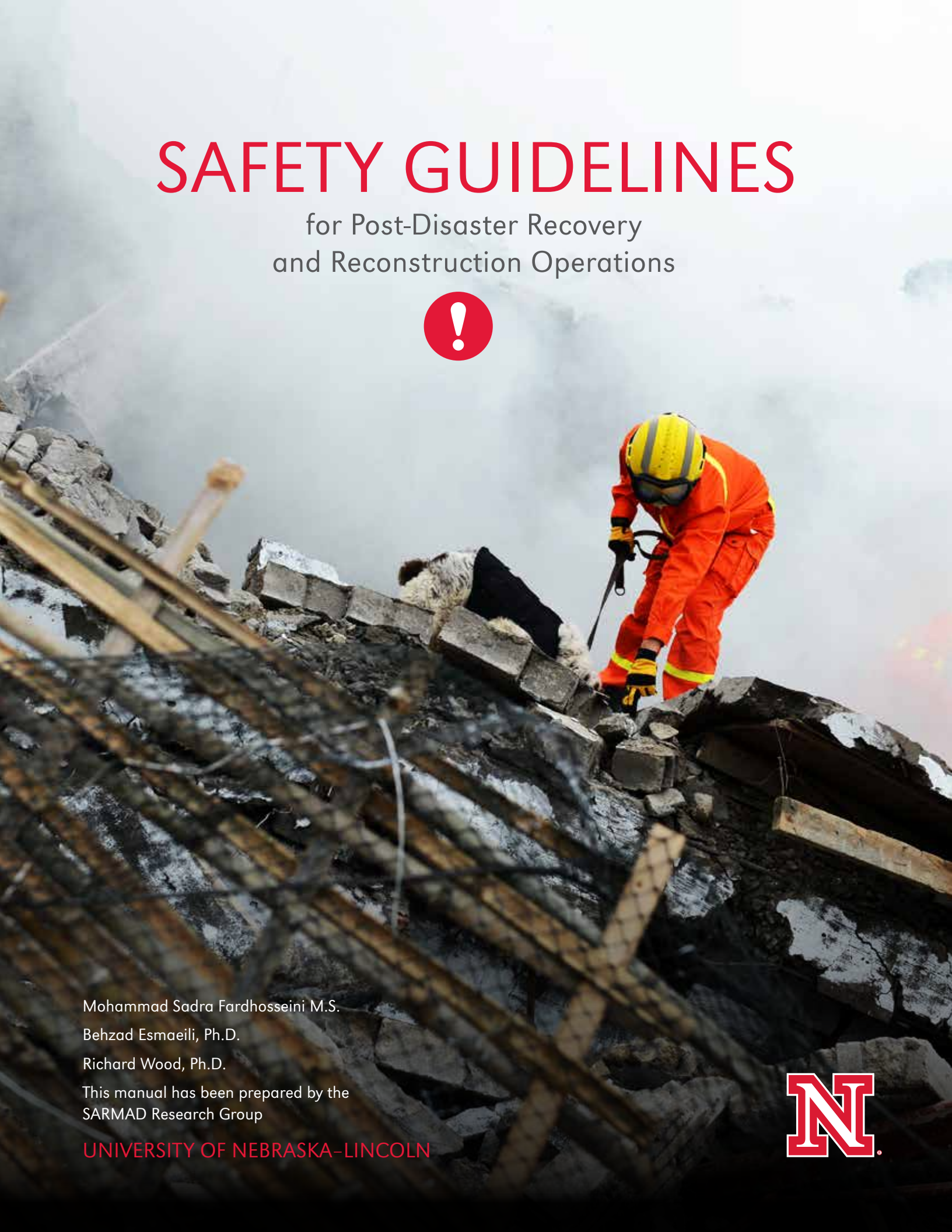
SAFETY GUIDELINES

for Post-Disaster Recovery and Reconstruction Operations



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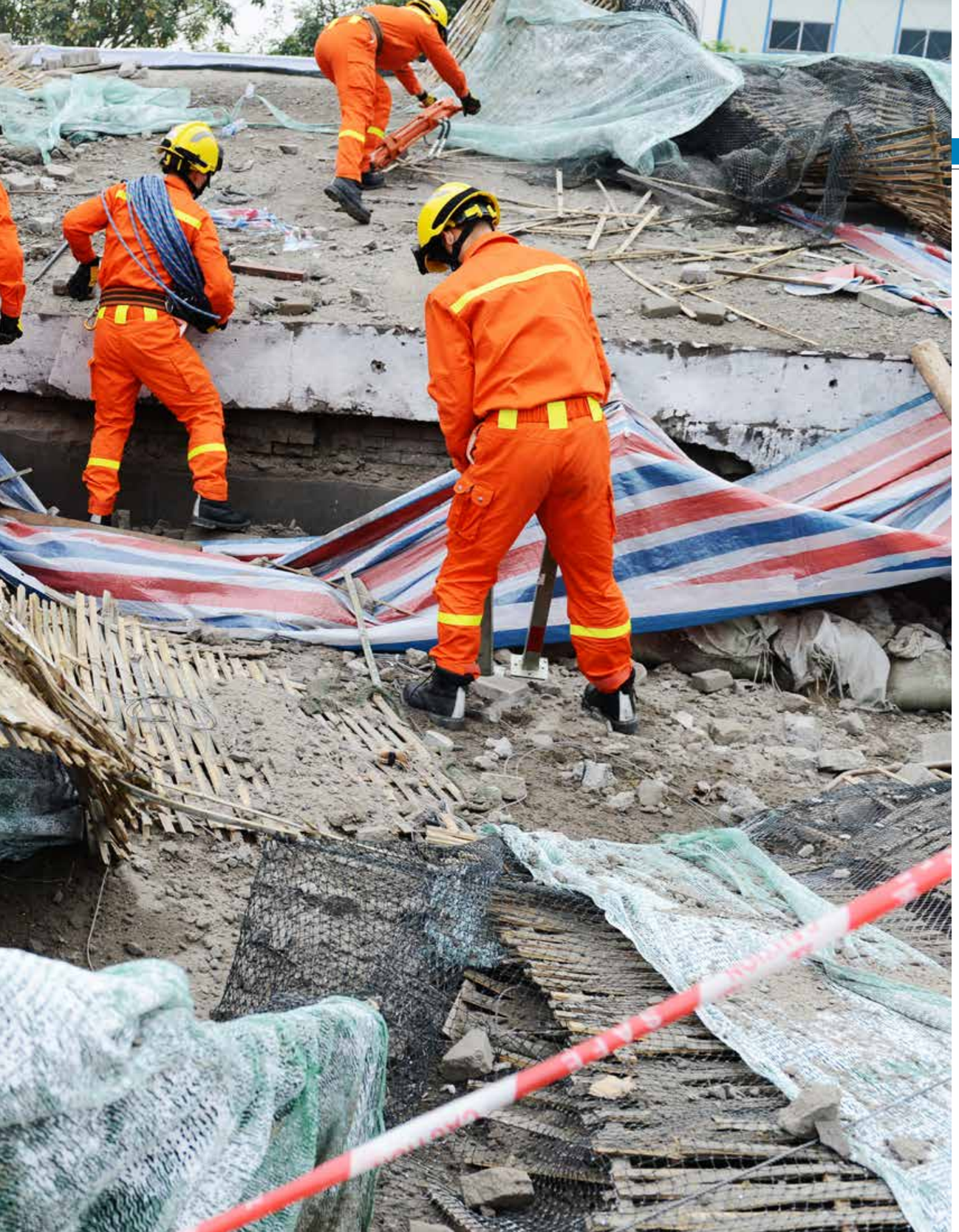

TABLE OF CONTENTS

Introduction 5
Risk Assessment 6-7
Risk Matrix 8-9
Hazard Scenarios 10-25
Personnel Protective Equipment (PPE) 26-32
- Head Protection 26
- Eye Protection 27
- Face Protection 27
- Hearing Protection 28
- Foot Protection 28
- Hand Protection 29
- Body Protection 30
- Respiratory Protection 31
- Choosing the Right Level of Protection 31

Fall Prevention 33-35
- Guardrails 33
- Safety Net Systems 34
- Personal Fall Arrest System (PFAS) 34
- Covers 35
- Positioning Device Systems 35

Struck-by Injury Prevention 36-37
- Falling Objects 36
- Heavy Equipment and Motor Vehicles 36
- Tools 37

Caught-in Injury Prevention 38-39
Electrocution Prevention 40-41
- Proper PPE 40
- Inspection of the Isolation of Electrical Parts 41
- Overhead Power Line Protection 41
- Control of Wires and Cords 41
- Ground Fault Circuit Interrupters (GFCI) 41
- Follow Lock Out/Tag Out Procedure 41

Chemical Exposure Prevention 42-43
- Gases 42
- Vapors 42
- Fumes 42
- Dust and Fibers 43
- Mists 43

Biological Hazard Prevention 44-45
- Handwashing 45
- Proper Personnel Protective Equipment (PPE) 45
- Immunization of workers 45

Ergonomic Hazard Prevention 46-47
Weather-related Hazard Prevention 48-49
- Heat 48
- Cold 49

Noise 50-51
Psychological 52
Author Bios 54
References 55

INTRODUCTION

On average, natural and man-made disasters cause approximately $24 billion worth of damage and affect the lives of 60 million people around the world every year.

In the United States alone (1980-1999), thirteen hurricanes caused $68 billion in damages and more than 400 deaths. Recently, in January 2010, the Haiti earthquake ruined around 250,000 houses. To cope with such a huge loss, a large number of studies have been conducted to develop emergency response plans, revise land-use regulations, improve building retrofitting programs, or design more effective early warning systems.

Natural disasters, such as hurricanes and floods, can cause severe damage and demand infrastructural recovery, operations that typically involve construction workers. The number of workers who are involved in post-disaster recovery and reconstruction depends on the scale of the catastrophe; however, this number can reach up to 18,000 workers. Workers involved in cleaning and reconstruction operations after a disaster face greater danger than traditional workers because they are exposed to chemical-biological materials, contaminated floodwater, downed energized power lines, confined space entry, potential structural collapse, or other high-risk situations. For this reason, careful attention should be paid to identifying and assessing potential safety risks for these workers.

To address this emerging need, safety guidelines were developed by the Durham School of Architectural Engineering and Construction and the Department of Civil Engineering at the University of Nebraska–Lincoln to help project managers and workers mitigate the potential safety hazards during recovery and reconstruction operations. It is expected that the suggestions provided in this manual will enhance safety performance of workers involved in post-disaster recovery operations.

RISK ASSESSMENT

A major focus of workers involved in cleaning operations after a disaster is construction safety because there are several unknown hazards that differ from hazards in a typical construction project. The risk can be compounded by the fact that construction activities after a disaster are usually conducted by small companies or property owners with limited knowledge of safety practices. Therefore, the objective of this study was to develop a safety-risk management plan for recovery after disasters. The objective was achieved in two distinct phases. The first phase of the study focused on risk identification. An extensive literature review was conducted to identify hazards in post-disaster operations. The primary list of hazards was identified and classified into seven major groups: (1) physical; (2) chemical; (3) biological; (4) weather and temperature; (5) ergonomic; (6) psychological; and (7) other (e.g., natural hazards and noise). During the second phase of the study, risk assessment was conducted to quantify the safety risk of the hazards identified in the previous phase. Fourteen safety professionals with an average 18 years of experience participated in the risk assessment. The frequency and severity values for each hazard were independently quantified on a Likert scale with high level of consistency (Cronbach alpha for the frequency = 0.984; Cronbach alpha for the severity = 0.992). It was found that being caught in/between a trench, being electrocuted while using cranes or boomed vehicles near energized power lines, and being electrocuted while using conductive tools, ladders, or scaffolds near energized power lines are the hazards that cause the most severe injuries. Concurrently, working in cold or windy weather is the most frequent and risky hazard in post-disaster recovery operations.

Table 1. Median of frequency, severity, and risk factors obtained from safety managers

		Hazards	Frequency *	Severity **	Risk (F×S)
Physical (Phy)	1	Falling from a ladder	2	3	6
	2	Falling from an unprotected edge, opening, or skylight	1	4	4
	3	Falling from a scaffold	2	3.5	7
	4	Falling from a structural frame (tower, steel frame, etc.)	2	4	8
	5	Falling from an aerial platform	1	4	4
	6	Struck by a boomed vehicle	1	3.5	3.5
	7	Struck by construction equipment	1.5	4	6
	8	Struck by a nail gun	1	2.5	2.5
	9	Struck by personal vehicle	2	4	8
	10	Struck by flying debris/objects	2.5	3	7.5
	11	Struck by falling objects	2	3	6
	12	Caught in/between a trench	1	4.5	4.5
	13	Electrocuted while using cranes or boomed vehicles near energized power lines	1	4.5	4.5
	14	Electrocuted while using conductive tools, ladders, or scaffolds near energized power lines	1	4.5	4.5
	15	Electrocuted while working on/near live wiring or energized circuit	1	5	5
	16	Electrocuted while working with electrical device or tool	1	4	4
	17	Electrocuted after contact with underground, buried power lines	1.5	4	6
Chemical Chem	18	Entering a confined place that has the probability of toxic gas emission	1	3.5	3.5
	19	Touching paint and plastic materials that can cause asthma	1.5	3	4.5
	20	Demolition, plumbing, or painting that exposes workers to lead	1	3	3
	21	Exposure to metal materials coating and metal cleaners	1	2.5	2.5
	22	Exposure to rust-prevention products on steel	1.5	2.5	3.75
	23	Inhaling fumes during welding, grinding, and cutting (galvanized metal, alloy, and brass)	3	3	9
	24	Demolition, dry wall installation, enhancing fire-proofing, and insulation activities that expose workers to asbestos	1	2.5	2.5
	25	Stone dressing, masons quarry, and stone cutting	1	2	2
	26	Inhaling cement particles while mixing concrete, which can cause lung cancer, chest pain, and difficulty in breathing	2	3	6
	27	Working with MDF in demolition and sawing, which can cause coughing, wheezing, or stomach pain	1.5	2.5	3.75
Biological (Bio)	28	Exposure to fungi, mildews, yeasts, and mold	2	3	6
	29	Encountering corpses of people and animals during rescue operations	2	2.5	5
	30	Touching poisonous plants or inhaling the fumes that result from burning such poisonous plants	2	2	4
	31	Exposure to disease, such as hepatitis, tuberculosis, tetanus, legionella, and rabies	2	3	6
	32	Exposure to sludge and debris	2	2	4
Weather	33	Working in hot and humid outdoor conditions for a long duration	4	3.5	14
	34	Working in a hot indoor room without suitable ventilation	2	2.5	5
	35	Working in cold or windy weather	4.5	4	18
Ergonomic (Erg)	36	Lifting heavy weight in adverse positions	3	3	9
	37	Using excessive force (over-exertion)	2	3	6
	38	Using unsuitable devises for a specific job	2	2.5	5
	39	Griping a part of the body during the task	2	2	4
	40	Performing a repetitive activity	4	3	12
Psychological (Psy)	41	Substantial distress responses (e.g., sleep disturbance, fear, and worry-altered connections)	2	3	6
	42	Mental health and illness (e.g., post-traumatic stress disorder (PTSD), acute stress disorder (ASD), and depression)	2	3	6
	43	Behavioral changes in high-stress environment (e.g., smoking, evacuation, alcohol, and over-dedication)	2	3	6
Other	44	Encountering natural hazards (exposure to snakes, wasps and bees, spiders, scorpions, and mosquitoes)	3.5	3	10.5
	45	Exposure to high decibel noises	3.5	3	10.5

RISK MATRIX

A risk matrix was developed to provide a visual representation of the likelihood and consequence of potential accidents. It is expected that the results of this study will transform the current safety practices in post-disaster recovery operations by providing an easy-to-use safety-risk management tool.

Risk Assessment			FREQUENCY				
			Highly unlikely	Unlikely	Likely	Highly likely	Near certainty
			1	2	3	4	5
SEVERITY	Fatality	5	5 Phy (12, 13,14,15)	10	15	20	25
	Major injuries	4	4 Phy (2,5,6,16) Chem (18)	8 Phy (3,4,7,9,17)	12	16 Weather (33)	20 Weather (35)
	Moderate injuries	3	3 Phy (8) Chem (20,21,24)	6 Phy (1,11) Chem (19,22,26,27) Bio (28,29,31) Erg (37,38) Weather (34) Psy (41,42,43)	9 Phy (10) Chem (23) Erg (36)	12 Other (44,45) Erg (40)	15
	Minor injuries	2	2 Chem (25)	4 Bio (30,32) Erg (39)	6	8	10
	Trivial injuries	1	1	2	3	4	5

RED	YELLOW	GREEN
Extremely risky. Emergency attention is required.	Hazardous. These risks should be taken into consideration.	Negligence risks. Minimum action is needed for prevention.

Figure1. Risk matrix.

Table 2. Hazards and their assessed risks

Negligence risks	Risk	Hazard
Touching poisonous plants or inhaling the fumes that result from burning such poisonous plants	4	Bio
Exposed to sludge and debris	4	Bio
Gripping a part of the body during the task	4	Erg
Struck by a nail gun	3	Phy
Demolition, plumbing, or painting that exposes workers to lead	3	Chem
Exposure to metal materials coating and metal cleaners	3	Chem
Demolition, dry wall installation, enhancing fire-proofing, and insulation activities that expose workers to asbestos	3	Chem
Stone dressing, masons quarry, and stone cutting	2	Chem

Hazardous	Risk	Hazard
Encountering natural hazards (exposure to snakes, wasps and bees, spiders, scorpions, and mosquitoes)	12	Other
Exposure to disturbing noises	12	Other
Performing a repetitive activity	12	Erg
Struck by flying debris/objects	9	Phy
Inhaling fumes during welding and cutting (galvanized metal, alloy, and brass)	9	Chem
Lifting heavy weight in adverse positions	9	Erg
Falling from a scaffold	8	Phy
Falling from a structural frame (tower, steel frame, ...)	8	Phy
Struck by construction equipment	8	Phy
Struck by a personal vehicle	8	Phy
Electrocuted after contact with underground, buried power lines	8	Phy
Falling from a ladder	6	Phy
Struck by falling objects	6	Phy
Touching paint and plastic materials that can cause asthma	6	Chem
Exposure to rust-prevention products on steel	6	Chem
Inhaling cement particles while making concrete, which can cause lung cancer, chest pain, and difficulty in breathing	6	Chem
Working with MDF in demolition and sawing, which can cause coughing, wheezing, or stomach pain	6	Chem
Exposure to fungi, mildews, yeasts, and mold	6	Bio
Encountering corpses of people and animals during rescue operations	6	Bio
Exposure to disease, such as hepatitis, tuberculosis, tetanus, legionella and rabies	6	Bio
Using excessive force (over-exertion)	6	Erg
Using unsuitable devises for a specific job	6	Erg
Working in a hot indoor room without suitable ventilation	6	Weather
Substantial distress responses (e.g., sleep disturbance, fear, and worry-altered connections)	6	Psy
Mental health and illness (e.g., post-traumatic stress disorder (PTSD), acute stress disorder (ASD), and depression)	6	Psy
Behavioral changes in high-stress environment (e.g., smoking, evacuation, alcohol, and over-dedication)	6	Psy
Caught in/between a trench	5	Phy
Electrocuted while using cranes or boomed vehicles near energized power lines	5	Phy
Electrocuted while using conductive tools, ladders, or scaffolds near energized power lines	5	Phy
Electrocuted while working on/near live wiring or energized circuit	5	Phy
Falling from an unprotected edge, opening, or skylight	4	Phy
Falling from an aerial platform	4	Phy
Struck by a boomed vehicle	4	Phy
Electrocuted while working with electrical device, tool	4	Phy
Entering a confined place that has the probability of toxic gas emission	4	Chem

Extremely risky	Risk	Hazard
Working in cold or windy weather	20	Weather
Working in hot and humid outdoor conditions for a long time	16	Weather

HAZARD SCENARIOS

HAZARD SIGNS

Signs of potential hazards that might cause by the following scenarios in post-disaster recovery and reconstruction.

FALL PREVENTION | STRUCK-BY INJURY PREVENTION | CAUGHT-IN INJURY PREVENTION | ELECTROCUTION PREVENTION | CHEMICAL EXPOSURE PREVENTION

BIOLOGICAL HAZARD PREVENTION | ERGONOMIC HAZARD PREVENTION | WEATHER-RELATED HAZARD PREVENTION | NOISE | PSYCHOLOGICAL

HAZARD SCENARIOS

Hazard scenarios in post-disaster recovery operations were derived from literature review with the intention of proposing prevention measures. These scenarios are provided below.

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1. RESCUE OPERATION

After a disaster, emergency responders are the first to arrive at the exposed area to rescue people and save lives. Therefore, they will encounter many distressing scenes that they will need to cope with after the disaster recovery operation. Emergency responders are also engaged in medical services taking place around accumulated debris and rubble and nearly collapsed structures. Some of the most notable types of hazards that might threaten worker health are: exposure to corpses; extreme noises; damaged utility services; contaminated debris and dust; experiencing trips, slips, and falls from heights; being stuck in confined spaces; exposure to toxic gases; and being struck by heavy equipment and machinery. In order for the emergency responders to be successful in their rescue responsibilities, they will need to be able to identify these hazards and properly react to them.

*Shutterstock: QUEENS, NY - NOVEMBER 11: Damaged houses without power at night in the Rockaway beach due to impact from Hurricane Sandy in Bel Harbor - Queens, New York, U.S., on November 11, 2012.
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2. DEWATERING

The first and primary activity in recovery after a disaster is to remove the trapped water. Since the water may be mixed with animal and human sewage, decaying bodies, oil, gas and other chemicals, the water becomes contaminated. After Hurricane Katrina, workers used booms and skimmers to unwater New Orleans, and installed aeration units in canals to diminish the infection of the destination lake or river. In this case, the area is exposed to contagious diseases due to the existence of bacteria and poisonous metals (e.g. arsenic) in the water. After the unwatering process, some pollutants will still remain in the sediments. The evaporation of these materials in conjunction with the released chemical substances can affect the air quality of the disaster area. In addition, in such an unfavorable situation, the presence of rodents, insects, and the growth of fungi and molds (moisture condition), make the area more contaminated.

3. DEMOLITION

During demolition operation, workers are exposed to different types of hazards. The most hazardous situations related to demolition operations are: exposure to dust, silica and asbestos; getting struck by construction materials due to structural deficiencies; falling from unstable structures; exposure to hazardous and flammable chemicals; exposure to damaged utility functions; stuck in confined spaces; being injured from cuts and abrasions; and musculoskeletal injuries.

Before beginning the demolition process, making a comprehensive plan could dramatically enhance worker safety. This plan should be developed based on worker performance during demolition operation, required equipment and their potential hazards, and the most-used demolition methods. In addition, during the initial inspection of damaged structures, conditions of framing, walls, floors and braces should be accurately analyzed. In order to prevent additional hazards, beginning the demolition process from top to bottom while avoiding overly excessive pressures caused by dismantled masonry parts on the floor, is highly recommended by OSHA.

4. DISASTER CLEANUP RESPONSES

During cleaning up activities, there are many hazards that can cause injuries for workers. Innumerable debris was found in New Orleans as a result of Hurricane Katrina. This debris consisted of construction materials, damaged or destroyed building materials, sediments, green waste (trees, limbs, leaves and shrubs), white goods (utensils), asphalt, oil, chemical, and other substances. For example, the amount of debris was estimated around 55 million cubic yards. The volume of debris and the used management options are significant factors—therefore, the clean-up process is at utmost importance.

Lifting debris, tripping, slipping and falling while walking in the contaminated floodwater, exposure to fungi and mold, potential electrocutions, exposure to disease and bacteria, working in wet conditions, and potentially getting stuck in confined spaces are other significant musculoskeletal hazards threatening worker health. Sanitation and good hygiene is the cornerstone of preventing these hazards.

*Shutterstock: VAN, TURKEY - NOVEMBER 10, 2011: Rescue teams are removing the debris of the earthquake with the help of heavy equipment. Van, Turkey. November 10, 2011
Copyright: Kisa Kuyruk

5. WASTE MANAGEMENT

Debris management consists of various steps. The first step is to accumulate the entire debris. In the second step, hazardous materials should be categorized from other substances. During these operations, workers can be exposed to many different hazards such as electrocution; being poisoned by toxic materials; infectious agent and mold; structural instability; and perilous debris such as pesticides, drain cleaners, cleaning supplies, asbestos, and surfaces which are coated by lead based paint.

After pulling out hazardous materials from the pile of debris, the substances that are toxic, ignitable, corrosive, or reactive will be sent to municipal landfills. In the past, they were burned or buried. Currently, both of the aforementioned methods have a great deal of adverse impact on the communities. On the other hand, most of the time, reusing and recycling are the most common processes implemented on nonhazardous debris.

6. FACING FUNGI, MOLD, AND PARASITES

Due to the moisture at the disaster area (flood and hurricane), conditions are susceptible for the growth of different types of fungi (mildew, molds, rusts, and yeasts). Cleanup workers are committed to removing moldy building materials, crumbling vegetation, decaying waste substances and other fungi-infected objects. During this process, these workers might inhale airborne fungi and their spores. As a result of this inhalation, they are at risk of lung disease, dermatitis, allergies, asthma, and sinusitis. Mold, a hued mates with a foul smell, is the most common fungi which might appear after a disaster. Therefore, cleaning the area after the floodwater has receded is a significant task. In addition, cleanup workers should find the source of the mold (moisture and oxygen) and remove it sooner rather than later. Using a 10% bleach water solution is an effective method to disinfect molds. It is crucial to note that, after the removal process, molds and other fungi should be placed in an isolated plastic bag and then discarded.

Aside from fungi-material contamination hazard, trapped flood water is an appropriate place for parasites and mosquitoes to reproduce. Therefore, workers are exposed to high risk of related diseases such as malaria, West Nile fever, and dengue. Per biological guidelines, it is of utmost importance to eliminate these hazards.

HAZARD SCENARIOS

6. DOWNED ELECTRICAL WIRE

Following the disasters, there are numerous potential electrical hazards during clean-up and debris removal activities. Implied by previous studies, getting burned or electrocuted by downed electrical wires have been two of the most wide speared hazards in recovery operations. Downed wires can electrify objects such as fences, water pipes, debris, rebar, vegetation, and utility cables. Being cautious while working near such a hazardous situation and following the conventional electrocution guidelines could lead workers to a higher level of safety.

8. RE-ROOFING

Falling from roofs is responsible for one third of all fall deaths in the construction industry. Laborers working on re-roofing are prone to falling from heights. Thus, fall-protection systems could lead to enhanced worker safety during recovery operations. Although most of the re-roofing guidelines are similar with roofing activity in construction, due to the high risk of working on roofs, the writers incorporate re-roofing operations to potentially hazardous scenarios. Re-roofing encompasses two steps, first demolishing the old roof and then installing a new one. Falling is the main hazard causing injuries and even death during this operation. Sheathing, sudden gusts of wind, loose roofing materials, and wet slicks are the unforeseen reasons for falling from roofs. Being struck by flying materials is another hazard reported in recovery operations. To prevent these kinds of hazards, attention should be paid to falling and struck by hazards.

*Shutterstock: BROOKLYN, NY - NOVEMBER 03: Trees and electric poles felt down to the ground in the Sheapsheadbay neighborhood due to strong wind from Hurricane Sandy in Brooklyn, NY, U.S., on November 03, 2012.
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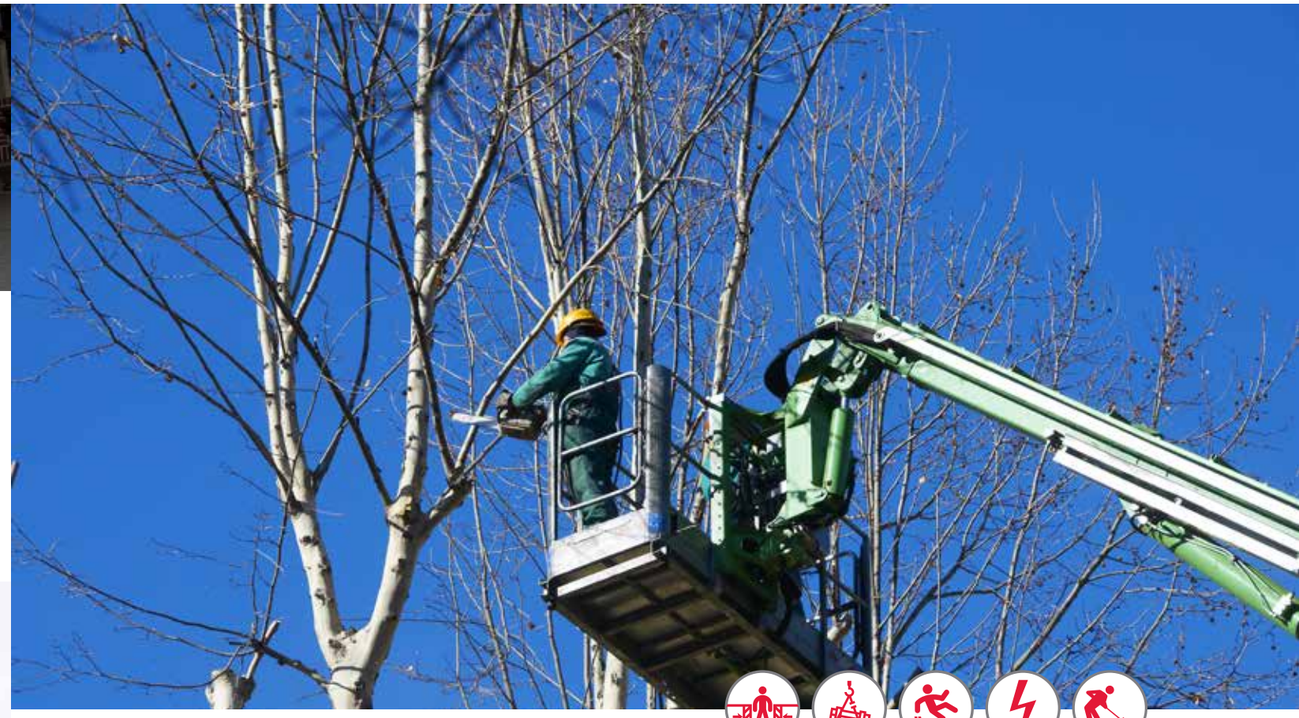

9. TREE TRIMMING

Numerous trees can be rooted out by intense hurricanes and floods. These eradicated trees can pull out power lines and other utilities, unguardedly exposing people and workers involved in recovery operations to hazards. Therefore, after a disaster, adequate attention should be placed on tree trimming and dead-tree removal. Felling operation requires cutting the trees down in an aimed direction in order to cause less damages. So, being struck by cut tree limbs is a probable hazard during tree trimming. In addition, potential fall and musculoskeletal hazards during this operation might threaten workers as well. Finally, chain saws, one of the most portable tree trimming power tools, might cause several problems for workers. Hence, when a chain saw has been chosen for tree trimming, checking the chain saw before starting, keeping hands just on the handle, and never cutting exactly overhead should be heeded.

10. WORKING WITH POWER TOOLS

Power tools are subdivided into five major groups: electric, pneumatic, liquid fuel, hydraulic, and powder-actuated. If each of these tools does not have proper guards or safety switches, working with them is not recommended. Using these tools could cause fumes, dust and sparks; generating flying, abrasive, splashing substances, and electrocution. Therefore, while working with tools such as compressed air tools (nail gun), hand tools, jackhammers, pavement saws, abrasion wheels, saws, drills and grinders, paying enough attention to the following guidelines can help workers keep themselves safe:

- Wear safety glasses and goggles
- Wear hard hats and proper safety boots
- Use hearing protection (ear muffs)
- Participate in training before using these tools
- Examine each tool before using
- Use the tools based on their instructions
- Ensure that all required guards are implemented

11. USING PORTABLE GENERATORS

Since power lines might get disconnected as a result of most disasters, a remote power source is necessary during diverse recovery operations such as demolition with power tools. A portable generator is one of the most-used electric-generator engines. Since the generator produces electricity, there will always be a potential electrocution hazard for the workers. Other hazards associated with portable generators that workers should be vigilant about include the emission of carbon monoxide, the possibility of fire, loud noise, and fatigue. It is recommended to use the generators outdoors, keep them dry, and always utilize a circuit breaker.

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12. USING EQUIPMENT

Ladders, scaffolds, and cranes are equipment employed in both construction and reconstruction operations. Therefore, here is a short description of the potential hazards pertaining to each of them.

Ladders: Ladders are employed to almost all reconstruction activities. Cross bracing and extension ladders are the two most-used ladders during recovery and reconstruction after a disaster. While working on a ladder, workers are at high risk of falling and electrocution, causing severe injuries or even death. Using nonconductive ladders, securing ladders on a stable surface, not overloading ladders, ensuring use of standard ladders based on the activities (rungs are spaced between 10 and 14 inches) and finally not using the highest step during an activity are some of the most significant directions suggested by OSHA.

Scaffold: Scaffold, an escalated temporary work platform, has been divided into three types—supported scaffolds, suspended scaffolds, and aerial lifts. In post-disaster recovery, scaffolds have large applicability during demolition and reconstruction processes. Falling from elevation, tripping on the scaffold, being struck by flying and dropped tools, and electrocution can be enumerated as hazards while working on a scaffold. Following falling and electrocution protection instructions, stabilizing the scaffolds and not overloading them should be considered.

Cranes: Cranes are used in demolition and reconstruction in order to expedite the entire process. Although there are different types of cranes (mobile, hydraulic, overhead, gantry, and tower), a few of them can be employed for recovery purposes. Contacting power lines, overturning, falling and mechanical failures are the most common accidents for this heavy equipment. The cause of these accidents can be summarized as: instability, communication deficiencies, inadequate training, and insufficient inspection. Not exceeding the permissible turning speed of cranes, not overloading the crane, guarding the swing radius, and using outriggers are important points while using a crane in post-disaster recovery and reconstruction.

13. ENTERING CONFINED SPACES

There are nearly 92 fatalities caused by entering confined spaces every year. Confined spaces have limited options for entry or exit, limited air flow (poor ventilation), and are not designed to be occupied by a worker for any length of time. Boiler, furnace, storage tanks, pipeline, pit, pumping station, septic tank, vessels, silos, compartments of ships, tunnels, sewage digester, degreasers, utility vault, ventilation and exhaust ducts, as well as wells and basements are some of the confined spaces that might cause problems for workers in post disaster recovery and reconstruction. The reason for this problem is the existence of venomous gases, insufficient oxygen, and the potential of explosions in these places. Two common toxic gases in post-disaster recovery operations are carbon monoxide and hydrogen sulfide.

Carbon Monoxide: In post-disaster recovery and reconstruction, workers are exposed to carbon monoxide that appears without notice. Carbon monoxide, the colorless, odorless gas, impacts the oxygen's transportation system of the body, resulting in neurological damage, illness, coma, and finally death. Mostly employed equipment emitting carbon monoxide are portable generators, concrete cutting saws, compressors, power trowels, floor buffers, space heaters, welding devices, and pumps. Thus, the usage of the mentioned gas-powered tools are not allowed except with an appropriate ventilation system.

Hydrogen Sulfide: Hydrogen sulfide is a flammable, colorless gas with a rotten egg smell resulting from the combination of flood water and organic sewage. Before entering manholes, basements, or other enclosed spaces that might have the potential of confining someone, workers should check the air quality in the space. Inhaling these gases could lead to shock, convulsions, coma, or death.

Following directions could be considerably helpful for workers:

- Many venomous gases are invisible or do not have any particular smell. Therefore, workers should enter a confined space based cautiously.
- Training and proper PPE are required before entering a confined space.
- A supervisor should monitor the condition when a worker has to enter a confined space.

*Shutterstock: DONETSK, UKRAINE - August, 16, 2013: Miner working in a confined space clears from the slag conveyor. Mine is named Chelyuskintsev.
Copyright: DmyTo

14. FACING CARCINOGEN SUBSTANCES

In recovery after disaster, there are several reports highlighting the importance of carcinogen substances. Although these elements might not kill the infected workers at the moment, their impacts will create lots of problems in the future. Consequently, focusing on these substances in conjunction with describing the most useful methods of protection could prevent additional deaths. Three of the most common carcinogen substances in post-disaster recovery operations are lead, asbestos, and silica.

Lead: Lead is one of the carcinogenic substances that can easily be found at the construction and reconstruction sites. Lead will penetrate into the body either by inhalation or ingestion. In detail, it affects the circulatory and neurological system of the body. Therefore, before eating, washing your hands and face and changing work clothes that were exposed to lead are highly recommended. In the recovery and reconstruction process, lead-related hazards could be seen in demolition salvage, removal, encapsulation, renovation cleaning up, and repairing activities such as plumbing, painting, welding, and cutting. Headache, vomiting, tremors, convulsion, and even gastrointestinal problems and coma, are the most noted consequences of lead exposure.

Asbestos: Asbestos, the mineral fiber causing fatal lung disease, had been applied in many parts of structures including cement pipe, floor and roofing felts, dry wall, ceilings, and floor tiles. After discovering asbestos hazardous health effects, despite its outstanding insulating features, excellent flames sustainability and finally corrosion resistance, using asbestos in structures has been discouraged. However, in recovery operations, workers might encounter asbestos during demolition, rehabilitation and renovation, exclusively in insulation activities and installation of drywalls. Mesothelioma and lung cancer are the worst result of prolong exposure to asbestos. Therefore, legal exposure time of workers to asbestos is limited to 0.1 fiber/cm^3 for every 8 hours. Warning signs could considerably contribute to the workers' awareness of asbestos existence in a particular area.

Silica: When silica, the mineral dust founded in stone, soil, sand, concrete, brick, mortar, and other construction materials, is inhaled by workers, it can cause silicosis or other fatal lung diseases. During recovery and reconstruction operations, working with power tools, including stationary masonry saws, vehicle-mounted drilling rigs, tuck-pointing/mortar removal, hand-operated grinders, rotary hammers, jackhammers, and handheld masonry saws, creates lots of silica dust. Silica dust generates serious problems for respiratory systems. Breathing infected silica air might result in symptoms such as chest pain, sputum cough, and difficulty in usual breathing. Vacuum dust collection systems and wet methods (wet cutting) are the most suggested approaches in coping with the potential hazards, effectively mitigating the amount of silica during recovery and reconstruction operations.

15. TRANSPORTATION

The Bureau of Labor Statistics (BLS) reveals that in 2013, transportation incidents accounted for 40% of fatalities among all fatal occupational injuries. Following a disaster, the noisy and chaotic situations that will distract workers' concentration could lead to higher fatality and injury rates. Different types of workers involved in recovery operations are exposed to struck-by hazards associated with motor vehicles and mobile equipment. Therefore, particular regulations should be enacted in order to keep workers safe. In the areas with the potential hazards of being hit by motor vehicles, a traffic control plan should be ratified. Also, employing signs, traffic control devices, work zone protection, flagging and lighting suggested by OSHA, could effectively decrease the amount of incidents and precipitate the planned services for people in exposed area.

16. FIRE

After a disaster, the existence of ignitable debris and smoldering wood, along with the release of gas and oil, raise the probability of a fire or explosion. Contacting a heat source material or flammable substance with oxygen could cause a giant flame that might also cause workers to inhale ash, soot, and other substances. Furthermore, products spoiled by a fire could breed bacteria. Generally, hazards that might threaten worker health, after a combustion are as follows: electrocution, carbon monoxide, musculskeletal hazards, extreme heat, being struck by projected materials, getting stuck in confined spaces, fatigue, and respiratory problems. Therefore, workers should pay attention when working in such a dangerous conditions. It is recommended that they carry fire extinguishers during these recovery operations.

17. WILDLIFE INCIDENTS

Facing natural hazards during post-disaster recovery and reconstruction, could be a contingent scenario. According to collected data during recovery operations of Hurricane Katrina, alligators and snakes were seen in some drainage pipes. In addition, there are other reports associated with alligator encounters in flood waters. Apart from running across wild animals, plants such as poison ivy, poison oak, and poison sumac could cause injuries to workers. Therefore, workers should prepare themselves for these unforeseen hazards. Report these hazards to supervisors and assist workers in confronting and handling these hazards.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

To keep workers safe during different operations, employers should provide proper personnel protective equipment (PPE) for workers. PPE is defined as any clothing and accessories that hinder hazard occurrence for workers in the exposed area.

Different types of PPE are used in recovery operations after a disaster. Table 3 lists some of the most common PPE used for various body parts.

Body Part	Protection
Head	Hard hat
Eye	Goggles, safety glasses
Face	Face shield
Hearing	Earmuffs, earplugs
Feet	Safety shoes
Hands	Gloves
Bodies	Vests
Respiratory System	Masks and respirators

Table 3. Common personnel protective equipment for different parts of the body.

HEAD PROTECTION

Head injury is a common incident in recovery operations after a disaster. People who are working in debris removal can be exposed to flying debris or falling objects due to structural collapse. Thus, wearing proper head protection can help workers keep their heads safe from these hazards. There are three diverse classes of head protection:

Class A: This hard hat is used in general services such as mining, construction, shipbuilding, tunneling, lumbering and manufacturing. It is made of insulation substances in order to keep the workers safe from being struck by flying objects and electrocution up to 2,200 volts.
Class B: This type of hard hat is used by electrical workers since it can protect workers against up to 20,000 volts. This kind of helmet was produced for workers in utility services.

Class C: This type of hard hat is manufactured from aluminum and is used to provide lightweight comfort and minimum protection. In contrast with the previous types, it is not resistant against electrocution and corrosive substances.

EYE PROTECTION

Safety glasses, goggles, and laser safety goggles are the most important devices used to protect eyes. Flying objects and dust, molten metal (which poses danger from splashing), corrosive gases and vapors, light radiation during welding, and contaminated materials are some hazardous exposures against which workers' eyes should be protected.

a) **Safety glasses**: In most cases, they are designed with a metal/plastic frame and side shields. They can be used for moderate impacts in different operations.
b) **Goggles**: The purpose of this equipment is to keep eyes and the surrounding area safe from impacts, dust and splashes.
c) **Laser safety goggles**: These goggles protect eyes against drastic radiation light in welding.

Figure 2. Eye protection: (a) safety glasses; (b) goggles; (c) laser safety goggles.

FACE PROTECTION AND WELDING SHIELDS

Face shields create a barrier between face, dust, and splashes. However, they are not resistant against impacts. Thus, wearing eye protection underneath a face shield is required. In addition, a welding shield is used to protect eyes and face against radiation rays, sparks, and particles during welding.

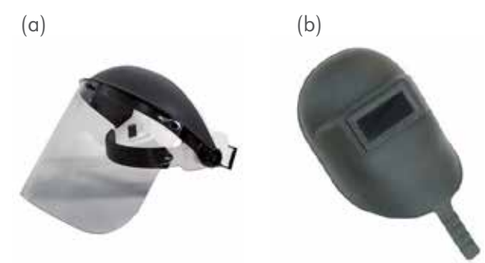

Figure 3. Face protection: (a) face protection; (b) welding shield.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

More than 500,000 hand injuries occur every year in the U.S. These injuries not only have adverse consequences for injured workers, but they also are costly for employers.

HEARING PROTECTION

To protect workers' hearing during operations, ear muffs, canal caps, and earplugs are used. If noise is unavoidable, these devices will protect workers from noise hazards (85 dB is the criterion for noise hazard).

(a) (b) (c)

Figure 4. Types of hearing protection used in recovery operations: (a) ear muffs; (b) canal caps; (c) ear plugs.

FOOT PROTECTION

Foot and toe injuries are responsible for 20% of all disabilities in the construction industry. Cause of most foot and toe injuries include:

- Impact by heavy objects
- Impact by sharp devices such as nails or spikes
- Compression by a roll-over object
- Exposure to molten metal
- Electrocution by energized sources
- Slipping on hot and wet surfaces (unstable)
- Puncturing through the sole

To protect against these hazards during recovery operations, different kinds of protective shoes should be used, as described in Table 4 and shown in Figure 5.

Kind of Shoes	Materials	Hazard
Steel toe	Metal in front	Impact
Rubber or vinyl	Rubber, synthetic and vinyl (avoid leather)	Chemical
Puncture resistant sole	Metal insole	Sharp object
Electrical resistant	Metal free or boots	Electrical shock
Heat resistant sole	Fiberglass, aluminum alloy, galvanized steel	Hot surface such as roofing or paving
Electrical conductive	-	Explosive
Slip resistant sole	-	Slippery surface

Table 4. Types of protective shoes that should be used in particular conditions in post-disaster recovery.

(a)

(b)

Figure 5. Protective shoes: (a) steel toe; (b) rubber.

HAND PROTECTION

More than 500,000 hand injuries occur every year in the U.S. These injuries not only have adverse consequences for injured workers, but they also are costly for employers. To protect hands against burns, bruises, abrasions, cuts, punctures, fractures, amputation and chemical exposures in diverse recovery operations, the various types of gloves described in Table 5 are recommended by OSHA.

Type of Gloves	Protection
Durable (metal, mesh, leather or canvas)	Cuts, burns, and heat
Fabric and coated fabric	Dirt or abrasions
Chemical and liquid resistant	Burns, irritation, and dermatitis
Butyl rubber	Cuts and abrasions; specifically against solvents, chemicals, and petroleum
Nitrile rubber	Gas and water vapors; specifically, chemicals and heat
Kevlar	Cuts, slashes, and abrasions
Chain link or metal mesh	Maximum abrasion and cut resistance
Polyethylene	Abrasion resistance, but has some weakness in cut resistance and high temperatures
Aramids	Cuts, abrasions, and heat resistance
Stainless steel cord	Cuts and lacerations

Table 5. Types of gloves that should be used for specific kinds of protection in the post-disaster situation.

(a)

(b)

Figure 6. Gloves: (a) fabric; (b) polyethylene.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

After evaluating the area that was hit by the disaster, the most appropriate equipment based on the operations (e.g. rescue operation, recovery and cleaning up operations, debris removal, unwatering and finally reconstruction) should be selected.

BODY PROTECTION

Intense heat, splashes of hot metal during reconstruction, radiation, chemical hazards, handling of animal and human remains, and impacts from tools and machinery are the major causes of bodily injury during diverse recovery operations. Some common body protection equipment includes vests, aprons, jackets, coveralls, full body suits, and sleeves.

Figure 7. Body protection: (a) sleeves and aprons; b) cooling vests; (c) full body suit; (d) safety coveralls.

RESPIRATORY PROTECTION

To protect workers who are exposed to dust, fog, fumes, mist, gasses, smokes, sprays, or vapors during recovery operations while entering confined spaces, OSHA obliges workers to put on respirators. Air filtering and air supplying are two types of respirators.

a) **Air filtering:** This respirator filters the toxic particles and allows workers to breathe purified air. It is designed in 3 classes, each of which has 3 different levels: 95%, 99% and 99.97%. The classes are explained in Table 6.

Type of Filters	Using Situation
Class N	Used in an oil-free environment
Class R	Used in every contaminated atmosphere. The filter should be changed after the specified duration (oil resistant but not oil proof)
Class P	This respirator can be used everywhere (oil proof)

Table 6. The usage of different types of respirators based on the situation.

b) **Air supplying:** When the atmosphere contamination is drastic, workers have no choice except to use an air supplier. It provides fresh air from a tank and completely blocks air from the environment.

CHOOSING THE RIGHT LEVEL OF PROTECTION

The Environmental Protection Agency (EPA) has divided the utilization of PPE into four levels of protection.

Level A protection: When the greatest potential hazards might occur, using the following PPE is highly recommended:

- Positive pressure, full-face piece self-contained breathing apparatus (SCBA) or positive-pressure supplied air respirator with escape SCBA
- Totally encapsulated chemical- and vapor-protective suit
- Inner and outer chemical-resistant gloves
- Disposable protective suit, gloves and boots

Level B protection: In a slightly less hazardous outdoor waste site that has the probability of different vapor and gas emissions, EPA suggests the following PPE:

- Positive pressure, full-face piece SCBA or positive-pressure supplied air respirator with escape SCBA
- Inner and outer chemical-resistant gloves
- Face shield
- Hooded chemical resistant clothing
- Coveralls
- Outer chemical-resistant boots

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Intense heat, splashes of hot metal during reconstruction, radiation, chemical hazards, handling of animal and human remains, and impacts from tools and machinery are the major causes of bodily injury during diverse recovery operations.

Level C protection: When the criteria for using air purifying respirators are known, these types of PPE will be used:

- Full-face air purifying respirators
- Inner and outer chemical-resistant gloves
- Hard hat
- Escape mask
- Disposable chemical-resistant outer boots

Level D protection: When minimum protection is required, this level of protection is suggested:

- Gloves
- Coveralls
- Safety glasses
- Face shield
- Chemical-resistant, steel-toe boots, or shoes

After evaluating the area that was hit by the disaster, the most appropriate equipment based on the operations (e.g. rescue operation, recovery and cleaning up operations, debris removal, unwatering and finally reconstruction) should be selected. Training the workers how to use PPE is another important issue that should be taken into account.

FALL PREVENTION

Falls are the leading cause of deaths in the construction industry and are responsible for around 34% of fatal injuries in this field.

Ladders, scaffolds, work platforms, form works, bridges, structural steel openings, reinforcing steel, stay-in-place decking, cluttered/congested areas, and excavations are the most probable locations in which falling can occur on construction sites. Fall protection systems used in the construction industry comprise guardrails, safety net systems, positioning device systems, personal fall arrest systems, warning line systems, control of access zones, and safety monitoring systems. Six feet is the height limit used to implement the fall protection systems.

GUARDRAILS

A proper guardrail should have the following features:

- The guardrail must be between 39-45 inches tall
- The toe board should be 3½ inches high
- The guardrail should be able to endure a force of at least 200 pounds
- The front edge of platforms must not be more than 14 inches from the work area, unless using guardrails and/or a personal fall arrest system

Elevated work platforms, scaffolds, openings in floors, other unprotected surfaces, and unprotected sides of ramps/stairways/platforms are the conditions in which guardrails should be applied.

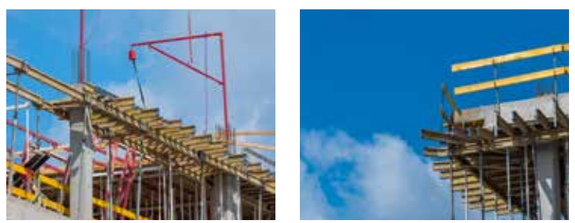

Figure 8. Using guardrails at unprotected edges.

FALL PREVENTION

Preventing falls in conjunction with distributing the energy of impact is the main purpose of PFAS.

SAFETY NET SYSTEMS

Safety nets must be installed as close as possible to the place where falling may potentially occur and should be at a maximum of 30 feet below the promontory. Table 7 shows the accurate vertical and horizontal distance at which the net should be installed. In addition, the safety net must withstand 5,000 pounds.

Vertical	Horizontal
Less than 5 feet	8
Between 5 and 10 feet	10
More than 10 feet	13

Table 7. The accuracy of installing a safety net.

Figure 9. Safety net.

PERSONAL FALL ARREST SYSTEM (PFAS)

Preventing falls in conjunction with distributing the energy of impact is the main purpose of PFAS. It includes the following components, the features of which are listed in Table 8 and illustrated in Figure 10:

- Anchorage (component and structure)
- Body support (full body harness and safety belt)
- Connector (lanyard, lifeline, and devices)

Components	Features
Connectors	Smooth and made of drop-forged, pressed or formed steel
Dee-rings and snap hooks	At least 5,000 pounds
Lanyard and lifeline	At least 5,000 pounds
Anchorages	At least 5,000 pounds

Table 8. The features of PFAS's components.

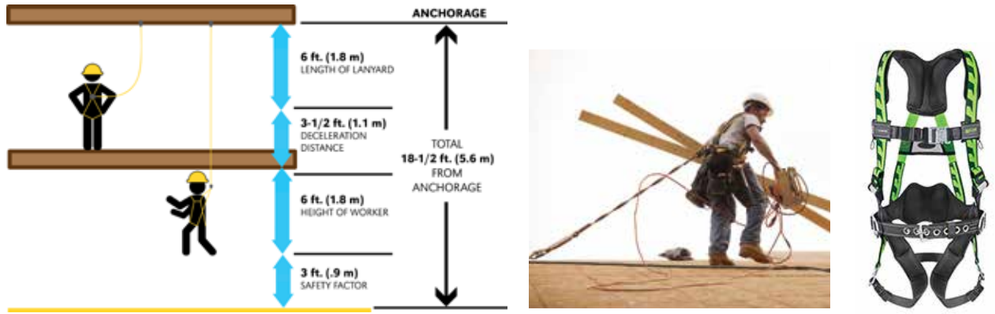

Figure 10. Personal fall arrest system.

COVERS

As an alternative to guardrails, holes/openings can be covered completely and securely. When using covers for openings, the following circumstances should be noted:

- Vehicular traffic – cover must support 2 times the maximum axle load of the largest vehicle
- Foot traffic – cover must support 2 times the weight of expected load
- Covers should be secured to prevent displacement
- Covers should be marked "holes/covers," color-coded or marked with a similar warning

Figure 11. Broken skylight without a cover.

POSITIONING DEVICE SYSTEMS

As an alternative to a personal fall arrest system and to ensure a worker's free-fall is no more than 2 feet, positioning device systems should be used. Features of positioning device systems are:

- The whole system should have a strength of 3,000 pounds
- Snap hooks and dee-rings used in the system should withstand 3,600 pounds
- Connecting assemblies should tolerate a force of 5,000 pounds

Figure 12.
Position device system.

STRUCK-BY INJURY PREVENTION

Among 4,405 fatal injuries that occurred in 2013, 16% happened due to contact with objects and equipment, and 11% occurred as a result of struck-by accidents.

Struck-by accidents are common in recovery after disasters. In addition, these are the most common struck-by hazards in the construction and reconstruction industry:

- Falling objects (from cranes and scaffold platforms)
- Impact by heavy equipment and motor vehicles
- Impact by tools (hand tools, powder actuated tools, and compressed air)

Therefore, OSHA (2011) offers guidelines in each area to prevent injury.

FALLING OBJECTS

- Wear hard hats.
- Use toe boards (3½ inch height and 50 pounds strength) and guardrails in scaffolds, aerial lifts and near the edges.
- Use a panel or screen if the toe board does not have sufficient height.
- Build a canopy or erect a net below the reconstruction area.
- When working at a height, store and remove materials at least 4 feet from the edge.

HEAVY EQUIPMENT AND MOTOR VEHICLES

- Avoid going near equipment and vehicles during operations.
- Install safe guards to barricade the hazardous area where machinery is operating.
- Be aware of the radius zone of cranes and do not enter that area during operations.
- Avoid excess or unbalanced loads on trucks and vehicles.

TOOLS

Tools might cause struck-by injuries, electrocution and caught-in hazards. Thus, considering how they should be used is of utmost importantance. Tools used in construction operations can be classified as hand tools and power tools. Common hand tools used in construction projects that might cause injuries are saws, pliers, hammers, screwdrivers, and shovels. Misuse and improper maintenance are the main reasons of injuries for people who are using hand tools.

On the other hand, power tools are classified into five major groups: electric, pneumatic, liquid fuel, hydraulic, and powder actuated. If any of these tools does not have a proper guard (safe guards should be in placed around moving parts such as belts, gears, and shafts) or safety switche, working with them is not recommended.

Using hand and power tools could cause fumes, dust and sparks; generating flying, abrasive and splashing substances; electrocution, etc. Wearing safety glasses, gloves and ear protection, using power tools properly, maintaining the tools with care, training with the tools before using them in operations, and inspecting the tools before usage are some of the most common safety rules associated with tools. To have a better understanding of these guidelines, some related-directions are provided below:

Compressed Air

- Decreasing the air pressure to 30 psi if it is applied for cleaning
- Workers should avoid dead-ending them against themselves

Hand Tools

- The usage of impact tools with mushroomed heads along with tools with cracked handles should be avoided

Jack Hammers and Pavement Saws

- Checking the tools before using
- Workers should practice before using these tools in the operation
- Using personal protective equipment (PPE), particularly, safety shoes, ear protection, and safety glasses

Abrasive Wheel Tools

- Inspecting the tools
- Workers should not stand in alignment with the abrasion wheels since fragments might be projected

Saws, Drills, Grinders

- Operating within their design limitation
- Checking the tools before using

Pushing or Pulling Objects That May Become Airborne

- Preserving the tools against sliding and falling
- Preserving the tools against wind

Liquid Fuel Tools

- Being cautious about maintaining fuels
- Tools need to be both off and cool before refilling

Powder Actuated Tools

- Only trained workers are allowed to use these tools
- Not loading the tools unless they will be used immediately
- Adjusting the speed level of these tools before usage
- These tools can easily get combusted. Therefore, attention should be paid to its usage instruction

Hydraulic Power tools

- Fire resistant fluid should be used for these tools
- Stop indicators and stop loading limits should not be exceeded in jacks
- Safe pressure should be adjusted for these tools

CAUGHT-IN INJURY PREVENTION

According to Bureau of Labor statistics, of the 717 fatal injuries occurring due to contacting objects and equipment in 2013, 105 were due to caught-in hazards.

The most common types of caught-in hazards in the construction industry are being caught by unguarded machinery, buried during excavation operation and pinned between pieces of equipment. During excavation and demolition operation after disasters, workers are exposed to caught-in hazards. Thus, the following points should be taken into consideration:

- A supervisor should monitor the whole process and area.
- Protection is required in excavations deeper than 5 feet or if there is a possibility of a cave-in.
- Excavations must be inspected daily.
- Access/egress is required for work occurring below 4 feet deep.
- A rescue plan must be in place.
- Types of soil (stable, moderately stable, and least stable) must be considered.

OSHA (2011) suggests that workers follow these protective guidelines to avoid caught-in hazards:

- Use machinery and tools that are appropriately guarded (safe guarded).
- Wear visible clothes so truck drivers will see them to minimize the danger of being struck or crushed.
- Avoid placing oneself between moving material and an immovable object.
- Provide protection in excavation (see Figure 13):
  a. Slope or bench the sides of excavation.
  b. Fortify the sides of the excavation by shoring (supporting devices such as a wooden structure, mechanical or hydraulic system).
  c. Place a trench box or shield between the sides of excavation (this may not prevent a cave-in, but it can protect workers).

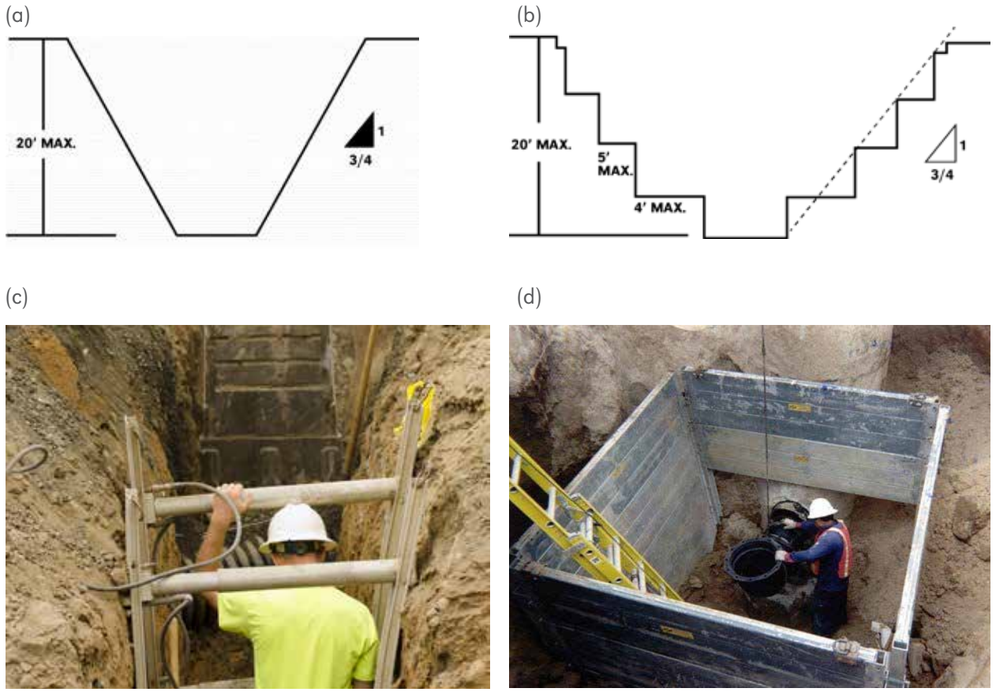

Figure 13. Protection in excavation: (a) sloping; (b) benching; (c) shoring; and (d) trench box.

ELECTROCUTION PREVENTION

Electrocution is the fourth leading cause of death and injuries in the construction industry. Every week, approximately five workers are injured from electrocution.

The death rate from electrocution in 2005 was 1.1 per 100,000 workers, or an average of 121 electrocutions per year. Contacting overhead and buried power lines, touching energized sources, and inappropriate usage of cords, are the critical causes of electrocution. After a disaster, workers can be exposed to electrocution hazards because of downed energized power lines or use of electrical generators.

Therefore, workers should consider the following controls to guard against electrocution:

PROPER PPE

- Appropriate foot protection (non-conductive shoes)
- Rubber insulating gloves, hoods and sleeve matting
- Hard hats (non-conductive)
- Insulated tools

Figure 14. Examples of rubber insulated gloves.

INSPECTION OF THE ISOLATION OF ELECTRICAL PARTS

- Use guards with electrical equipment (required for more than 50 volts)
- Use proper covers to separate electrical sections from other sections

OVERHEAD POWER LINE PROTECTION

- Keep a safe distance from overhead power lines (10 feet)
- Use non-conducting ladders (e.g., ladders made of wood or fiberglass)
- Train workers before working with power lines

CONTROL OF WIRES AND CORDS

- Inspect the insulation condition of wires and cords
- Use fixed cords rather than flexible cords
- Use extension cords accurately
- Use cords that have use of ground wire and are hard or extra hard

GROUND FAULT CIRCUIT INTERRUPTERS (GFCI)

- Apply GFCI on all 120-volt hand-held power tools.
- Use fuses and other circuit breakers when the current is greater than advisable.

FOLLOW LOCK OUT/TAG OUT PROCEDURE

- Lock the power sources after de-energizing.
- Use tags to shut off controls.
- Tag de-energized equipment and circuitry.
- Use tags to identify equipment and circuitry being worked on.

Figure 15. Ground fault circuit interrupters.

Figure 16. Lock out/tag out procedure.

CHEMICAL EXPOSURE PREVENTION

During different post-disaster operations, such as debris removal, welding, and cutting, workers are exposed to a large number of chemical hazards.

Exposure to hazardous chemical materials might cause problems in various organs of the body, such as the lungs, skin, eyes, and mucus membranes. Headache, skin rashes, dizziness, nausea, excitability, weakness, and fatigue can be listed as the most noticed symptoms of exposure to chemicals. In addition, inhalation, absorption, ingestion, and injection are the four major ways that chemicals can enter a worker's body. To provide helpful protection guidelines, chemicals are categorized into five major groups as gases, vapors, fumes, dust and fibers, and mists.

Wearing suitable respiratory protection, gloves (chemical- and liquid-resistant), steel toe boots, goggles, outer clothing (coveralls and chemical aprons), and other PPE are commonly suggested to reduce the severity of chemical hazards.

Inhalation is one of the most common ways chemicals come into a worker's body. Therefore, using appropriate respiratory systems based on chemical forms that workers will be exposed to should be taken into consideration. High Efficiency Particulate Air (HEPA) filters should be used where airborne particles are less than 10 microns (μm). Various airborne hazards and the most useful respiratory systems to prevent inhalation are described here.

GASES

Respirators should consist of acid gas cartridges, organic vapor, and multi-vapor gas cartridges.

VAPORS

Respirators should include organic vapor cartridges, organic vapor acid gas cartridges, and multi-vapor gas cartridges.

FUMES

According to the situation, various classes of filtered respiratory protectors (as described in the PPE section), could be used. However, the most suitable respirator for asphalt fumes is any half-face piece, air purifying, P100 and R100 combined filter respirators, which is equipped with organic vapor cartridge.

Chemical Form	Example	Causes
Gases	Welding gases	Welding arc, burning process, and ultraviolet radiation action
	Carbon monoxide	Incomplete combustion of fuels; welding
	Hydrogen sulfide	Decomposition of organic matters (sewers)
Vapors	Solvents	Glue solvents and paint thinners
	Gasolines	Fuel
	Paints and coatings	Painting
Fumes	Lead	Melting of lead for making cast iron joints
	Hexavalent chromium (CrVI) – stainless steel	Stainless steel and chromium metals
	Zinc (galvanized metals)	Welding
Dust and fibers	Asbestos	Insulation
	Silica (concrete)	Making concrete
	Lead	Painting, cutting metals, sawing metals, scraping rust, and coating (demolition)
Mists	Paints and coatings	Pesticide spraying and paint spraying operation
	Lubricants	Cutting operation

Table 9. Five different chemical categories.

DUST AND FIBERS

Workers should wear 100-level HEPA respirators when they are exposed to silica, lead, and asbestos. In addition, 95-, 99- or 100-level HEPA respirators should be employed while working in conditions that are prone to fiberglass insulation and nuisance dust.

MISTS

Based on the amount of oil in the environment ("P", "R" or "N"), workers are supposed to wear filter respirators. The effectiveness of the aforementioned respirators is the same as 95-, 97-, and 100-level HEPA respirators.

Examples for each kind of respirator are provided in Figure 17.

(a) (b) (c) (d) (e) (f)

Figure 17. Examples of various respirators: (a) HEPA; (b) exposure to gases–3M organic vapor (yellow)/acid gas respirators 5000 series; (c) exposure to vapors–North 7700 series half-face respirator equipped with organic vapor acid gas cartridge; (d) exposure to fumes–MSA Advantage Series 420 half-mask respirator; (e) exposure to dust and fibers; (f) exposure to mists–AO Safety 95110 paint spray respirator.

BIOLOGICAL HAZARD PREVENTION

During demolition, cleaning up operations, debris removal, landscaping, rescue operations and unwatering, workers are exposed to several biological hazards.

First, a typical source of biological hazard is contaminated water. For example, after Hurricane Katrina, 114 million gallons of water were removed from New Orleans; however, since the water was mixed with animal and human sewage, decaying bodies, oil, gas, and other chemicals, it was highly contaminated. Second, the polluted water can provide a nurturing condition for mosquitoes and parasites to reproduce. In disaster areas, workers are exposed to a high risk of related diseases (hepatitis, tuberculosis, tetanus, Leptospira and Legionella). Allergies, dermatitis, asthma, sinusitis, and lung disease are the most common symptoms of infections by biological hazards.

Another source of biological hazards are mold and fungi (mushrooms, mildews, and yeasts) that easily grow in wet conditions. In fact, it is common for cleanup workers to get engaged with removing moldy building materials, crumbling vegetation, decaying waste substances, and other fungi- infected things. During this process, workers might inhale airborne fungi and their spores. Inhalation of these substances could result in diseases and allergies such as eye irritations, wheezing, and nasal stuffiness.

In face of biological hazards in recovery operation, remembering the following suggested rules provided by OSHA could assist workers:

- Not drinking the flood water under any circumstances. Drinking water that has been boiled or confirmed as safe is allowed.
- Using appropriate personal protective equipment (PPE). For instance, gloves and eye protection, and verified respiratory protection (at least N-95) by NIOSH are highly recommended.
- Using a 10% bleach water solution is an effective method to disinfect molds.
- Shedding all of the water-damaged materials. If a material is thought to be covered by mold, it should be disinfected by water and a disinfectant like bleach.
- In order to prevent the wide spread of fungal materials, molds, and other fungi should be placed in an isolated plastic bag and then discarded.
- Due to sweating resulting from the activities during operations, workers are exposed to fungal skin infections. Therefore, washing the skin with warm soapy water and keeping it as dry as possible is important.

In addition, after a disaster, due to the moist conditions, deficient hygiene, and prevalence of animal corpses a large number of rodents might surge into exposed areas. Increased incidence of rabies aside, the presence of rodents make their hunters (snakes, scorpions, and spiders) follow them into the regions. Therefore, careful attention should be paid to natural hazards. Being cautious in drainage pipes in conjunction with wearing proper pants, boots, gloves and outer clothing will help workers to keep themselves safe during operations.

Figure 18. Hand washing protects workers against diseases.

Following safety practices can keep workers safe against biological hazards during post-disaster recovery and reconstruction.

HANDWASHING

It is suggested to shed all of the water-damaged materials. Sanitizing hands with materials such as alcohol can even reduce the amount of biological hazards that might be problematic for workers.

PROPER PERSONAL PROTECTIVE EQUIPMENT (PPE)

- Waterproof boots with steel toe and insole
- Impenetrable coveralls and body suit (chemical-resistant suits)
- Rubber or latex gloves
- Non-vented goggles
- Appropriate respiratory protection (full-face piece, elastomeric, air purifying respirator—any combination of N, R & P with efficiency 95%, 99%, or 100%).

Figure 19. Full-face piece respirators suggested by NIOSH guard against mold.

IMMUNIZATION OF WORKERS

Immunization against contagious disease (tetanus, coli, hepatitis A, salmonella, typhoid, diarrhea, and abdominal cramps) resulting from the contaminated areas is another crucial step which should be taken into consideration. For example, tetanus is a bacteria impacting the nervous system and creating muscle spasms. Thus, being up to date with vaccinations and shots is imperative.

Use of insect repellent, sun block, and lip balm is required for workers who are involved in disaster areas.

Figure 20. Immunization against bacteria and viruses.

ERGONOMIC HAZARD PREVENTION

Ergonomic hazards, also known as cumulative trauma disorders and musculoskeletal disorders, are the most widespread causes of injuries among workers in the United States.

Ergonomic hazards are possible hazards that might happen due to the poor relation between work features and mental and physical abilities of the employees. Tendinitis, carpal tunnel syndrome, thoracic outlet syndrome, tenosynovitis, bursitis, sprains, strains, and other pains are some of the most prevalent effects of ergonomic hazards.

Ergonomic hazards that can take place during recovery and reconstruction operation may have several causes:

- Awkward postures (prolonged work in an abnormal body position)
- Prolonged repetitive motions
- Forceful pulling, pushing, and lifting
- Static postures (sustained body positions without any movement)
- Fast movement
- Vibration
- Lack of adequate recovery time
- Contact stress (touching a hard or sharp object again and again)

(a) (b)

Figure 21. (a) Workers should reduce the distance between body and load when they are picking up loads. (b) Prolonged work in an abnormal position can be a hazard.

The following guidelines could be significantly helpful for workers to prevent ergonomic hazards.

1. Wear proper PPE (vibration-absorbing gloves, rubber mats, braces, wrist splints, and back belts).
2. Exercise and stretch at the beginning and conclusion of each day.
3. Rotate job assignments to prevent work repetition.
4. Change the products transportation approaches. For instance,
   a. Use assist devices for lifting heavy products
   b. Reduce the distance between the load and the body while lifting
   c. Avoid excessive twisting
   d. Do not traverse with the load more than 10 feet.
5. Revise the process or product to diminish vulnerability to hazardous factors.
6. Modify workstation layout so tools or equipment are easy to reach.
7. Use proper hand tools that are comfortable for workers.
8. Avoid lifting objects weighing more than 50 pounds by just one person.

Figure 22. Exercising and stretching at the beginning and conclusion of each workday could help workers considerably hinder ergonomic hazards.

WEATHER-RELATED HAZARD PREVENTION

It is common for workers involved in post-disaster recovery to work in extreme weather. However, working in such conditions might cause exhaustion or expose workers to different types of diseases.

Therefore, working under specific weather conditions can be considered hazardous. These types of hazards are divided into two major groups.

HEAT

Workers who work outdoors in hot and humid weather should wear suitable PPE. Heat cramps, heat exhaustion, heat rashes, and heat stroke are the outcome of prolonged heat exposure. When workers are exposed to sun, their skin might be affected drastically. Sunburn is the most obvious symptom of these hazards. Prolonged exposure to sun over time can cause skin cancer.

Figure 23. Working in hot weather.

When the weather is extremely hot, several measures should be employed to protect workers:

1. Wear proper PPE (wide brim hard hat, UV absorption sunglass)
2. Use sun screen
3. Wear long-sleeved, light-colored, loose-fitting cotton clothing
4. Eat in small portions
5. Avoid drinking caffeinated beverages or alcohol
6. Provide cool liquids for workers
7. Allow frequent breaks.

In addition to hot weather, humidity can also cause discomfort with workers. Table 10 indicates the relationship between humidity and comfort.

Humidity(%)	Level of Comfort
20-29	Comfortable
30-39	Moderate degree of comfort
40-45	Uncomfortable
Over 46	Many workers must be restricted

Table 10. Relationship between humidity and comfort.

(a)

(b)

Figure 24. (a) Wide brim hard hat; (b) UV absorption sunglasses.

COLD

Working in a cold weather (below 32°F) for a long time could be extremely hazardous for workers. The condition can be even worse when weather becomes windy and wet. Potentially fatal injuries caused by cold weather are frostbite, hypothermia, and trench foot. There are several effective ways to mitigate the impact of cold weather for workers involved in such risky conditions.

1. Wear proper clothes.
   a. Several layers of clothing
   b. Warm gloves and hats
   c. Several socks—footwear should not be tight nor penetrable
   d. Scarf to cover the entire face
2. Drink a lot of hot drinks (drinks with caffeine and alcohol should be avoided).
3. Take regular breaks.
4. Report any weird symptoms to the supervisor.

Figure 25. Working in cold weather.

NOISE

Every year around 30 million construction workers suffer from injuries caused by noises generated on construction sites. Prolonged exposure to high levels of noise can cause hearing loss.

Workers can get distracted by high levels of noise and get injured. In recovery operations, the exposure to high levels of noise can be even more significant. For instance, using heavy equipment to remove debris or reconstructing drywalls using a pneumatic chip hammer are common sources of noise in recovery operations.

According to OSHA, when noise levels exceeds115 dB, it is considered hazardous. On the other hand, noise levels below 80 dB is considered to be safer for workers. Table 11 depicts the relationship between noise exposure and sound level.

Hours Permitted Per Day	Sound Level (dB)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Table 11. Exposure to high-level noises.

In addition, these are the most common noise-producing tools used in recovery and reconstruction projects and ways to mitigate noise hazards.

- Equipment that makes noise over 100 db and requiring immediate usage of noise hazard protection includes pneumatic chip hammers, jackhammers, concrete joint cutters, chain saws, impact wrenches, pile drivers, bulldozers (no cab), sandblasters, compressed air blowers, and pavers.
- Equipment that makes noise around 90-99 dB and requiring noise hazard protection includes portable power tools (router, circular saw, drill, sander), table saws/planers, tampers, cranes, hammers, earthmovers, front-end loaders, and metal shears.
- Equipment that makes noise between 85-89 dB for which noise hazard protection is recommended includes welding machines, heavy equipment (in cab), backhoes, and concrete mixers.

Figure 26. Exposure to high-level noises.

To most effectively mitigate noise hazards, workers should:

- Wear hearing protection devices (ear muffs, canal caps and ear plugs—see the earlier section on PPE for more information about ear protection equipment)
- Decrease the noise from the source
- Disrupt the noise path
- Diminish reverberation
- Reduce structure-borne vibration
- Monitor workers to observe the regulation.

PSYCHOLOGICAL

The workers in post-disaster rescue and recovery operations, as the first responders, are considerably exposed to psychological hazards. Working in a high-stress environment is one of the main causes of post-traumatic stress disorder (PTSD).

Long term and intensive work including observation injuries to others, personal injuries or loss of loved ones, and encountering dead bodies are some factors increasing stress and post traumatic stress disorder (PTSD). PTSD was found in 90% of workers involved in recovery after a disaster operation. Headaches, loss of sleep, nervousness and nightmares are some symptoms of PTSD.

Consequences of psychological hazards are subdivided into three groups:

1) Substantial distress responses: sleep disturbance, fear, anxiety, anger and sadness
2) Mental health and illness: post traumatic stress disorder (PTSD), acute stress disorder (ASD), and depression
3) Behavioral changes in high stress environment: smoking, alcohol use, and over-dedication

All previous studies agree that improvements in social science research can mitigate injuries and fatalities in this area.

To control psychological hazards, workers exposed to psychological stresses should be provided with periodic medical treatment, counseling services, training programs (e.g., relaxation, medication and biofeedback), and recreational activities.

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