-art dust suppression, closed-circuit water use, and energy efficiency technologies should be made a legal requirement for temporary plants. The environmental performance of these plants should be continuously and transparently monitored and inspected by relevant ministries and municipalities. Remote sensing and real-time monitoring technologies could enhance inspection capacity in chaotic post-disaster environments.

Promotion of Circular Economy and Alternative Materials: Circular economy principles should be placed at the center of reconstruction. Government incentive mechanisms should be established for using recycled disaster debris as aggregate, widespread use of cement substitute materials (e.g., fly ash, slag), and alternatives such as low-carbon footprint green concrete. This approach simultaneously addresses waste management and reduces demand for virgin materials.

Community Participation and Transparency: Plant siting decisions, monitoring data, and inspection results should be shared transparently with affected communities. Accessible mechanisms should be established for public complaints and suggestions, ensuring community participation. Local knowledge can contribute to identifying sensitive areas and monitoring environmental violations.

Capacity Building for Inspectors: Environmental inspection agencies should receive specific training and resources for post-disaster situations, including protocols for rapid assessment and enforcement in challenging conditions.

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5.2. Recommendations for Future Research

Future studies should focus on:

Creating specific emission inventories for concrete plants in disaster areas and correlating them with real-time air quality data.

Conducting longitudinal health studies in exposed communities to document long-term health outcomes.

Developing and assessing the feasibility of mobile, low-impact concrete plant prototypes powered by renewable energy sources.

Comparative studies examining different governance approaches to post-disaster industrial siting across countries.

Economic valuation of the environmental and health externalities of temporary concrete plants to inform cost-benefit analyses in reconstruction planning.

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