

Exposure Assessment To Inhalable And Respirable Dust In The Post-Earthquake Construction Sites In The City Of L'aquila

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Abstract

Following an earthquake occurred in the middle Italy in 2009, the involved territory hosted in ten years thousands of construction sites. The aim of this study is to assess the chemical exposure of the construction workers involved in the reconstruction of the city. To assess the exposure we collected 91 air samples to quantify the occupational exposure to airborne dusts and free crystalline silica dusts. Six construction companies joined the study and hosted the air sampling activities. We identified 4 work tasks: bricklayer and similar; scaffolder and carpenter; manual demolition; other tasks. Personal air sampling was performed by using the SKC AirCheck XR5000 sample pumps. Respirable dust and respirable crystalline silica dusts were collected by using a GS-3 Cyclones and 25 mm PVC filters; inhalable dust was collected by using a I.O.M. sampler and 25 mm PVC filters. The analyses were carried out by using gravimetric determination. Sampling time varied from 4 to 8 hours. The geometric mean values of inhalable dust concentration for the work tasks was: 3,65 mg/m³ for scaffolder and carpenter; 18,16 mg/m³ for manual demolition workers; 8,76 mg/m³ for bricklayer and similar; 6,33 mg/m³ for other work tasks. The geometric mean values of respirable dust concentration for the work tasks was: 0,67 mg/m³ for scaffolder and carpenter; 0,92 mg/m³ for manual demolition workers; 0,72 mg/m³ for bricklayer and similar; 0,45 mg/m³ for other work tasks. About the Crystalline Free Silica dust exposure, the average concentration in mg/m³ was: 0,0038 for manual demolition workers, 0,0057 for scaffolder and carpenter, 0,004 for bricklayer and similar, 0,0035 for other tasks. The comparison of the results shows that manual demolition workers are exposed to considerably high levels of inhalable dusts, exceeding the ACGIH TLV-TWA limit of 10 mg/m³. About the respirable dust concentration, none of the work tasks dust concentration exceeded the ACGIH TLV-TWA limit of 3 mg/m³. Measurements of crystalline silica dust have shown levels below the threshold limit value of 0,025 mg/m³. This is in line with the average concentrations of respirable dust.

Background

Following the 2009 earthquake, 8,124 construction sites have been erected across the territory which surrounds the city of L'Aquila. Of these, 592 construction sites are currently in place and operating [1]. Construction site activities involve significant risks and hazards associated with chemical exposure from work processes or from the generation of substances and mixtures; thus workers in construction industries are commonly exposed to fibres and dust with variable aerodynamic diameter, particularly workers in building demolition sites [2, 3]. The purpose of this study was to determine the dust exposure levels accounting for the work environment. The construction industry includes several sectors and work tasks. Thus, due to the variation between the different work tasks within construction sites, it can be difficult to assess or quantify accurately dust exposure levels among construction workers [4]. Dust exposure on construction sites may cause respiratory diseases, such as Chronic Obstructive Pulmonary Disease (COPD) [4, 5].

The deposition of dust within the respiratory tract is dependent on particle size and shape. Particles can be classified based on the inhalable, respirable and thoracic fraction of dust. The inhalable fraction is

defined as the fraction of airborne particles which is inhaled through the nose and mouth and deposits in the upper respiratory tract. The respirable fraction is defined as the fraction of airborne particles capable of passing beyond the larynx. The thoracic fraction is defined as the fraction of inhaled airborne particulate matter that can penetrate the head airways and enter the airways of the lung [6].

Crystalline Free Silica (CFS) particles are classified as respirable crystalline silica due to their granulometry and whose inhalation may cause pulmonary diseases. Crystalline silica is widely used in many construction sites and is a natural substance found in rocks, sand, clay, and gravel [7].

Crystalline free silica particles smaller than 10 µm in aerodynamic diameter are biologically active, and can therefore penetrate into the lung causing silicosis. Short exposures to silica concentrations might also account for occurrence of silicosis, particularly if crystalline silica dust results from freshly fractured particulate matter. Exposure to Crystalline Free Silica in the construction industry is generally higher than the Occupational Exposure Levels (OEL) [8]. CFS has been classified by the International Agency for Research on Cancer (IARC) as a Group 1 carcinogen [9]. Furthermore, evidence indicates that a low cumulative exposure to CFS increases the risk of developing lung diseases, such as COPD, bronchitis, emphysema, and renal diseases [5, 9, 10].

The aim of this study was to estimate the exposure to inhalable and respirable dust in the post-earthquake construction sites and assessing the risk level using the occupational exposure levels known as Threshold Limit Values (TLVs) issued by the ACGIH (American Conference of Governmental Industrial Hygienists). TLVs refer to the airborne particulate concentration, which is set at 10 mg/m³ for inhalable particulates and at 3 mg/m³ for respirable dust. These threshold limit values, defined as Time-Weighted Average (TWA), apply for a conventional 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed for a working lifetime without adverse effects. A further aim of this study was to investigate the exposure to Crystalline Free Silica (CFS) for which the ACGIH recommends a Threshold Limit Value (TLV-TWA) of 0.025 mg/m³ [11].

The threshold limit values established by the ACGIH were taken into account as being more precautionary. We also referred to the TWA limit values recommended by the Occupational Safety and Health Administration (OSHA) and by the National Institute for Occupational Safety and Health (NIOSH). The two Agencies recommend the Permissible Exposure Limits (PEL) and the Recommended Exposure Limits (REL), respectively. The former are defined as the maximum airborne TWA concentration that should not be exceeded at any time during an 8-hour workday and a 40-hour workweek. The Recommended Exposure Limits are defined as the maximum TWA concentration that should not be exceeded during a 10-hour workday and a 40-hour workweek [12].

Table 1: Occupational exposure limits for Crystalline Free Silica from different agencies

	OSHA PEL	NIOSH REL	ACGIH TLV
TWA (Time Weighted Average)	(30 mg/m ³) / (%SiO ₂ +2)	0.05 mg/m ³	0.025 mg/m ³

Table 2: Occupational exposure limits for Respirable and Inhalable Dust from different agencies

	OSHA PEL	NIOSH REL	ACGIH TLV
TWA (Time Weighted Average) Respirable Dust	5 mg/m ³	N.P.	3 mg/m ³
TWA (Time Weighted Average) Inhalable Dust	15 mg/m ³	N.P.	10 mg/m ³

Methods

Participation by the construction companies in the study was voluntary and their enrolment was carried out by the Comitato Paritetico Territoriale (*Joint Local Committee*), by the Università degli Studi dell'Aquila, and by the technical staff of the Local Health Authority of Abruzzo.

To date, six companies have joined the project and the sampling activities in the construction sites have been carried out after a survey of the most relevant work tasks.

In order to perform personal air sampling, the selection of the workers was carried out based on the work tasks within the building site. The selected work tasks were 4: “bricklayer or similar”, “scaffolder and carpenter”, “manual demolition worker” and “other work tasks”; the latter category includes a variety of activities related to different job types. Each of the above mentioned task involves the performance of various duties. The following are the specific tasks identified in the construction sites we visited to perform the sampling:

- Bricklayer and similar: masonry work, resin and mortar injections, insulation, plasterwork, roofing work, installation of systems;
- Scaffolder and carpenter: carpentry activities and scaffolding erection;
- Manual demolition worker: demolition works and buried electrical conduits;
- Other tasks: installation of window and door mouldings, drilling, wood finishing, wood cutting, electrical wiring, driver, sandblasting, installation of plumbing systems, welding.

The following table (Table 1) shows the number of companies that took part in the study, the measurements performed, the number of workers and the total number of sampling hours (excluding breaks).

Table 3: Sampling duration in hours and workers involved by dust diameter

	Number of companies	Number of construction sites	Number of measurements	Number of workers	Total sampling hours
Inhalable dust	6	28	47	47	265
Respirable dust	5	28	44	43	243

Personal air sampling was performed using the SKC AirCheck XR5000 sample pumps.

Inhalable and respirable dust

The concentration of inhalable dust was measured by personal sampling during over a full 4- to 8-hour shift. I.O.M samplers and 25-mm, 5 µm pore size, PVC filters with a 2 L/min flow rate were used. The sampling heads were mounted within the individual breathing zone of each worker. The flow rate was monitored before and after the sampling through a portable field flowmeter kit (SKC field rotameter; 0.4-5.0 L/min), and each measurement of inhalable dust was monitored and adjusted by using a white filter. Filters were conditioned and weighed in an environment where the temperature and humidity were carefully controlled before and after sampling.

Respirable dust sampling was performed using GS-3 Cyclones with a cut-point of 4 µm, and 25-mm, 5 µm pore size, PVC filters. Flow rate at 2.75 L/min was set and monitored through the portable field flowmeter before and after sampling. Sampling time varied from a 4- to 8-hour shift.

Gravimetric determination was performed to quantify the concentrations of airborne inhalable and respirable dust concentrations.

Crystalline Free Silica

The concentration of ***Crystalline Free Silica*** was measured through a 4- to 8-hour full shift personal air sampling, using GS-3 Cyclones with a cut-point of 4 µm, and 25-mm, 5 µm pore size, PVC filters. Flow rate at 2.75 L/min was set and monitored through the portable field flowmeter before and after sampling. The filters were therefore collected and analyzed by an accredited laboratory in compliance with the Unichim (*Association for Unification in the Sector of Chemical Industry*) M.U. 2398:11 method. The X-ray diffraction was performed using a Philips PW3830 X-ray generator, a Philips PW1820 goniometer, and a Philips PW1710 diffraction control unit.

Data analysis

Data were analyzed using the STATA software package (STATA analysis and statistical software, release IC/14).

The dust exposure levels were described by arithmetic mean (AM) and geometric mean (GM).

Results

Measurement time ranged from 4 to 8 hours based on the duration of the different work tasks; while percentage of the sample was 48.94% for the respirable dust and 51.06% for the inhalable dust.

When controlling for seasonal variations over a two-year period, we found that measurement of particle distribution was: 20.21% winter, 17.02% spring, 50% summer, and 12.76% autumn.

Inhalable dust

The geometric mean concentration of inhalable dust for all work tasks was 8.84 mg/m³ ranging from 0.83 mg/m³ to 90.93 mg/m³. A geometric mean value higher than the 10 mg/m³ limit value was recorded only for the “manual demolition worker”. Out of 47 measurements of inhalable dust, 2 were below the level of detection.

Table 4: Concentration of inhalable dust by work task

Work task	Number of measurements	Number of measurements < LOD	Average sampling time (min) (min-max sampling time: 240-480)	GM mg/m ³	AM mg/m ³	SD	Min - Max	% ≥ TLV
Scaffolder and carpenter	7	0	308	3.65	5.86	7.03	0.83-21.35	14.28
Manual demolition worker	12	0	385	18.16	30.44	30.39	2.92-90.93	66.67
Bricklayer and similar	18	0	320	8,76	13,52	14.51	1.25-53.33	44.44
Other work tasks	10	2	360	6,33	9,65	6,7	2.29-16.25	62.5
All tasks	47	2	343	8.76	16.16	20.23	0.83-90.93	48.88

Legend - LOD: Level of detection; GM: Geometric mean of the exposure concentration; AM: Arithmetic mean of the exposure concentration; SD: Standard deviation; %>TLV: percent of exposures exceeding the TLV.

Respirable dust

The geometric mean concentration of respirable dust was 0.69 mg/m³ ranging from 0.15 mg/m³ to 18.2 mg/m³. No work task recorded a geometric mean higher than the threshold limit value of 3 mg/m³. Out of 44 measurements of respirable dust concentrations, 9 were below the level of detection.

Table 5: Concentration of respirable dust by work task

Work task	Number of measurements	Number of measurements < LOD	Average sampling time (min) (min-max sampling time: 240-480)	GM mg/m ³	AM mg/m ³	SD	Min - Max	% ≥ TLV
Scaffolder and carpenter	9	3	286	0.67	1.60	2.25	0.30-6.02	16,66
Manual demolition worker	7	1	343	0,92	1,9	2,13	0.15-5.86	16,66
Bricklayer and similar	20	2	324	0.72	2.13	4.42	0.15-18.2	16,66
Other work tasks	8	3	390	0.45	0.86	0.86	0.15-2.00	0
All tasks	44	9	331	0.69	1.82	3.38	0.15-18.2	14,28

Legend - LOD: Level of detection; Geometric mean of the exposure concentration; AM: Arithmetic mean of the exposure concentration; SD: Standard deviation; %>TLV: percent of exposures exceeding the TLV.

Crystalline Free Silica

The samplings of Crystalline Free Silica and of respirable dust were run concurrently. We carried out 22 measurements, of which 8 were below the level of detection. In all cases, the concentration of Crystalline Free Silica was below the threshold limit value of 0.025 mg/m³ recommended by the ACGIH. The following table shows the concentration values related to the tasks performed by the workers who collected the dust samples.

Table 6: Average concentrations of CFS positive samples by work task

Work task	Average concentration of CFS (mg/ml)	Number of samples collected	% positive
Manual demolition worker	0.0038	4	50
Scaffolder and carpenter	0.0057	5	80
Bricklayer and similar work tasks	0.004	10	50
Other work tasks	0.0035	3	100

Conclusions

The mean values of exposure to inhalable dust, expressed as concentration in mg/m^3 , are related to the job types and work tasks carried out by the workers. As reported in Table 4, manual demolition workers resulted to be exposed to higher concentrations of inhalable dust which exceed the threshold limit value recommended by the ACGIH. On the other hand, the average concentrations of respirable dust were found to be below the threshold limit value recommended by the abovementioned American association (Table 3).

The results obtained can be compared with those reported by Kirkeskov L. [4]. Both studies performed dust sampling for two specific work tasks: “manual demolition workers” and “carpenters”. The comparison of the results shows that manual demolition workers are exposed to considerably high levels of inhalable dust. Conversely, exposure concentrations of respirable dust among the same workers were shown to be lower than the threshold limit value. On the other hand, the study shows that carpenters are exposed to concentrations of inhalable and respirable dust which are below the threshold limit values. Thus, the level of dust exposure depends on the different job functions and work tasks.

Measurements of crystalline silica dust, expressed as concentration in mg/m^3 , have shown levels below the selected threshold limit value (TLV ACGIH). This is in line with the average concentrations of respirable dust that resulted to be below the threshold limit value.

In conclusion, we should highlight that the threshold limit values applied in this study are recommended for indoor work environments and that construction sites may have different ventilation characteristics compared to indoor work environments.

The several constructions sites which have been erected across the province of L’Aquila after 2009 are subject to strict health and safety measures and inspections. The exposure level is consistent with the data in the literature, although to the best of our knowledge, at the time of this study, no other Italian comparable studies had been published.

Abbreviations

PVC: poly vinyl chloride;

ACGIH: American Conference of Governmental Industrial Hygienists;

TLV-TWA: Threshold limit value – time weighted average;

COPD: Chronic Obstructive Pulmonary Disease;

CFS: Crystalline free silica;

OEL: Occupational exposure limit;

IARC: International Agency for Research on Cancer;

OSHA: Occupational Safety and Health Administration;

NIOSH: National Institute for Occupational Safety and Health;

PEL: Permissible exposure limit;

REL: Recommended exposure limit;

AM: Arithmetic mean;

GM: Geometric mean;

LOD: Limit of detection

Declarations

Ethics approval and consent to participate

This study does not involve human participants, data or tissue

Consent for publication

This study does not contain any individual person's data in any form

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All the authors read and approved the manuscript.

RM planned and carried out the sampling activities, participated to the gravimetric analyses of the dust samples and collected and analysed the results; AC and TL carried out the gravimetric analyses of the dust samples; EI planned and carried out the sampling activities and participated to the gravimetric analyses of the dust samples; ES managed the funding providing of the INAIL institute and supervised the scientific activities; DP managed the funding providing of the Local Health Authority of Abruzzo and supervised the scientific activities; LC managed the funding providing of the CPT and supervised the scientific activities; MS collected and analysed the results; LF managed the funding providing of the Università degli Studi dell'Aquila and supervised the scientific activities.

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