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Review Article

Beyond the Blueprint: Dermatological and Systemic Implications of Cement Exposure in Gloveless Construction Workers

Mahin Jamil[1], Zeenat Khan[2]* and Daud Khan[3]

[1]Department of Civil Engineering, University of Engineering and Technology (UET), Pakistan

[2]Department of Bioinformatics and Biosciences, Capital University of Science & Technology, Pakistan

[3]Department of Civil Engineering, Capital University of Science & Technology, Pakistan

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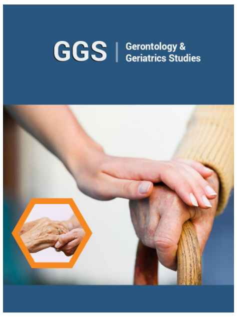

***Corresponding authors:** Zeenat Khan, Department of Bioinformatics and Biosciences, Capital University of Science & Technology, Islamabad, Pakistan

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Abstract

Cement, a cornerstone of modern construction, carries hidden occupational hazards that extend far beyond its structural role. Workers handling cement without protective gloves are exposed to its highly alkaline and chemically complex nature, leading to a cascade of dermatological and systemic effects. Direct skin contact precipitates irritant and allergic dermatitis, chemical burns, chronic eczema and hyperkeratosis, with hexavalent chromium and trace metals acting as potent sensitizers that amplify immune responses. Beyond the skin, cement dust inhalation and accidental ingestion trigger systemic biochemical perturbations, including oxidative stress, depletion of antioxidant defenses, elevated liver and kidney enzymes and activation of inflammatory pathways. The resulting multi-organ impact underscores cement as a silent but pervasive occupational toxin. Epidemiological and toxicological studies reveal widespread prevalence of skin disorders and biochemical disruptions among exposed construction workers, highlighting an urgent need for innovative protective strategies. Implementation of high-quality personal protective equipment, chromium-reduced cement formulations, workplace ventilation and biomarker-based health surveillance can mitigate these risks. Future research must integrate mechanistic, longitudinal and socio-economic perspectives to elucidate dose-response relationships, cumulative effects and molecular pathways of toxicity. By reframing cement not just as a building material but as a bioactive occupational hazard, this review emphasizes the critical intersection of industrial practice, human health and material innovation, advocating for science-driven protective measures that safeguard worker well-being in construction environments.

Keywords: Cement dust; Occupational toxicity; Dermatitis; Oxidative stress; Heavy metal exposure

Highlights

A. Cement acts as both a structural material and a hidden occupational toxin with dermatological and systemic impacts.

B. Hexavalent chromium and trace metals drive oxidative stress, immune sensitization and multi-organ dysfunction.

C. Innovative prevention including chromium-reduced cement, PPE and biomarker monitoring is essential for worker safety.

Introduction

Cement, a fundamental material in the construction industry, is chemically complex, comprising major oxides such as calcium oxide, silicon dioxide, aluminum oxide, iron oxide and magnesium oxide, along with secondary compounds like sulfur trioxide and trace alkali oxides [1]. Upon hydration, these constituents create a highly alkaline environment, primarily due to calcium hydroxide formation, which can disrupt the skin's natural protective barrier [2]. Additionally, trace metals including chromium, nickel, cobalt, selenium, thallium and lead, either inherent in raw materials or introduced during manufacturing, elevate the potential for toxic and allergenic reactions [3]. Prolonged dermal exposure, especially among workers who handle cement without gloves or protective clothing, can result in irritant and allergic contact dermatitis, chemical burns, chronic eczema and systemic inflammatory responses [4]. The combination of chemical reactivity, alkalinity and abrasive particles underscores cement as a significant occupational hazard, highlighting the critical need for awareness and preventive safety measures in construction environments [5].

Construction workers are frequently exposed to cement, which poses significant dermatological hazards due to its highly alkaline nature, abrasive particles and sensitizing metals such as chromium and cobalt [6]. Direct contact, particularly with wet cement and in the absence of protective equipment, can lead to a spectrum of skin disorders ranging from mild irritation, dryness and scaling to severe conditions including irritant and allergic contact dermatitis, chemical burns and chronic hyperkeratosis [7]. Repeated exposure disrupts the skin barrier, increases trans epidermal water loss and facilitates deeper penetration of toxic compounds, thereby predisposing workers to persistent inflammation, secondary infections and long-term sensitization [8]. Epidemiological studies consistently demonstrate that hands, forearms and lower limbs are the most affected sites and chronic exposure can compromise both occupational performance and quality of life [9]. These observations underscore the need for preventive strategies, including protective clothing, hygiene practices and workplace interventions, as well as heightened awareness of cement-related dermatological risks in occupational health planning [10].

Exposure to cement dust poses significant biochemical and cellular risks due to its complex composition, including toxic elements such as chromium, cadmium, lead, nickel, cobalt and fine mineral oxides [11]. Inhalation, dermal contact, or ingestion of cement dust can lead to systemic absorption and bioaccumulation of these substances in organs including the liver, kidneys and lungs, disrupting normal cellular metabolism [12]. Occupational studies have demonstrated that prolonged exposure induces oxidative stress, evidenced by elevated reactive oxygen species and lipid peroxidation, depletion of antioxidant defenses and activation of inflammatory pathways [13]. These biochemical disturbances manifest as elevated liver and kidney enzymes, impaired renal function and chronic inflammatory responses, while heavy metals such as hexavalent chromium can trigger immune sensitization, DNA damage and carcinogenic effects [14]. Additionally, cement's alkaline and abrasive nature compromises skin barrier integrity, facilitating further penetration of toxic compounds and increasing susceptibility to dermatitis and secondary infections [15]. Collectively, these findings highlight the multi-systemic toxic potential of cement dust and underscore the critical need for protective measures, occupational monitoring and regulatory strategies to mitigate health risks in construction environments [16].

Prolonged exposure to cement, especially among construction workers who do not use protective gloves, constitutes a significant occupational health concern with both dermatological and systemic implications [17]. Cement dust, rich in alkaline compounds and trace heavy metals such as hexavalent chromium, can cause irritant and allergic contact dermatitis, eczema, chemical burns and chronic skin disorders, while also promoting systemic biochemical disturbances, including oxidative stress and impaired antioxidant defenses [18]. Epidemiological evidence indicates that a considerable proportion of workers experience work-related skin diseases, underscoring the widespread nature of this hazard [19]. Effective risk reduction depends on consistent use of personal protective equipment, adherence to hygiene protocols, proper workplace ventilation, material substitution and regular health monitoring, yet these measures are often inconsistently applied [20]. Future research should emphasize longitudinal and mechanistic studies to clarify dose-response relationships, investigate innovative cement formulations or chromium-reduced alternatives and explore molecular pathways underlying toxicity, while also addressing socio-economic barriers to occupational safety [21]. Such integrated efforts are essential to protect workers' health and translate scientific findings into practical preventive strategies [22].

Chemical Composition of Cement and Potential Skin Hazards

Cement used in the construction industry is a chemically complex material composed of multiple mineral oxides and trace elements that can exert significant effects on human skin upon prolonged exposure [23]. The primary constituents of cement include calcium oxide, silicon dioxide, aluminum trioxide, ferric oxide and magnesium oxide, which collectively contribute to the structural and binding properties of the material (Table 1) [24]. When cement is mixed with water during construction processes, these compounds undergo hydration reactions that produce a highly alkaline environment [25]. The elevated alkalinity, primarily due to calcium hydroxide formation, can disrupt the natural protective barrier of the skin [26]. Continuous exposure to wet cement therefore causes irritation and dryness by damaging the lipid layer that maintains skin hydration [27]. In addition to the major oxides, cement also contains trace elements and impurities such as chromium, nickel, cobalt, selenium, thallium and lead [28]. These metals are introduced either naturally from raw materials such as limestone and clay or during the manufacturing process [29]. The presence of such elements increases the potential for toxic interactions with human tissues [30]. In occupational settings, workers frequently come into direct contact with cement while mixing, pouring, or finishing concrete, allowing these chemical constituents to interact directly with exposed skin surfaces [31]. Prolonged dermal exposure is particularly common in situations where workers do not use protective equipment such as gloves or protective clothing [32]. Repeated contact can gradually weaken the epidermal barrier, making the skin more susceptible to irritation and chemical penetration [33]. As a result, the complex chemical composition of cement represents a significant occupational hazard that can lead to both immediate and long-term dermatological effects in construction workers [34,35].

Table 1: Chemical composition and typical oxide content ranges of Portland cement used in construction materials [24,35].

Component Category	Chemical Constituent	Chemical Formula	Typical Composition Range (%)	Functional Role in Cement
Major Oxide	Lime	CaO	60-65	Responsible for strength development and formation of calcium silicates during hydration
Major Oxide	Silica	SiO_2	17-25	Contributes to strength and durability through formation of calcium silicate hydrates
Minor Oxide	Alumina	Al_2O_3	3.0-7.5	Influences setting time and contributes to early strength development
Minor Oxide	Iron Oxide	Fe_2O_3	0.5-6	Provides color and participates in formation of ferrite phases
Minor Oxide	Magnesium Oxide	MgO	0.1-4	Affects soundness and volume stability when present in controlled amounts
Secondary Compound	Sulphur Trioxide	SO_3	1.3-3	Regulates setting time through gypsum interaction
Alkali Oxides	Potassium and Sodium Oxides	K_2O, Na_2O	0.4-1.3	Influence alkali–aggregate reactions and overall chemical reactivity

The interaction between cement constituents and the skin can lead to a variety of dermatological conditions ranging from mild irritation to severe inflammatory responses [36]. Wet cement is strongly alkaline and can produce irritant contact dermatitis through prolonged exposure, particularly when it remains trapped against the skin under clothing or footwear [37]. The abrasive nature of sand particles in cement mixtures further exacerbates this effect by mechanically damaging the skin surface, allowing chemical components to penetrate deeper layers [38]. Among the trace elements present in cement, chromium is recognized as one of the most potent sensitizing agents capable of inducing allergic contact dermatitis [39]. Sensitization occurs when repeated exposure triggers an immune response that results in persistent itching, redness, swelling and scaling of the skin [40]. In addition to chromium, metals such as cobalt and nickel can also contribute to hypersensitivity reactions and chronic eczema in exposed individuals [41]. Workers who regularly handle cement without protective barriers often develop symptoms including dryness, fissuring, pruritus and erythema, particularly on the hands and forearms [42]. In more severe cases, prolonged exposure to highly alkaline cement can cause chemical burns that damage deeper skin tissues and lead to ulceration or permanent scarring [43]. The accumulation of heavy metals within the skin may also contribute to chronic dermatological disorders and systemic inflammatory responses [44]. Over time, these chemical interactions can impair the natural regenerative capacity of the skin and increase susceptibility to secondary infections [45].

Dermatological Effects of Cement Exposure

Dermatological disorders represent one of the most frequently reported occupational health problems among workers in the construction and cement industries [46]. Continuous contact with cement, particularly in its wet form, exposes workers to highly alkaline compounds, abrasive particles and sensitizing metals that can damage the skin barrier and initiate inflammatory responses [47]. Cement handling tasks such as mixing, transporting, pouring and finishing concrete frequently involve direct dermal contact, especially in situations where personal protective equipment is not consistently used [48]. The chemical composition of cement, which includes calcium oxide, silica, aluminum compounds and trace metals such as chromium and cobalt, contributes to a variety of dermatological reactions [49]. These reactions range from mild skin irritation and dryness to severe allergic dermatitis and chemical burns [50]. The hands, forearms and lower limbs are the most commonly affected areas because these body parts are directly exposed during construction activities [51]. Workers in cement manufacturing plants, cement transport operations and construction sites are therefore at a heightened risk of developing skin disorders associated with occupational exposure [52].

The prevalence and severity of cement-related dermatological conditions depend on several factors including duration of exposure, concentration of chemical components, environmental conditions and individual susceptibility [53]. Prolonged exposure to wet cement can disrupt the natural protective barrier of the skin, increasing its permeability and making it more vulnerable to irritants and allergens [54]. In addition, abrasive particles present in cement mixtures can cause microtrauma to the skin, facilitating deeper penetration of harmful substances [55]. Epidemiological observations from different occupational settings indicate that irritant contact dermatitis, allergic contact dermatitis and chemical burns are among the most common skin disorders associated with cement exposure [56]. Chronic dermatological conditions such as fissured skin, hyperkeratosis and secondary infections may also develop after repeated exposure [57]. The evidence from occupational health studies demonstrates that dermatological effects are not only common but can significantly impact workers' productivity, quality of life and long-term health outcomes [58]. Table 2 summarizes selected observational studies and surveillance reports describing dermatological outcomes associated with cement exposure in occupational environments [59].

Table 2: Selected studies reporting dermatological effects of cement exposure in workers.

Study Context / Location	Sample Size / Population	Key Findings	Dermatological Outcome	Ref.
Patch testing surveillance of dermatology patients	4846 patients tested	146 individuals (3%) showed chromate sensitivity; 31.5% had occupational allergic contact dermatitis and 59% of these were linked to cement exposure	Allergic contact dermatitis caused by chromate in cement	[27]
Occupational exposure assessment among cement workers	108 cement workers	Higher urinary chromium levels correlated with increased transepidermal water loss indicating impaired skin barrier function	Skin barrier disruption and increased susceptibility to dermatitis	[49]
Tunnel construction surveillance program	1138 workers assessed; 466 cement grouters	332 workers diagnosed with occupational dermatitis; 65% of tested grouters showed chromate allergy	Occupational dermatitis related to cement exposure	[53]
Occupational dermatology study in construction workers	Construction laborers exposed to wet cement	Hand eczema observed in nearly 88.9% of chromate-sensitive workers	Chronic hand dermatitis	[31]
Cement factory dermatological study	Cement factory workers	3.7% incidence of occupational dermatosis; majority cases related to cement exposure	Dermatitis and chronic skin irritation	[58]
Occupational health observation among construction workers	Workers handling cement	7.8% developed irritant contact dermatitis and 4.3% developed contact dermatitis	Irritant and allergic dermatitis	[43]

Irritant Contact Dermatitis

Irritant contact dermatitis is widely recognized as one of the most common dermatological conditions affecting workers exposed to cement in occupational settings [60]. The primary mechanism underlying this condition is the highly alkaline nature of wet cement, which can reach a pH level close to 12 during hydration reactions [61]. Such alkalinity disrupts the natural lipid barrier of the skin and leads to direct chemical irritation of the epidermal layer [62]. Workers frequently come into contact with cement while mixing or applying concrete and prolonged dermal exposure allows alkaline compounds to penetrate the skin surface [63]. This penetration results in inflammation characterized by redness, dryness, itching and burning sensations [64]. Mechanical abrasion caused by sand particles in cement mixtures can further aggravate the condition by producing micro-injuries that increase the permeability of the skin barrier [65]. In many occupational environments, irritant dermatitis develops gradually after repeated contact with cement without adequate protective equipment [66]. Environmental conditions such as moisture, sweating and prolonged working hours can also intensify skin irritation [67].

The progression of irritant contact dermatitis often begins with mild symptoms but can evolve into more severe dermatological complications if exposure continues [68]. Initial manifestations typically include dryness and erythema, followed by scaling, fissuring and increased sensitivity of the affected skin areas [69]. Over time, repeated chemical irritation can weaken the epidermal barrier and increase trans epidermal water loss, indicating impaired skin integrity [70]. Occupational studies have demonstrated that workers exposed to cement frequently exhibit signs of compromised skin barrier function, which predisposes them to further irritation and inflammation [71]. The hands are the most commonly affected region due to direct contact with wet cement mixtures during manual work tasks [72]. In addition to discomfort and pain, persistent irritant dermatitis can reduce manual dexterity and limit a worker's ability to perform routine construction activities [73]. Secondary infections may also occur when cracks or fissures in the skin allow microorganisms to enter deeper tissues [74]. Without proper protective measures and medical management, irritant dermatitis may progress into chronic dermatological disease [75]. These outcomes emphasize the importance of preventive strategies such as protective gloves, improved hygiene practices and education about the risks of cement exposure [76].

Allergic Contact Dermatitis

Allergic contact dermatitis associated with cement exposure occurs primarily due to sensitization to hexavalent chromium compounds present in cement [77]. Chromium is widely recognized as one of the most potent allergens encountered in occupational environments and repeated dermal exposure can trigger immune-mediated hypersensitivity reactions [78]. Unlike irritant dermatitis, which results from direct chemical damage, allergic dermatitis develops when the immune system becomes sensitized to chromium ions that penetrate the skin barrier [79]. Once sensitization occurs, even minimal exposure to chromium-containing cement can provoke a strong inflammatory response [80]. Workers handling cement without gloves or protective clothing are particularly vulnerable because wet cement facilitates the release and penetration of chromium compounds into the skin [81]. Clinical symptoms often include itching, redness, swelling and eczema-like lesions, which frequently appear on the hands and forearms [82]. Occupational health investigations have shown that chromate sensitivity represents a significant proportion of cement-related dermatological disorders among construction workers [83].

The long-term consequences of allergic contact dermatitis can be substantial because sensitization to chromium often persists even after exposure has been reduced [84]. Once the immune system becomes sensitized, workers may experience recurring episodes of eczema whenever they come into contact with chromium-containing materials [85]. This persistent hypersensitivity can lead to chronic dermatitis characterized by itching, inflammation and scaling of the skin [86]. In some occupational settings, workers who develop severe allergic reactions may need to change their job roles or avoid cement exposure entirely [87]. However, symptoms may still continue due to previous sensitization or accidental exposure to chromium in other materials [88]. Clinical observations indicate that allergic dermatitis can significantly affect the quality of life of affected workers by causing discomfort, sleep disturbances and reduced work performance [89]. Additionally, co-sensitization with other metals such as cobalt has been reported in workers exposed to cement, further complicating the clinical condition [46]. Preventive strategies such as reducing the concentration of hexavalent chromium in cement through chemical treatment have been introduced in some regions to minimize sensitization risk [47].

Cement Burns and Skin Ulceration

Cement burns are severe dermatological injuries that occur when wet cement remains in prolonged contact with the skin, resulting in chemical damage caused by highly alkaline compounds [48]. The hydration of cement generates calcium hydroxide, which produces a strongly alkaline environment capable of damaging skin tissues through chemical corrosion [49]. Workers performing tasks such as kneeling in wet concrete, handling cement mixtures, or working with soaked clothing are particularly susceptible to these injuries [50]. Unlike thermal burns, cement burns develop gradually and may not cause immediate pain, which often leads to delayed recognition of the injury [51]. Initial symptoms typically include mild irritation, redness and a burning sensation that may appear several hours after exposure [52].

If contact continues, alkaline substances penetrate deeper layers of the skin and cause progressive tissue damage [53]. The abrasive properties of cement mixtures, which contain sand and other particulate materials, can also damage the skin surface and facilitate deeper penetration of corrosive chemicals [54]. As a result, the injury can progress from superficial irritation to deeper ulceration [55]. Cement burns therefore represent a serious occupational hazard for construction workers who frequently come into contact with wet concrete during their daily tasks [56]. The clinical progression of cement burns may lead to severe skin damage if exposure is not promptly recognized and treated [57]. Within several hours after exposure, affected areas may develop blisters, inflammation and intense pain [58]. In more severe cases, chemical corrosion may extend into deeper skin layers, producing partial-thickness or full-thickness burns [59]. These injuries often require medical treatment and may result in permanent scarring or loss of skin function [60].

Chronic Skin Conditions in Construction Workers

Chronic dermatological conditions frequently develop among construction workers who experience long-term exposure to cement and related construction materials [61]. Continuous contact with cement dust and wet cement mixtures gradually weakens the skin barrier and reduces its natural protective capacity [62]. As a result, workers often develop persistent dryness, scaling and thickening of the skin after repeated exposure [63]. These conditions commonly appear on the hands and fingers, which are the body parts most frequently exposed during manual construction work [64]. Chronic irritation may stimulate excessive keratin production, resulting in hyperkeratosis characterized by thickened and hardened skin [65]. Although this response may initially act as a protective mechanism, it often leads to painful cracking and fissuring that can interfere with manual work activities [66]. Repeated exposure to cement dust also removes natural oils from the skin surface, contributing to dehydration and roughness [67].

Over time, these changes can lead to persistent dermatological problems that remain present even when acute inflammation subsides [68]. Observational studies summarized in Table 2 indicate that construction workers exposed to cement frequently report chronic dermatological symptoms affecting their hands and forearms [69]. These findings emphasize the cumulative effect of cement exposure on skin health among workers in the construction industry [70]. The long-term impact of chronic dermatological conditions can significantly affect both the health and occupational performance of construction workers [71]. Persistent dryness and cracking of the skin create openings that allow microorganisms to penetrate deeper tissues, increasing the risk of bacterial and fungal infections [72]. Such infections may lead to further inflammation and delayed healing of affected areas [73]. In some cases, workers may develop chronic eczema or other inflammatory skin disorders due to repeated irritation and sensitization [74]. Poor workplace hygiene conditions and limited use of protective equipment can further exacerbate these dermatological problems [75]. Workers employed in cement factories, transportation operations and construction sites therefore face a continuous risk of developing chronic skin conditions associated with cement exposure [76]. The cumulative nature of occupational exposure means that symptoms may worsen with increasing years of employment in the construction sector [77]. Chronic dermatological disorders can also reduce a worker's ability to perform manual tasks and may lead to reduced productivity or work absence [78]. These outcomes highlight the need for improved occupational health practices, including protective equipment, worker education and regular medical surveillance [79]. Therefore, chronic skin conditions associated with cement exposure represent a significant occupational health challenge in the construction industry [80].

Biochemical and Cellular Effects of Cement Exposure

Cement dust exposure has been widely recognized as a significant occupational health concern due to its complex chemical composition (Figure 1) and potential to induce systemic biochemical disturbances [63]. Cement dust contains several toxic elements including silicon oxide, aluminum oxide, iron oxide, chromium, lead, cadmium, nickel, cobalt, arsenic, sodium, potassium, sulphur and magnesium compounds [60]. These substances can act as environmental xenobiotics that interact with biological tissues after inhalation, ingestion, or dermal contact [68]. Once inhaled, fine cement particles can be trapped in the respiratory tract and subsequently transported through the mucociliary clearance mechanism to the gastrointestinal system, where they may be absorbed into systemic circulation [61]. Following absorption, these toxic constituents can accumulate in various organs such as the liver, kidneys, lungs and gastrointestinal tissues [80].

Bioaccumulation of heavy metals and particulate matter can disrupt normal cellular metabolism and lead to structural and functional damage in multiple organs [66]. Evidence from toxicological studies indicates that these interactions may result in oxidative stress, cellular damage and inflammatory responses that contribute to the development of several diseases including respiratory disorders, liver abnormalities and gastrointestinal dysfunction [72].

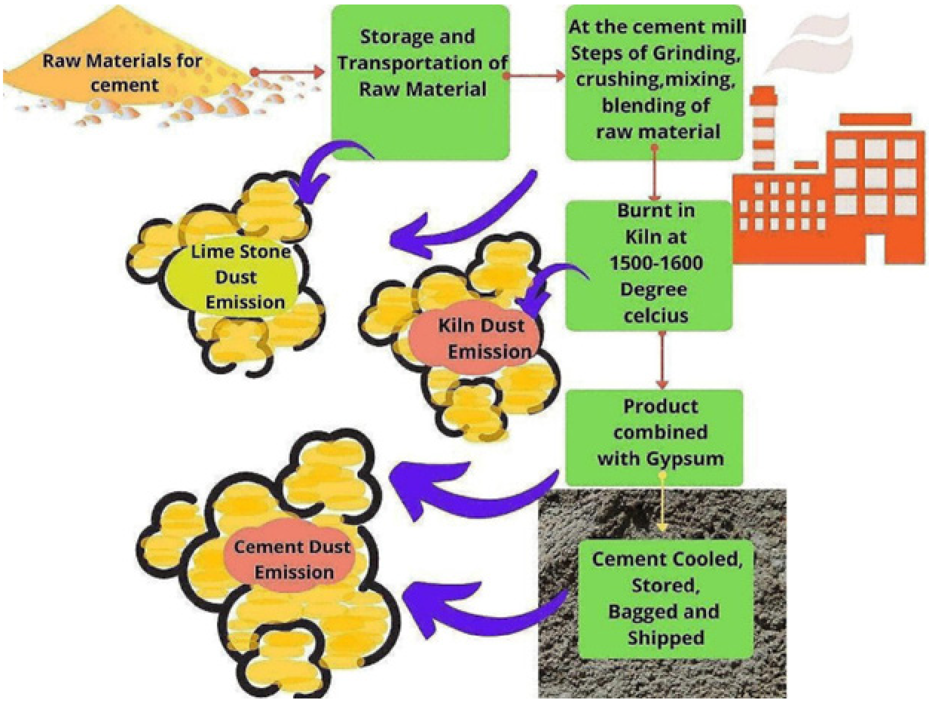

Figure 1: Dust generation throughout the different phases of cement manufacturing [57].

Experimental and epidemiological studies have demonstrated that cement dust exposure can trigger multiple biochemical alterations within the body (Table 3) [64]. Inhalation of cement dust particles has been associated with elevated levels of liver enzymes such as Aspartate Aminotransferase (AST), Alanine Aminotransferase (ALT) and Alkaline Phosphatase (ALP), which indicate hepatic tissue injury [81]. Similarly, increased serum concentrations of creatinine and urea have been reported in exposed individuals, suggesting impaired renal function [71]. These biochemical abnormalities are often accompanied by increased lipid peroxidation and depletion of antioxidant enzymes such as Superoxide Dismutase (SOD) and Catalase (CAT), reflecting oxidative damage at the cellular level [62]. Furthermore, inflammatory markers such as C-reactive protein and nitric oxide have been observed to increase in individuals exposed to cement dust, indicating the activation of immune responses and inflammatory pathways [82]. These findings suggest that prolonged exposure to cement dust can disrupt cellular homeostasis and contribute to tissue degeneration through biochemical and molecular mechanisms [74].

Table 3: Selected case studies on biochemical and cellular effects of cement dust exposure.

Study / Population	Study Design	Sample Size	Key Biomarkers Measured	Major Findings
Wistar rat inhalation experiment	Experimental animal study	30 rats (control, 14-day exposure, 28-day exposure)	AST, ALT, ALP, urea, creatinine, nitric oxide, SOD, CAT, MDA	Cement dust exposure increased organ weight, heavy metal bioaccumulation, oxidative stress, and liver and kidney enzyme levels [66].
Cement plant worker oxidative stress study	Cross-sectional occupational study	40 exposed workers vs 40 controls	MDA, SOD, CAT, TAC, ALP, AST	Higher oxidative stress marker (MDA) and elevated liver enzymes in exposed workers; antioxidant capacity reduced [81].
Cement handlers biochemical study (Nigeria)	Occupational cohort study	120 exposed workers vs 60 controls	Creatinine, urea, AST, ALT, ALP, MDA, CRP, cystatin-C, eGFR	Exposed workers showed increased kidney and liver damage markers with reduced albumin, total protein, and eGFR [97].
Neurocognitive and oxidative stress evaluation	Case-control study	41 exposed vs 41 control workers	Triglycerides, ALT, ALP, oxidative stress markers	Higher triglycerides and liver enzymes in exposed workers with evidence of oxidative damage [75].
Occupational health survey of cement workers	Cross-sectional survey	Multiple industrial workers	WBC, RBC, hemoglobin	Elevated WBC counts and reduced hemoglobin levels indicating inflammation and possible anemia [83].

Skin Barrier Disruption

Cement exposure can significantly impair the integrity of the skin barrier, primarily due to its highly alkaline nature and abrasive particulate composition [69]. Wet cement typically has a high pH that can reach levels above 12, which is capable of disrupting the protective lipid layers of the epidermis [83]. The outermost layer of the skin, the stratum corneum, serves as a protective barrier that prevents the entry of harmful substances and regulates water loss [70]. When cement particles come into prolonged contact with the skin, the alkaline compounds dissolve lipids and denature structural proteins within the epidermal layers [84]. This process weakens the protective barrier and increases skin permeability to irritants and allergens [60]. Mechanical abrasion from sand and silica particles further damages the epidermal surface, creating micro-injuries that facilitate deeper penetration of toxic substances [85]. As a result, workers frequently exposed to cement dust often experience dryness, redness, itching and scaling of the skin [75].

Repeated exposure can lead to chronic skin conditions characterized by progressive deterioration of epidermal tissue [86]. The disruption of the skin barrier increases trans epidermal water loss, causing persistent dehydration and reduced elasticity of the skin [77]. In severe cases, prolonged exposure may lead to fissures, ulcerations and inflammatory lesions that compromise normal skin function [87]. Occupational surveys have reported a high prevalence of dermatitis, eczema and skin irritation among cement factory workers and construction laborers [79]. In some cases, these dermatological conditions are aggravated by the presence of heavy metals such as chromium in cement dust, which can induce allergic sensitization [88]. Chronic skin barrier disruption may also allow microbial pathogens to penetrate the damaged epidermis, increasing the risk of secondary infections [80]. These findings highlight the importance of protective measures such as gloves, protective clothing and proper hygiene practices in minimizing dermal exposure to cement dust in occupational environments [89].

Oxidative Stress and Inflammatory Responses

Exposure to cement dust has been shown to induce oxidative stress through the generation of Reactive Oxygen Species (ROS) within cells [81]. The fine particulate nature of cement dust allows it to penetrate deeply into the respiratory tract and enter systemic circulation, where it can interact with cellular components [90]. Once inside the body, toxic metals and particulate matter stimulate the production of ROS such as superoxide radicals and hydrogen peroxide [82]. These reactive molecules can damage cellular membranes, proteins and DNA through oxidative reactions [91]. Lipid peroxidation is one of the primary consequences of oxidative stress, leading to the formation of Malondialdehyde (MDA), a biomarker commonly used to assess oxidative damage [83]. Occupational studies have consistently reported elevated levels of MDA in individuals exposed to cement dust, indicating increased oxidative damage at the cellular level [92]. Simultaneously, antioxidant defense systems such as superoxide dismutase and catalase may become depleted due to prolonged oxidative challenges [84].

The oxidative imbalance caused by cement dust exposure can trigger inflammatory responses in multiple tissues [93]. Reactive oxygen species activate signaling pathways that stimulate immune cells to release inflammatory mediators such as cytokines and nitric oxide [85]. Increased nitric oxide levels have been observed in experimental models exposed to cement dust, suggesting activation of inflammatory processes within organs such as the liver and kidneys [94]. These inflammatory responses may contribute to tissue damage, fibrosis and impaired organ function over time [86]. Elevated levels of inflammatory markers such as C-reactive protein have also been reported among occupationally exposed cement workers [95]. Persistent oxidative stress and inflammation can therefore lead to chronic diseases affecting multiple organs, including the liver, lungs, kidneys and cardiovascular system [87]. These findings demonstrate that oxidative stress plays a central role in the pathophysiological effects of cement dust exposure [96-100].

Toxicological Effects of Heavy Metals

Heavy metals present in cement dust contribute significantly to its toxicological effects on human health [61]. Elements such as chromium, cadmium, lead, cobalt and nickel are commonly detected in cement dust and can accumulate in biological tissues following prolonged exposure [97]. Among these metals, hexavalent chromium is particularly hazardous due to its strong oxidizing properties and ability to penetrate biological membranes [62]. Once absorbed into the body, chromium compounds can interact with cellular proteins and nucleic acids, leading to structural damage and interference with normal metabolic processes [98]. Toxicological studies have shown that chromium exposure can induce genetic mutations, DNA damage and chromosomal abnormalities, which may increase the risk of cancer [63].

In addition to its carcinogenic potential, chromium exposure can also disrupt immune system function [99]. Chronic exposure to heavy metals may alter the activity of immune cells, including neutrophils and lymphocytes, thereby affecting the body's ability to respond to infections and inflammatory stimuli [64]. Studies have reported reduced phagocytic activity of polymorphonuclear neutrophils in individuals exposed to cement dust containing high concentrations of cadmium and other metals [100]. This reduction in immune defense can increase susceptibility to infections and inflammatory diseases [65]. Furthermore, bioaccumulation of heavy metals in organs such as the kidneys and liver can lead to long-term toxic effects, including renal dysfunction and hepatic injury [66]. These toxicological mechanisms highlight the significant health risks associated with occupational exposure to cement dust and underscore the need for strict environmental and workplace safety regulations to limit heavy metal exposure [68].

SIRT1-Mediated Effects of Cement

Sirtuin 1 (SIRT1), a NAD^+-dependent deacetylase, plays a central role in regulating cellular aging, oxidative stress responses and metabolic homeostasis, making it highly relevant in occupational exposure contexts [101]. Cement dust contains a complex mixture of xenobiotics, including alkaline compounds and trace heavy metals such as hexavalent chromium, which can interfere with intracellular signaling pathways and contribute to SIRT1 inactivation [102]. The suppression of SIRT1 activity has been linked to increased production of reactive oxygen species, impaired DNA repair mechanisms and the activation of pro-inflammatory pathways, ultimately accelerating cellular senescence and tissue damage [103]. In construction workers exposed to cement without protective gloves, these molecular disruptions may exacerbate dermatological deterioration while simultaneously promoting systemic toxicity affecting multiple organ systems [104].

Furthermore, the balance between SIRT1 activators and inhibitors is increasingly recognized as a determinant of cellular resilience against environmental stressors, suggesting that occupational exposures may shift this balance toward a pro-aging phenotype [105]. Reduced SIRT1 expression has been associated with metabolic dysregulation, hepatic dysfunction and chronic inflammatory conditions, all of which have been reported in populations exposed to cement dust and related pollutants [101]. Monitoring plasma or tissue levels of SIRT1 in exposed workers may therefore provide an early biomarker for cumulative toxic effects and disease progression [102]. Future research should focus on elucidating dose–response relationships between cement-derived xenobiotics and SIRT1 modulation, as well as exploring targeted interventions that could restore its protective functions in high-risk occupational groups [103].

Occupational Health Implications, Preventive Strategies and Future Research Directions

Prolonged exposure to cement, particularly among construction workers who handle it without protective gloves, presents significant occupational health concerns well supported by epidemiological evidence [106]. Occupational dermatosis due to cement exposure is one of the most frequently reported work-related skin disorders globally, with prevalence estimates ranging from 5 to 15 percent of construction workers developing dermatitis during their careers, most commonly among masons and concrete workers [107]. In some hospital-based assessments, nearly 46 percent of construction workers examined exhibited work-related skin diseases such as contact dermatitis and callosities, with contact dermatitis present in nearly 20 percent of cases [108]. Direct dermal contact with cement dust, rich in alkaline compounds and trace heavy metals like hexavalent chromium, can provoke acute irritant reactions, allergic dermatitis, eczema and in severe cases chemical burns and ulceration [109]. Beyond visible dermatological manifestations, emerging evidence from occupational exposure studies indicates systemic biochemical disturbances, including elevated markers of oxidative stress such as malondialdehyde and reduced antioxidant capacity in exposed workers compared with controls, reflecting cellular injury [110]. Such multi-systemic impacts underscore the complexity of cement dust as an occupational hazard that not only compromises immediate health but may predispose workers to long-term chronic conditions [111].

Mitigation of these risks relies on the implementation of comprehensive protective measures that go beyond basic awareness [112]. The consistent use of personal protective equipment, particularly high-quality gloves and protective clothing, remains the most direct barrier against contact with irritants and sensitizing agents and periodic workplace training enhances hazard recognition and compliance [113]. Efforts such as adding ferrous sulfate to cement to reduce chromate sensitization have shown promise in significantly lowering allergic dermatitis incidence, though such interventions are not yet universally adopted [114]. Complementary workplace strategies, including improved ventilation to control airborne dust, substitution of high-risk materials where feasible, routine skin hygiene protocols and health surveillance with targeted biomarker monitoring, further strengthen occupational safety frameworks to minimize both acute and long-term effects [115].

Future research should seek to broaden and deepen our understanding of cement-induced health effects through well-designed longitudinal and mechanistic studies that integrate both dermatological and systemic outcomes [116]. While cross-sectional studies have documented associations between cement dust exposure and oxidative stress parameters, there remains a need for research that clarifies dose-response relationships, temporal progression of biochemical alterations and the cumulative effects of mixed exposures in construction settings [117]. Investigations into innovative materials, such as bioengineered surface treatments or chromium-reduced cement formulations, could provide transformative occupational safety solutions [118]. Further, elucidating molecular pathways affected by chemical irritants and heavy metals may reveal targeted strategies to counteract toxicity and prevent cellular damage [119]. Finally, socio-economic dimensions, including equitable access to personal protective equipment, training programs and occupational health services across diverse construction environments, must be integrated into future research and policy frameworks to ensure that scientific insights are translated into practical protections for vulnerable worker populations [120].

Conclusion

Cement, a chemically complex and widely used construction material, poses significant occupational hazards for workers, particularly those handling it without proper protective gloves and clothing. The combination of high alkalinity, abrasive particles and sensitizing heavy metals such as hexavalent chromium, cobalt and nickel contributes to both dermatological and systemic health effects. Chronic dermal exposure frequently leads to irritant and allergic contact dermatitis, chemical burns, eczema and hyperkeratosis, with the hands, forearms and lower limbs being the most affected regions. Epidemiological and occupational studies demonstrate the prevalence of these conditions among construction workers, highlighting the need for preventive interventions in workplace settings.

Beyond the visible dermatological effects, cement dust exposure induces substantial biochemical and cellular disturbances. Inhalation, dermal contact or ingestion of fine cement particles allows toxic elements including silicon oxide, aluminum oxide, chromium, cadmium, lead and other heavy metals to accumulate in organs such as the liver, kidneys and lungs, disrupting cellular homeostasis. Prolonged exposure triggers oxidative stress, lipid peroxidation, depletion of antioxidant enzymes such as SOD and CAT and activation of inflammatory pathways, as reflected in elevated liver and kidney enzymes, creatinine, urea, malondialdehyde and C-reactive protein levels. Experimental and occupational studies confirm these biochemical alterations, including oxidative damage and organ dysfunction in both animal models and human workers.

Preventive strategies remain the cornerstone for mitigating cement-related health risks. The consistent use of high-quality gloves, protective clothing, workplace ventilation, hygiene protocols and health surveillance can substantially reduce both acute and chronic adverse effects. Interventions such as the addition of ferrous sulfate to cement to reduce hexavalent chromium content show promise in lowering the incidence of allergic dermatitis, while education and regular training enhance compliance with protective measures. Despite these solutions, gaps remain in adoption and awareness, particularly in developing countries or informal construction sectors, emphasizing the need for stricter occupational safety regulations and effective implementation of protective practices.

Future research should focus on longitudinal and mechanistic studies that evaluate the cumulative effects of cement exposure on dermatological, biochemical and systemic outcomes. Investigations into innovative materials including chromium-reduced cement formulations and bioengineered surface treatments can offer transformative solutions to reduce occupational hazards. Furthermore, integrating socio-economic considerations such as equitable access to protective equipment and health monitoring will be essential to ensure that scientific findings translate into effective protection for construction workers. Taken together, these insights underscore the multi-systemic impact of cement exposure and the critical importance of combining preventive strategies, policy measures and research advancements to safeguard worker health in the construction industry.

Conflict of Interest

The author declares no conflict of interest.

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