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Original
Six–vertex model with domain wall boundary conditions in the Bethe–Peierls approximation / L. F., C., G., G., Pelizzola, A.. - In: JOURNAL OF STATISTICAL MECHANICS: THEORY AND EXPERIMENT. - ISSN 1742-5468. - 2015:(2015), p. P06008. [10.1088/1742-5468/2015/06/P06008]

Availability:
This version is available at: 11583/2609355 since:

Publisher:
IOPscience

Published
DOI:10.1088/1742-5468/2015/06/P06008

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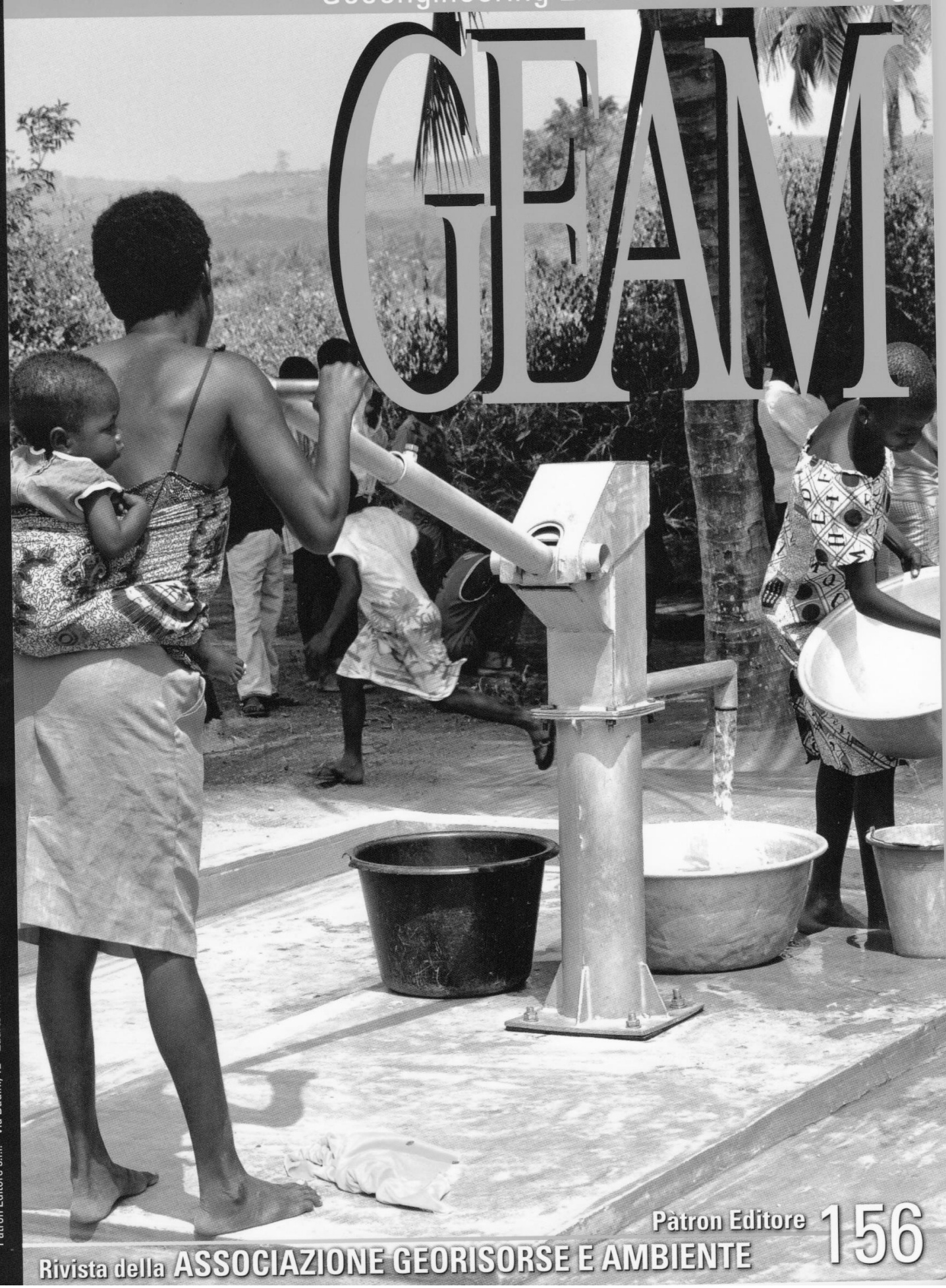
31 October 2026

ISSN 1121-9041

Geoingegneria Ambientale e Mineraria

Geoengineering Environment and Mining

GEAM



GEAM - Anno LVI - n. 1 gennaio-aprile 2019 - Quadrimestrale - Poste Italiane S.p.A. Sped. in Abb. Postale DL 353/2003 (conv. in Legge 27/02/2004 n. 46 Art. 1, Comma 1) - CN/BO
Pàtron Editore s.r.l. - Via Badini, 12 - Quarto Inferiore - 40057 Granarolo dell'Emilia (Bo)

Pàtron Editore 156

Rivista della ASSOCIAZIONE GEORISORSE E AMBIENTE

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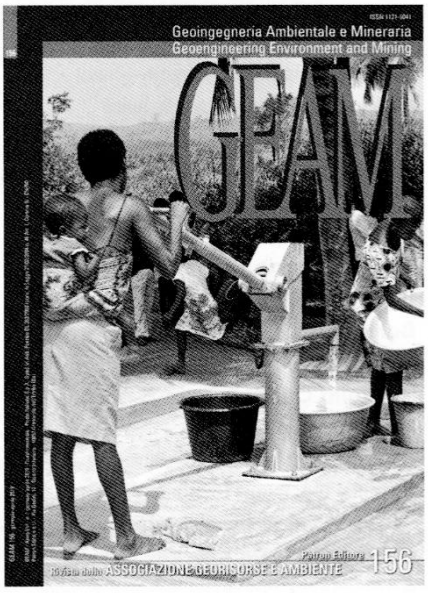
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A woman pumps clean water at a well in Ghana.

Una donna pompa acqua fresca da un pozzo in Ghana

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USAID/Kasia McCormick, 2012.

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Direzione e redazione

Associazione Georisorse e Ambiente
c/o DIATI – Dip. Ingegneria dell'Ambiente, del Territorio, e delle Infrastrutture - Politecnico di Torino, Corso Duca degli Abruzzi, 24 – 10129 Torino. Tel.: 011 0907681
e-mail: geam@polito.it – www.geam.org

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Gestione editoriale affidata a:

Pàtron Editore – Via Badini, 12 – 40057 Quarto Inferiore – Granarolo dell'Emilia – Bologna, Tel. 051 767003

Singoli fascicoli: € 39,00 Italia – € 49,00 Estero
PDF articoli: € 14,00.

Per ordinare:
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Modalità di pagamento:
Versamento anticipato adottando una delle seguenti soluzioni:

- c.c.p. n. 000016141400 intestato a Pàtron editore – via Badini 12 – Quarto Inferiore – 40057 Granarolo dell'Emilia – Bologna – Italia
- bonifico bancario a INTESA SAN PAOLO SpA – Agenzia 68 – Via Pertini 8 – Quarto Inferiore – 40057 Granarolo dell'Emilia – Bologna – Italia – BIC BCITITMM; IBAN IT 58 V030 6936 85607400 0000782
- carta di credito o carta prepagata a mezzo PAYPAL www.paypal.it specificando l'indirizzo e-mail: amministrazione@patroneditore.com nel modulo di compilazione per l'invio della conferma di pagamento all'Editore.

Per ricevere la rivista in abbonamento contattare:
Associazione Georisorse e Ambiente
Tel. 011/0907681 – geam@polito.it

I fascicoli cartacei, se non pervenuti, possono essere richiesti all'Editore.
Tel. 051/767003 – abbonamenti@patroneditore.com

Pubblicità

advertising@patroneditore.com

Grafica e impaginazione

Exegi Snc - Bologna

Stampa

Tipografia LI.PE. Litografia Persicetana - San Giovanni in Persiceto, Bologna, giugno 2019

Riconosciuta dal C.N.R. quale rivista nazionale del settore Geo-Minerario, viene pubblicata sotto gli auspici del CONSIGLIO NAZIONALE DELLE RICERCHE
Anagrafe Naz. Ricerche 518915NF – ISSN 1121 - 9041
Autorizzazione del Tribunale di Torino, n. 1682 del 20-11-1964

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The role of the airborne asbestos fibers measurement in the classification of working environments: the case of Large Public Facilities

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The residual presence of critical components (e.g. Asbestos Containing Materials – ACMs) still represents one of the main criticalities for the Occupational Safety and Health – OS&H in many large public facilities (Lee and Van Orden, 2007).
Since the areas characterized by ACMs in good conditions are the most crucial to manage, due to the presence of the Hazard Factor in dormant conditions, an effective assessment and management of the related risk is pivotal. The Italian regulation (D.M. 06/09/94) provides general information on the approach for the analysis, stating the possibility to adopt two criteria: 1. examination of the artefacts condition, to detect possible deteriorations resulting in airborne fibers release, 2. indoor airborne fibers concentration measurements. The same Decree specifies that the airborne measurements alone cannot be a valid criterion to detect the possible fibers release from the pre-identified ACMs deterioration .
The paper discusses the actual contribution that airborne asbestos measurements can provide to the Risk Management, in particular in the identification of incipient deteriorations of ACMs. The research work was performed by implementing a special measuring strategy, in a real scenario, to increase the method sensitivity and collect data useful to relate the indoor pollution to the ACMs deterioration.
Keywords: *occupational safety and health, asbestos risk assessment and management, quality approach to OS&H, asbestos containing materials, data uncertainty evaluation, airborne fibers measurements, dissemination of culture of safety.*

Il ruolo della misurazione di fibre aerodiserse di amianto nella classificazione degli ambienti di lavoro: il caso delle Grandi Strutture Pubbliche. *La presenza residua di componenti critiche (e.g. Materiali Contenenti Amianto – MCA) è ancora oggi una delle maggiori criticità nell'ambito della Sicurezza e Salute sul Lavoro – OS&H in molte grandi strutture pubbliche (Lee and Van Orden, 2007).*
Poiché le aree caratterizzate da MCA in buone condizioni risultano essere le più cruciali da gestire, a causa della presenza di un Fattore di Pericolo dormiente, una efficace Valutazione e Gestione del Rischio correlato alla presenza di Amianto risulta essenziale. La normativa (D.M. 06/09/94) fornisce informazioni generali riguardo al metodo di analisi, indicando la possibile adozione di due differenti approcci: 1. accurato esame delle condizioni dei manufatti per individuare possibili deterioramenti potenzialmente in grado di liberare fibre, 2. misurazione indoor della concentrazione di fibre aerodisperse. Il medesimo Decreto specifica che le sole misurazioni di fibre aerodisperse non costituiscono un valido criterio per l'identificazione del possibile rilascio dovuto al deterioramento dei MCA. Il presente lavoro è stato sviluppato per investigare sul reale contributo che le misurazioni di fibre aerodisperse possono fornire nella Valutazione e Gestione del Rischio Amianto, in particolare nella identificazione di incipienti fenomeni di degradazione dei prodotti che lo contengono. Lo studio è stato condotto tramite implementazione di una speciale strategia di misurazione, appositamente messa a punto ed applicata in un reale scenario lavorativo, al fine di migliorare la sensibilità del metodo e raccogliere dati utili per correlare l'inquinamento indoor con il deterioramento dei MCA preventivamente identificati.
Parole chiave: *sicurezza e salute sul lavoro, valutazione e gestione del rischio amianto, approccio in qualità all'OS&H, materiali contenenti amianto, valutazione dell'incertezza di misura, misurazione di fibre aerodisperse, disseminazione della cultura della sicurezza.*

1. Introduction

In line with the D.M 06/09/94, indoor air dispersed asbestos fibers measurements could periodically confirm the good conditions of the pre-identified ACMs (Borchiellini et al. 2016), along the time. In no other situation the environmental pollution measures are necessary, since the presence of asbestos containing deteriorated artefacts or of damaged sealings/enclosures pertains to a scenario where the area involved is no more considered a workplace.

The same Decree specifies that the airborne measurements alone cannot be a valid approach to detect the possible ACMs deterioration. It is important to evaluate the role, the contribution and the effectiveness of airborne measurements in the identification of incipient deteriorations of asbestos containing products in good conditions, as collateral support to Quality Risk Management of the involved areas. Even more given the common, but not exhaustive, practice to monitor the artefacts condition evaluating the airborne fibers concentrations collected by occasional airborne fibers samplings – assuming a direct correlation between pollution and ACMs conditions, without any consideration on the factors affecting the indoor pollution (mainly in ter-

ms of boundary conditions). This approach can be debated since it is affected by different criticalities and difficulties:

1. the collection of a limited number of indoor asbestos airborne fibers concentration measures inside the areas containing ACMs can provide only a "snapshot" of the pollution in a limited time span;
2. the extent of possible fibers release due to incipient artefacts deterioration results in an increase of concentration barely measureable (comparable with the outdoor background), as confirmed by some research works on the evaluation of fibers release from artefacts subject to stress conditions (Paustenbach *et al.*, 2004). Therefore, the indoor pollution variability due to artefacts deterioration can be heavily influenced by the outdoor concentration fluctuations (e.g. outdoor pollution variability);
3. the method uncertainly (sampling and analysis) should be carefully defined: in some cases, (e.g. in the Phase Contrast Microscopy – PCM analysis) the measure expanded uncertainty becomes important and comparable to the numerical value of the measured concentration (NOHSC, 2005); the decision making becomes then difficult, in particular in very low concentration conditions.

Hence, a presumed prompt identification of the ACMs even slight alteration by means of indoor airborne measurements presents not negligible lacks.

The target of the study entails the possibility to detect very low concentrations: hence, the method sensitivity was increased by selecting a peculiar sampling context, adopting a special sampling and analysis strategy, and implementing an approach for the data interpretation characterized by a well-defined logical (metrology-based) structure.

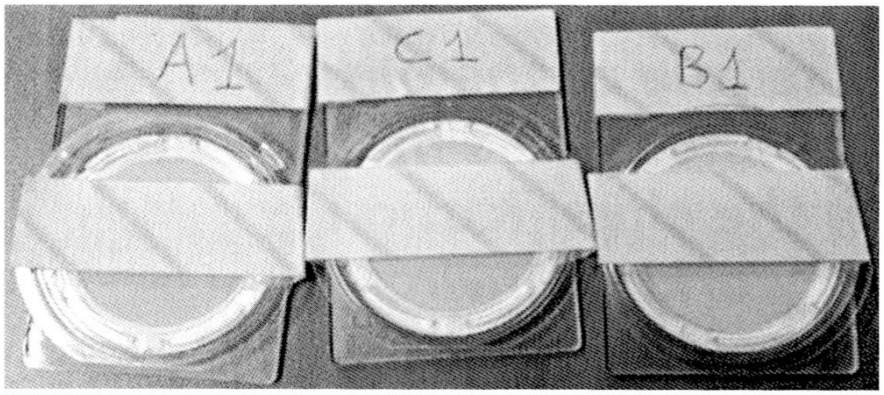


Fig. 1. First sampling session filters.
Membrane utilizzate nella prima sessione di campionamento.

2. Materials and methods

2.1. The sampling and measuring strategy

The context designated to perform the measurement campaigns pertains to window fixtures removal operations due to the presence of asbestos in mastic sealant in many areas of a large public facility. The removal yard, involving consecutively different parts of the buildings (e.g. single floors) can reproduce a context of ongoing deterioration of materials containing asbestos in limited amount. The situation is certainly worse, and most critical (just think to mechanical stresses on the window fixtures due to the removal operations) than a context where ACMs in compact matrix are exposed to stress actions due to natural deterioration and/or operative causes[1]. Therefore, this scenario could contribute to overcome the problems related to barely detectable airborne fibers concentrations, considering the mechanical wearing actions on artefacts producing potentially higher fibers releases.

In this context, the sampling campaign was designed and carried out following a special strategy, based on sessions of three simultaneous (matching starting sampling times) indoor/outdoor samplings, involving three different areas at a time:

1. the remediation working area (indoor environment), labelled as *area A;*
2. an indoor nearby area (*area B*) with the same criticalities (window fixtures with asbestos containing mastic sealant, to be successively removed);
3. the external environment (*area C*) close to the removal yard.

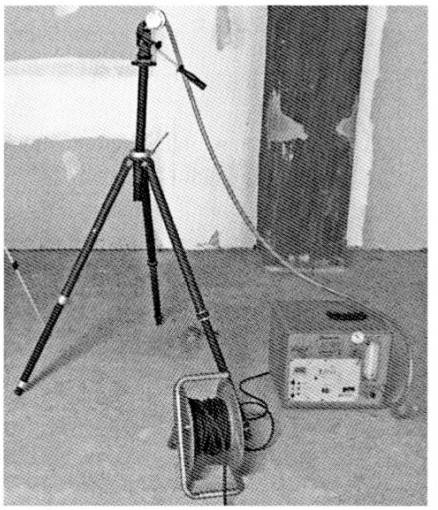
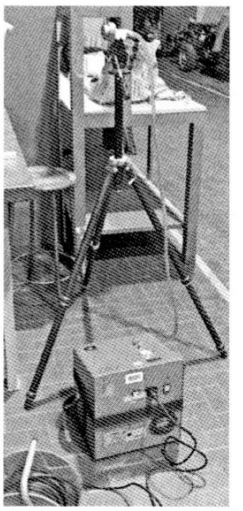
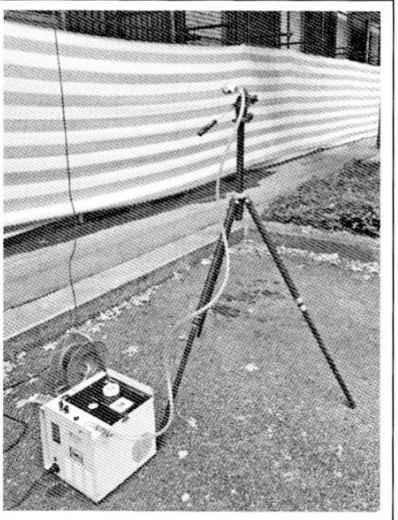
The identification of each zone typology by a specific letter simplified also the management of sampling operations, tagging the used membranes with the same letter of each sampling area, together with the progressive number of sampling session (fig. 1 shows the membranes related to the first sampling session).

The concurrent indoor/outdoor measurements can provide useful information to evaluate the potential effect of external pollution on the indoor measurements, considering that the expected indoor fibers concentrations could be comparable with the outdoor ones. The entire sampling campaign lasted from October 2016 to May 2017, in six "ordinary" and four "special" sampling stages.

The sampling phase and loca-

[1] Mechanical actions on the ACMs due to working/operational causes (e.g. maintenance or cleaning activities) are managed through a careful design of both the intended use and allowed activities.

Tab. 1. Sampling equipment used in the measuring campaign.
Attrezzatura di campionamento utilizzata nella campagna di misurazioni.

Sampling area	Area A	Area B	Area C
Sampling pumps			
	Zambelli 5000	*Zambelli ZB2*	*Tecora Bravo R*
Sampler	Open face samplers, positioned approx. 1,5 meters above the floor, using Mixed Cellulose Ester – MCE filters (47 mm diameter, 0,8 µm pore size).		

tion of the sampling stations were organized taking into account the parameters conditioning the quality of measures (e.g. microclimatic conditions in the three different sampling areas) and the peculiarities of the pollutant, in particular the negligible aerodynamic resistance of fibers.

The three simultaneous samplings were carried out using three high-flow/flow-controlled area sampling pumps equipped with open face samplers[2] (tab. 1).

According to the measuring processes and equipment setup in System Quality (Bisio et al. 2016), the used sampling equipment and analytical instrumentations fulfil the metrological confirmation condition, ensuring the quality of the results. Moreover, the three sampling pumps were calibrated by means of a flowmeter, before and after each sampling session, to verify the flowrate within the required interval: ± 5% of the set flowrate (UNI EN ISO 13137: 2015).

[2] Both defined in UNI EN ISO 13137:2015 standard

Action tested to increase the method sensitivity – sampling

Regarding the sampling phase, the improvement to increase the method sensitivity concerned the sampled air volume: the minimum volume suggested by the D.M 06/09/94 (3000 liters) was increased to 5000 liters, drawn in 200 minutes (sampling duration), with a reference flowrate Q_{ref} = 25 l/min, maintaining unchanged the ratio flowrate/membrane surface (0,35 m/s required for SEM analyses).

The entire campaign was completed in six sampling sessions, resulting in 18 membranes. During the collection of the three concurrent samplings, a multifunction measuring device monitored and recorded (every 30 minutes) the significant parameters potentially conditioning the sampling results (temperature, pressure, relative humidity and air velocity and direction).

The analytical method adopted conforms to the Italian regulation DM 06/09/94, Attachment 2: the analyses were carried out by means of a Hitachi TM 3000 SEM, equipped with SwiftED 3000 device for micro-analysis, working at 2000x magnification, with 15 kV acceleration voltage. The respirable fibers (complying the geometric requirements: length greater than 5 µm, cross dimension smaller than 3 µm, and length/diameter ratio equal to or greater than 3:1) are definitely recognized as asbestos fibers through micro-analysis.

Action tested to increase the method sensitivity – analysis

As for the sampling phase, one of the analytical parameters was improved to increase the method sensitivity. In particular, a larger filter section (1,27 mm2) was analyzed, this resulting in 400 reading fields of 0,0032 mm2, with an increase of approx. 22% of the routine value suggested by the already quoted D.M. 06/09/94.

2.2. The method implementation (data analysis)

To draw some considerations about the results of the above-described measuring strategy, based

on the comparison of the simultaneous concentration measures, the approach implementation followed three consecutive steps:

1. *determination of concentration and Limit of Detection*;
2. *evaluation of the measurement uncertainty*;
3. *data interpretation*.

2.2.1. Airborne fibers concentration and Limit of Detection

The starting point is the definition of the *mathematical model* (eq. 1) to calculate the airborne fibers concentration from the samplings and analysis parameters (tab. 2).

Table 3 summarizes the "nominal" values of the parameters, set in sampling and analysis stages, except for the variable N_f, whose value changes depending on the analytical results.

The concentration mathematical model (eq. 1) lays at the basis of the calculation of the *Limit of Detection* – LoD based on relationship (eq. 2) in Table 4: the number of fibers count (N_f) is replaced by the upper 95% confidence limit: the detection limit considers the confidence interval of the fibers count due to the Poisson distribution of fibers on the filter.

The *Limit of Detection* of a method specifies the smallest detectable quantity obtainable by the used method. In the case of SEM analysis, the Limit of Detection is defined as the numerical asbestos fibers concentration below which, with the 95% probability, the real concentration shall lie when no asbestos fibers are identified during the analysis (UNI EN ISO 16000 – 7 standard). Hence, this limit shall be determined for each single analysis, and in the case of a no fibers count, the outcome of the analysis will denote "below the LoD".

To verify the possibility of getting a higher fibers count, with a more reduction of the LoD, four additional samplings were carried out, with a further increase of the sampled air volume up to 10.000 liters, using the same membrane in two consecutive samplings of the usual 200 minutes sampling duration. The inlet airflow was monitored systematically to verify the minimum capturing velocity (0,35 m/s in the case of SEM analysis), taken into account the increased aerodynamic resistance due to the progressive filter obstruction.

Tab. 3. Values of parameters.
Valori dei parametri.

Parameters and "nominal" values					
N_f [ff]	A [mm^2]	N_c [n.]	a [mm^2]	Q [l/min]	t [min]
x	962	400	0,0032	25	200

2.2.2. Measurement uncertainty

The measuring processes aimed to define pollutant airborne concentrations (or in general for the quantification of a Hazard Factor) should take into account the sources of variability conditioning the results (fig. 2), with the goal to reduce the final expanded uncertainty affecting the measures (Barbato et al. 2013).

Even if, as suggested by literature, in the case of low fibers counts, the intrinsic uncertainty due to

Tab. 2. Airborne fibers concentration formula and parameters.
Formula e parametri per il calcolo della concentrazione di fibre aerodisperse.

Concentration mathematical model:

$$C[\text{ff/l}] = \frac{N_f \cdot A}{N_c \cdot a \cdot (Q \cdot t)} \qquad \text{(eq. 1)}$$

where:

- N_f is the number of fibers identified in the analyzed membrane section;
- A is the effective area of the filter [mm^2];
- N_c is the number of reading fields;
- a is the area of each reading field [mm^2];
- Q is the flowrate of the sampling pump [l/min];
- t is the sampling duration [min].

Multiplying Q and t results in the sampling volume (V) referred to the normal conditions (T = 25 °C, P = 1013 mbar).

Tab. 4. Limit of Detection and Confidence Limits.
Limite di Rilevabilità e Limiti di Confidenza.

Limit of Detection formula:

$$LoD = \frac{UCL \cdot A}{N_c \cdot a \cdot (Q \cdot t)} \qquad \text{(eq. 2)}$$

In general, the 95% confidence interval of a measurement, as function of the number of asbestos fibers counted, can be obtained from the two equations (eq. 3 and eq. 4):

$$x_{UCL} = d \cdot \left[1 - \left(\frac{1}{9 \cdot d}\right) + z \cdot \sqrt{\left(\frac{1}{9 \cdot d}\right)}\right]^3 \qquad \text{(eq. 3)}$$

$$x_{LCL} = x \cdot \left[1 - \left(\frac{1}{9 \cdot x}\right) - z \cdot \sqrt{\left(\frac{1}{9 \cdot x}\right)}\right]^3 \qquad \text{(eq. 4)}$$

where x is the fibers count, d = (x + 1) and z = 1,960 the standard normal deviate for the two-sided limits at the 95% probability level. The same data are available in the UNI EN ISO 16000 – 7 standard, Table 3.

The considered 95% confidence interval of a zero fibers count ranges from 3,69 [ff] Upper Confidence Limit – UCL, to 0 [ff] Lower Confidence Limit – LCL.

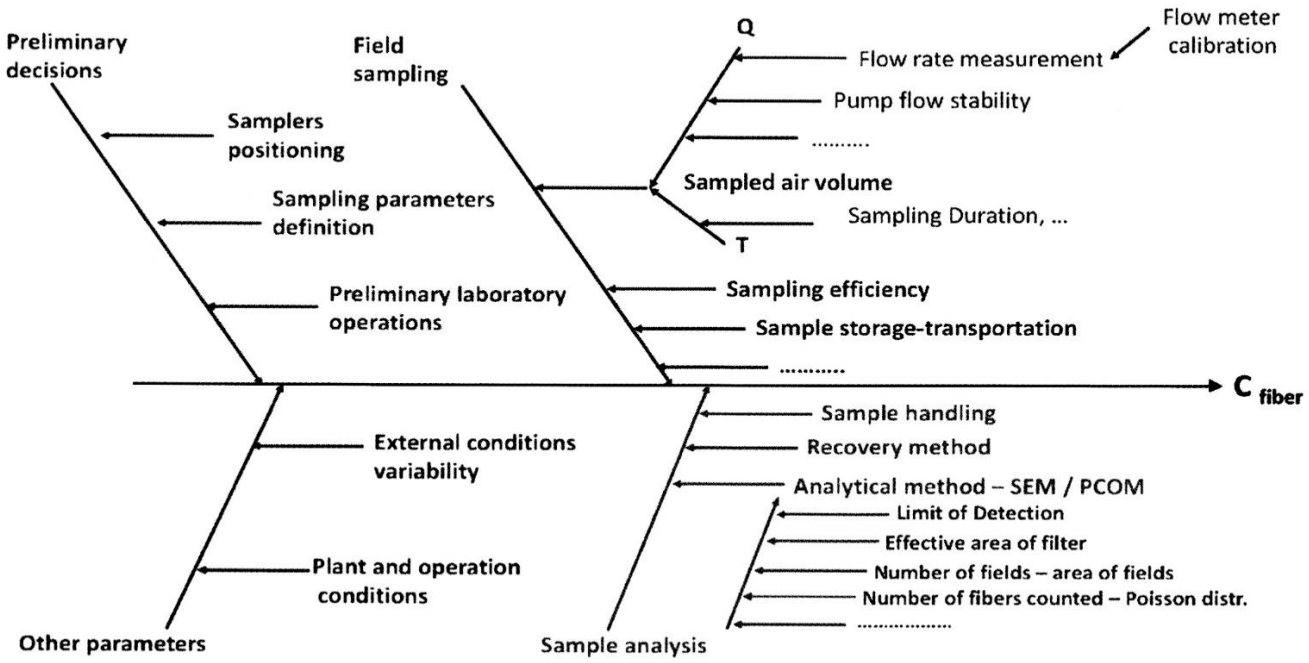


Fig. 2. Example of the Cause Effect – Hishikawa diagram (Center for Chemical Process Safety, 2008) of the main variability sources conditioning the fibers concentration data.
Esempio di diagramma di Hishikawa (Center for Chemical Process Safety, 2008) sulle principali sorgenti di variabilità che condizionano i dati di concentrazione.

the statistical Poisson distribution of fibers on the filters can make negligible the contribution of the remaining uncertainty sources, the experimental nature of the sampling and analytical method adopted made necessary to investigate whether the adjustments aimed to increase the method sensitivity introduce significant variability causes. The analysis was planned in three steps:

1. evaluation of *a-priori uncertainty* of the analytical method (predicted variability obtained by combining the various uncertainty components that characterize the measurement);
2. *a-posteriori assessment of uncertainty* of the method implementation, using measured data accurately processed to identify systematic effects/tendencies, outliers, etc.;
3. *conclusion* about the three set of concurrent measures in terms of both values and experimentally observed variability.

Typically, the a-priori uncertainty is evaluated previously to any measurement, and is based on the knowledge of influence factors mainly producing non-statistical uncertainty contributions. The adopted strategy of three simultaneous samplings results comparable to *three distinct processes*, carried out by means of comparable sampling equipment (with their own metrological characteristics), and same analytical instrument. The a-priori uncertainty assessment should provide indication on:

1. the predicted variability associated to each of the three processes;
2. the ranking of the uncertainty contributions, useful to make decisions about the sources to act upon to reduce the expanded uncertainty in the method implementation, identifying the most critical factors;
3. the effect of such decisions (point 2) in terms of expanded uncertainty reduction.

The knowledge of sampling and analysis activity/equipment made possible the identification of the uncertainties sources for each parameter, as summarized in Table 5.

The uncertainty contributions were estimated as suggested in the Procedure for Uncertainty MAnagement – PUMA: non-statistical information were transformed in statistical characteristics, in terms of variance, to be composed with statistical information, assessing the relevant statistical distribution, e.g. rectangular or triangular, for passing to variance. The determination of both the a-priori and a-posteriori uncertainties, and their comparison, makes possible to understand if the measurement system is correct.

2.2.3. Data interpretation

Assuming that data are correctly collected (Bisio et al. 2017), a possible approach for the data interpretation can be based on the ratio between the situation in areas where ACMs have been

Tab. 5. Parameters and their relevant variability sources.
Parametri e loro fonti di variabilità.

Parameters	Uncertainty source
N_f	- *Poisson distribution* of fibers on the membrane - *Resolution*
A	- *Caliper uncertainty* (zero error) - *Reproducibility* - *Reading uncertainty*
N_c	- *Bias*
a	- *Micrometer calibration*
Q	- *Reproducibility* - *Resolution* (sampling equipment characteristic) - *Accuracy* (sampling equipment characteristic)
t	- *Reproducibility* - *Resolution* (chronometer characteristic) - *Accuracy* (chronometer characteristic)

NOTE: the following definitions of the terms used in the table are drawn from JCGM 200:2012:
Resolution: smallest change in a quantity being measured that causes a perceptible change in the corresponding indication;
Reproducibility: measurement precision under reproducibility conditions of measurement (condition of measurement, out of a set of conditions that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects);
Bias: estimate of a systematic measurement error;
Accuracy[1]: closeness of agreement between a measured quantity value and a true quantity value of a measurand.-

[1] For the purpose of this research work, we still make reference to the term accuracy, even if the last updates of International Vocabulary of Metrology – VIM introduced some amendments on the term.

identified, but no activities involving emission are present, or situations where some activities can be expected to cause asbestos fibers release, and the common environment pollution, expressed in the relationship eq. 5:

$$K = \frac{\text{concentration in the indoor polluted area}}{\text{concentration in the external nearby area}} \quad \text{(eq. 5)}$$

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$$LoD = \frac{3{,}69[\text{ff}] \cdot 962[\text{mm}^2]}{400 \cdot 0{,}0032[\text{mm}^2] \cdot (25\,[\text{l/min}] \cdot 200[\text{min}])} = 0{,}56[\text{ff/l}] \quad \text{(eq. 6)}$$

3. Results and discussion

3.1. Concentration and LoD

Regarding the pollutant concentration data, the SEM analysis of the 18 membranes, from the six "ordinary" samplings, resulted

No background fibers were detected in the field blank analysis, proving the absence of membrane contamination.

3.2. Uncertainty evaluations

According to the analytical results, the measurement uncertainty evaluation was carried out by replacing the fibers count parameter (N_f) with the 95% upper confidence limit for a zero fibers count (3,69 [ff]).

The PUMA method adopted to perform the a-priori uncertainty analysis pointed out that the variability sources of the three processes resulted equivalent, except for the sampling pumps: the three used devices, even differing for producer and model, had very similar characteristics in terms of resolution, accuracy and reproducibility.

The predicted variability, achieved from the a-priori uncertainty calculation sheets, resulted similar for the three measuring processes/conditions (tab. 6).

On the basis of the standard uncertainty values $u_i^2(y)$ (values of the estimated variances associated with the output y – concentration generated by the estimated variance associated with each input estimate x_i.) it is possible to identify the most important uncertainty sources affecting each process. In

Tab. 6. A-priori expanded uncertainty in the three investigated situations.
Incertezza estesa a-priori per le tre situazioni esaminate.

A-priori uncertainty results			
	area A	*area B*	*area C*
Confidence level	0,95	0,95	0,95
Coverage factor (tStudent)	2	2	2
Expanded uncertainty U(y)	**0,093 ff / l**	**0,092 ff / l**	**0,092 ff / l**

Tab. 5. Parameters and their relevant variability sources.
Parametri e loro fonti di variabilità.

Parameters	Uncertainty source
N_f	- *Poisson distribution* of fibers on the membrane - *Resolution*
A	- *Caliper uncertainty* (zero error) - *Reproducibility* - *Reading uncertainty*
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Tab. 7. Ranking of the standard uncertainties in the three situations.
Ordinamento gerarchico nelle incertezze standard nelle tre situazioni.

Indoor work – A					Indoor not work – B			Outdoor – C		
Factor x_i					Factor x_i			Factor x_i		
Symbol	Value	Remarks	$u_i^2(y)$	Rank	Symbol	$u_i^2(y)$	Rank	Symbol	$u_i^2(y)$	Rank
Nf	3,7E+00	Poisson distr	1,1E-04	2	**Nf**	1,1E-04	2	**Nf**	1,1E-04	2
		resolution	1,9E-03	1		1,9E-03	1		1,9E-03	1
A	9,6E+02	caliper uncertainty (zero)	1,1E-11	13	**A**	1,1E-11	13	**A**	1,1E-11	13
		reproducibility	1,0E-10	12		1,0E-10	12		1,0E-10	12
		reading uncertainty	2,8E-08	8		2,8E-08	8		2,8E-08	8
Nc	4,0E+02	bias	2,6E-06	6	**Nc**	2,6E-06	7	**Nc**	2,6E-06	6
a	3,2E-03	microm calibr	1,0E-04	3	**a**	1,0E-04	3	**a**	1,0E-04	3
Q_{IW}	2,5E+01	reproducibility	4,1E-05	5	Q_{INW}	1,5E-05	5	Q_{OU}	2,6E-05	5
		resolution	1,6E-06	7		6,6E-06	6		1,6E-06	7
		accuracy	8,0E-05	4		2,6E-05	4		5,9E-05	4
t	2,0E+02	accuracy	4,1E-09	9	**t**	4,1E-09	9	**t**	4,1E-09	9
		reproducibility	1,6E-09	10		1,6E-09	10		1,6E-09	10
		resolution	1,8E-10	11		1,8E-10	11		1,8E-10	11

our case, the uncertainty contributions are almost in the same ranking between the three situations (tab. 7) and the fibers count represents the first important contribution to the final combined standard uncertainty $u_c(y)$[3].

Even if in our case the three rankings show limited differences, the result confirms the importance of hierarchical ordering of variability sources as key decision tool for the allocation of resources for sampling, analysis and measuring devices. The results of a-priori uncertainty analysis makes possible some significant considerations:

1. the original modifications implemented to increase the method sensitivity (i.e. higher air volume sampled and larger filter section analysed) do not introduce significant sources of uncertainties;
2. the three measuring systems (samplings and analysis) show a comparable variability degree; the variability related to the fibers count (resolution and Poisson distribution) remains the major uncertainty source.

The *a-posteriori uncertainty* requires to replace the estimated variability contributions (by PUMA method) with uncertainties statistically defined, in order to achieve the expanded uncertainty affecting the collected measures in specific operating conditions.

In the case under exam, the a-posteriori analysis would be ineffective owing to the preponderance of variability related to N_f on the remaining uncertainty sources, the difficulty to collect data on the third source of uncertainty (the reading field area – *a*), and the reduced contribution of the remaining sources[4].

3.3. Data interpretation

The accurate determination of concentration values in the three considered contexts, together with the associated variability range for each resulting measure, makes possible a reliable estimate of the K-ratio.

In our case, the concentration data resulted below the LoD of the method, in the three analysed situations, this leading to the estimate of concentration values of 0,56 [ff/l] plus 18% (expanded uncertainty), i.e. 0,66 [ff/l]. This result confirms that, even during the window fixtures removal the measurements in the operating area did not put into evidence a significant environmental pollution, and that there is no possibility of Risk Assessment for the three situations on the basis of airborne fibres samplings.

A quite different result is obtained in the case of important emissions of fibers from asbestos containing rock masses during tunnel driving operations (Poma and Puma, 2016): in proximity of the face the concentration values can result certainly high, and in some cases close (or higher) to the technical threshold limit (100 ff/l). In such a scenario, indoor/outdoor simultaneous airborne measurements become pivotal: the raising of indoor pollutant concentration attributable to the excavation activities could be detected by identifying significant

[3] The *combined standard uncertainty* is an estimated standard deviation characterizing the dispersion of the values that could reasonably be attributed to the measurand *y* (JCGM 100:2008)

[4] in the case of a-posteriori uncertainty calculation, it is necessary to consider also the uncertainty contribution of the measuring devices for temperature and pressure determination, needed in particular to normalize the sampled volume whilst these uncertainty contributions are not introduced in the a-priori uncertainty evaluations, since the variability related to flowrate is estimated on the basis of non-statistical information (e.g. samplers characteristics).

differences between indoor / outdoor concentrations. However, clearly this context is very far from the management of environments characterized by residual presence of Asbestos containing artefacts in good conservation conditions.

4. Conclusion

On the basis of the achieved results in a rigorous metrological approach, it is confirmed the impossibility to characterize the environments containing ACMs on the basis of airborne fibers concentration measurements, since, taken into account the uncertainty values related to such determinations, the concentrations result hardly comparable with the measures collected in areas with verified presence of ACMs without ongoing stresses, or in outdoor environments close to the abovementioned areas.

Very different is the situation in operative contexts where the quantities of asbestos containing materials and the involved stressing actions cause important pollution levels.

Hence, according to the D.M.06/09/94 indications, the importance of rigorous direct inspections is confirmed, both to localize ACMs in compact matrix (Hazard Factor dormant), and to identify transition situations from dormant to active Hazard Factor. Such a result cannot be achieved by means of airborne fibers measurements, except in the case of important fibers releases.

Future research developments will focus on the set up of rigorous instrumental techniques to support the direct investigations, reducing the impact of judgment subjectivity, thanks to the implementation of formalized methodologies of Canvassing, based on assisted image interpretation techniques.

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Annotazioni di Sicurezza e Salute sul Lavoro – OS&H

Costituzione della Repubblica Italiana
art.41: *"L'iniziativa economica privata è libera. Non può svolgersi in contrasto con l'utilità sociale o in modo da recare danno alla sicurezza, alla libertà, alla dignità umana..."*

OS&H
Occupational Safety and Health rev

Mario Patrucco, Docente di Valutazione dei rischi industriali e nella cantieristica, Università degli Studi di Torino
Rebecca Nebbia, Dottoranda, Gestione, Produzione e Design – Course curricula OS&H, Politecnico di Torino

Con questo primo numero del 2019, si riprende – e ne sono ovviamente grato a GEAM per la rinnovata stima e fiducia – la consueta gestione delle pagine destinate agli aspetti di Sicurezza e Salute del Lavoro.

Il tema è trattato secondo la consolidata impostazione, caratterizzata da Annotazioni con considerazioni non scevre di aspetti scientifici su questioni di attualità, nell'ambito delle quali sono presentate anche le successive note curate da esperti e verificate da autorevoli studiosi della materia facenti parte del Comitato Scientifico di GEAM sin dalla introduzione delle tematiche securistiche nella rivista, nel n. 1 del 2016.

Nel rispetto degli spazi concessici, tenuto conto che come già accennato in precedenti occasioni *soggettività* e *semplificazione arbitraria* possono inficiare gravemente l'azione di prevenzione, ho reputato preferibile limitare alle righe che precedono queste mie considerazioni, per lasciare spazio ad una sintesi curata dall'ing. Rebecca Nebbia sulla "delicatezza" di un corretto approccio alla fase di identificazione e quantificazione delle criticità in materia di OS&H, primo ed essenziale passo non solo per una corretta Gestione tecnologica dei Rischi, ma anche per l'impostazione di efficaci programmi di Sorveglianza Sanitaria.

Una valutazione del rischio non critica e, di conseguenza, una gestione del rischio priva di un approccio rigoroso è ancora un problema ricorrente nell'ambito della OS&H (De Cillis et al., 2018). Una delle cause che conducono ad una cattiva Valutazione dei rischi può essere una raccolta di dati incompleta o non di qualità a causa di semplificazioni errate. Semplificare non è certamente sbagliato in assoluto, ma poiché a monte delle semplificazioni ci sono sempre delle ipotesi, è necessario verificare in ogni contesto la validità delle stesse, soprattutto in fasi lavorative caratterizzate da elevata variabilità di conduzione e di contesto. Un esempio, nell'ambito OS&H, è il non attribuire importanza a pressione e temperatura in fase di valutazione di esposizioni ad agenti chimici e in particolare a particolato aerodisperso. Tuttavia, questi parametri sono importanti perché possono causare un aumento della dose inalata dell'inquinante (The Japan Society for Occupational Health, 2018) e sono anche componenti di incertezza associate alle procedure di campionamento (Standard ASTM D4532).

Sono oggi reperibili sul mercato campionatori personali per le frazioni inalabile e respirabile che effettuano direttamente la normalizzazione dei dati in temperatura e pressione senza la necessità di successive elaborazioni, il che li rende particolarmente adatti per campionamenti ad alta quota, o in cantieri anche a grande profondità (ad esempio in miniere profonde) in cui i suddetti parametri possono raggiungere valori estremi.

Le semplificazioni possono coinvolgere non solo le misurazioni, ma anche altri aspetti come la definizione di gruppi simili di esposizione (SEGs), approccio utile per ridurre durate ed oneri dell'indagine (UNI EN 689: 2018). Tuttavia, la norma stessa segnala la possibilità che due lavoratori addetti alla medesima mansione non risultino esposti allo stesso modo (variabilità tra lavoratori) e che si verifichino variazioni di esposizione da turno a turno (variabilità all'interno del lavoratore). Ne deriva che la valutazione dell'esposizione di un lavoratore non può essere tout court estesa ad altri che eseguono nominalmente la stessa mansione, e che i SEGs dovrebbero essere costituiti soltanto dopo una prima valutazione dell'esposizione di ogni singolo lavoratore, sulla base di dati dimostratamene significativi.

Concludendo, le semplificazioni nell'ambito della OS&H rispetto all'impiego esclusivo di criteri di rigore scientifico e metrologico sono di per loro certamente consentite, purché caso per caso giustificate senza mai perdere di vista il processo logico che le ha rese possibili.

Ci si ripromette di tornare su questo tema in forma estesa in una prossima nota.

In coerenza con l'approccio generale di Disseminazione della Cultura della Sicurezza alla base delle pagine sulla Sicurezza del Lavoro, verrà in particolare discusso, nella nota

The role of the airborne asbestos fibers measurement in the classification of working environments: the case of Large Public Facilities

il contributo che le misurazioni di fibre aerodisperse possono fornire nella Valutazione e Gestione del Rischio Amianto. Lo studio è stato condotto tramite implementazione di una strategia dedicata di misurazione, applicata in uno scenario reale, al fine di migliorare la sensibilità del metodo e raccogliere dati utili per correlare l'inquinamento indoor con il deterioramento dei MCA preventivamente identificati.

Ben ritrovati e buona lettura!

Mario Patrucco, Rebecca Nebbia

Bibliografia essenziale sulla "delicatezza" di un corretto approccio alla fase di identificazione e quantificazione delle criticità in materia di OS&H

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OCCUPATIONAL SAFETY AND HEALTH

Tips on Occupational Safety and Health – OS&H



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This first issue of 2019 resumes – I am grateful to GEAM for its renewed esteem and confidence – the usual organization of the pages dealing with the scientific aspects of Occupational Safety and Health.

The theme is treated according to a consolidated approach, characterised by Tips with scientific content discussing some topical issues, and introducing the following papers verified by experts belonging to the Scientific Committee of GEAM since the introduction of the OS&H issues in the journal, in n. 1, 2016.

Considering that, as already mentioned in previous occasions, subjectivity and arbitrary simplification can affect the action of prevention, I thought it appropriate to limit the lines preceding these my considerations, to leave room for a synthesis curated by Ing. Rebecca Nebbia on the "delicacy" of a correct approach to the phase of identification and quantification of criticalities in the field of OS&H. This is the first and essential step not only for the correct technological management of risks, but also for the setting of effective Health Surveillance programs.

Uncritical Risk Assessment, and consequently a Risk Management without a rigorous approach, is still a recurring problem within the OS&H (De Cillis et al., 2018). One of the causes that lead to poor Risk Assessment can be an incomplete or non-quality data collection due to erroneous simplifications. Simplifying is not wrong, but because upstream of the simplifications there are assumptions, it is necessary to verify in every context the validity of the same, especially in working phases characterized by high variability of conducting and context. An example, in the context of OS&H, is not to attach importance to pressure and temperature during the exposures' evaluation to chemical agents and in particular to airborne particulate. However, these parameters are important because they can cause an increase in the inhaled dose of the pollutant (The Japan Society for Occupational Health, 2018) and are also components of uncertainty associated with sampling procedures (Standard ASTM D4532).

Nowadays, personal samplers for inhalable and respirable fractions, that normalize data in temperature and pressure without the need for subsequent calculations, are available on the market. These samplers are suitable for high-altitude sampling and in deep yards (e.g. in deep mines) where the aforesaid parameters can reach extreme values.

Simplifications may involve not only measurements, but also other aspects such as the constitution of similar exposure groups (SEGs), that is a useful approach to reduce the duration and the costs of the survey (UNI EN 689: 2018). However, the standard itself indicates the possibility that two workers involved in the same job are not exposed in the same way (variability between workers) and that changes occur in exposure from shift to shift (variability within the worker). It follows that the assessment of the worker's exposure can't be extended to others who perform the same job nominally, and that the SEGs should be constituted only after a first exposure's assessment of each individual worker, and so on the basis of significant data.

In conclusion, the simplifications within the OS&H are certainly allowed, as long as case by case justified without losing sight of the logical process that made them possible.

A promise is to come back on this subject in extended form in a next paper.

In coherence with the theme of Dissemination of the Culture of Safety of the OS&H pages, the paper

The role of the airborne asbestos fibers measurement in the classification of working environments: the case of Large Public Facilities

discusses the actual contribution that airborne asbestos measurements can provide to the Risk Management, in particular in the identification of incipient deteriorations of ACMs. The research work was performed by implementing a special measuring strategy, in a real scenario, to increase the method sensitivity and collect data useful to relate the indoor pollution to ACMs deterioration.

Welcome back and enjoy your reading!

Mario Patrucco, Rebecca Nebbia