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Workers' risks in asbestos contaminated natural sites

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ABSTRACT - NOA is the acronym of Natural Occurring Asbestos and indicates the natural geological occurrence of asbestos fibrous minerals found in association with geological deposits such as rock, sediment, or soil that, undisturbed, may have little to no impact on the environment and human health.

In Italy, several Local Authorities, enterprises and Universities dealt with the problem of natural asbestos. Indeed, despite In Italy the use of asbestos has been banned since 1992, activities such as excavation, transport and processing of asbestos potentially containing rocks are allowed and disciplined by ministerial decree 14/5/96. Therefore, asbestos exposure for workers and population are still possible during these activities.

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The present paper reports two study cases of natural asbestos occurrences, which testify that, when National, Local Authorities and enterprises work in combination, operative models may be formed and applied to improve workers' health. These effective models should be standardized and spread to be used in other similar working situations.

Keywords: Naturally Occurring Asbestos; environmental exposure; fluoro-edenite; serpentine group minerals; Italy.

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1. INTRODUCTION

As it is known, natural asbestos presence and spreading are possible if asbestos containing rocks crop out in an area or, if buried, working activities (e.g. quarries, excavations for services or infrastructures) modify the original state of the territory or process stones to realize building products.

Serpentinites and Greenstones are rocks outcropping in several areas in Italy, above all in Central and Western Alps and in Apennines; they may contain asbestos minerals along fractures or in veins that cross or slip the rock texture (e.g. Alberico et al., 1997; Compagnoni and Groppo, 2006; Punturo et al., 2015; Bloise et al., 2016). The presence of these types of fibrous minerals depends on regional tectogenetics.

On the other side, asbestos minerals may be contained in other lithotypes, as put in evidence by many geological surveys carried out for building of sports facilities (Olympic Winter Games, Torino 2006), high speed railway lines (Valico di Giovi), urbanization yards (parks, roads, ski run, cycle lanes), or to study exposure conditions related to professional diseases in agricultural working activities on natural asbestos containing soils and rocks.

In addition, fibrous minerals, not belonging to asbestos group but likewise hazardous for human health have been detected in different rocks; the most important of these cases is the fluoro-edenite in Biancavilla area (Catania, Sicily Region) (Bruni et al., 2006); erionite, another fibrous mineral, has been detected in Nero Mt., San Pietro, Montecchio Maggiore areas (Vicenza, Veneto Region) (Liu et al., 2017; Passaglia et al., 1998).

In Italy the use of asbestos has been banned since 1992; excavation, transport and processing of asbestos potentially containing rocks are allowed and disciplined by ministerial decree 14/5/96.

So, asbestos exposure for workers and population are possible during these activities.

Italian legislation about NOA disciplines Greenstones mining and use; it also defines criteria to take care

of workers' health (Annex 4) during remediation of materials composed of asbestos containing Greenstones.

This decree, even now efficient, is focused on mining related activities thus it doesn't consider other productive activities - and the connected questions about workers' health - in which asbestos containing rocks may be involved.

The lack of national and uniform operative standards to approach natural asbestos management during working activities induced INAIL to create a work group, focused on natural asbestos, whose aims are:

national natural asbestos mapping

natural asbestos related to hazardous working situations

definition of best prevention practices to adopt for each hazardous situation.

Specifically, in this item authors, members of the work group, will describe two different experiences in collaboration with enterprises and Local Authorities.

2. PREVENTIVE MEASURES

In Italy, the problem of natural asbestos was dealt with by several Local Authorities, enterprises and Universities; the results of these studies, carried on for public works such as tunnelling, road or building yards, infrastructural works, are the main contents of several publications.

Even if these studies were carried on with different and not homogenous approaches, they put in evidence the common aspect of the need to improve and deepen the knowledge of the examined areas, from a geological, geo-structural and petrographic point of view, with the purpose to foresee and model asbestos fibers spreading during the execution of the planned activities.

With this view, the geological survey becomes the preliminary and unavoidable step to realize public works and to implement working activities in natural asbestos sites and the first action of prevention of asbestos workers' and population risk exposure.

In Italy, this first prevention action is based on the mandatory natural asbestos mapping as disciplined by ministerial decree 101/03, according to which Regions have to carry on and update yearly detailed mapped information about these sites to Local Authorities and to enterprises in order to avoid and to prevent asbestos exposure risks.

Local Authorities and enterprises have to deepen the geological study of the areas depending on the size of the planned activity, the lack of which may influence the project performance.

Geological, geo-structural and petrographic survey should define:

- type of rocks or soils
- the presence and type of asbestos minerals
- layering and texture
- degree of rock mass fracturing
- areal extension and depth of outcrops.

This in order to estimate the probability to intercept asbestos veins and, consequently, to determine the probability of asbestos fibers spreading in life or in working environment.

Many Italian studies put in evidence also the importance of regulation of working activities in natural asbestos sites because this means to avoid asbestos fibers spreading due to these activities.

In this way, the regulation of working activities in natural asbestos sites is the second prevention action. Actually, the basis of the regulation is the standardization of preventive measures to adopt in different working activities. It should be relevant to distinguish:

- public works: roads, tunnels, building yards (great works)
- ongoing activities: mines, site remediation, slope stability restoration.

This distinction is based on an operative approach. Mainly, the execution of great works implies the digging of rocks and soils in their natural places, while ongoing activities cause the rise of dust created by rock breaking.

So, preventive measures may be different and designers may include them in the planning of executive work depending on the activity.

In the following sections, authors will describe their experiences in two case studies that represent different problems, working conditions and related preventive measures, considering "surveys" as the first preventive action.

Geological skills were relevant in this context; authors are geologists working in an Inail's technical department (Advisory Department for Risks Assessment and Prevention: Contarp) whose tasks consist in detecting elements useful for risk assessment for the application of the rules concerning accidents insurance and in technical functions necessary to carry out the tasks assigned to Inail in the field of prevention and safety at workplace: arrangements, funding, control of compliance with the rules, even in collaboration with other National Institutions or with Local Authorities.

2.1. Urban development works: Biancavilla's experience

Since 2001, Italian legislation about contaminated sites has defined Biancavilla, a little town near the city of Catania in Sicily, as one of the national polluted sites to be included in the national remediation programme, because of the sanitary and environmental risk due to the presence of an asbestos-like fibrous mineral, named fluoro-edenite, inside the outcropping rocks in the area.

In fact, in the period 1988-1992, it caused a high number of asbestos related diseases in Biancavilla's population, as put in evidence in several epidemiological studies (Bruni et al 2006; Paoletti et al., 2000).

A high degree of fatal effects connected with pleural mesothelioma was due to an environmental exposure to fluoro-edenite fibers (d<1 micron; Burragato et al., 2005).

For this reason, in 2014, fluoro-edenite was classified as a human carcinogen in Group 1 by the International Agency for Research on Cancer (IARC).

Fluoro-edenite bearing stones were widely mined in

the recent past and used in civil engineering (Bruno et al., 2015).

Asbestiform fibers of fluoro-edenite are sited in metasomatized brecciated benmoritic basaltic lava dome and dyke complex, in Mount Calvario area, near to Biancavilla village, on SE slope of Etna volcano (Burragato et al., 2005; Romano, 1982) and in the Poggio Mottese area that is located east of Biancavilla and north of the Monte Calvario quarry (Bruni et al., 2006); (Fig.1). The dome of Mount Calvario dates back to the Ancient Mongibello phase and is aligned approximately in NE-SW direction. It is intensively fractured with open fissures up to 40-cm-wide (Fig. 2); its mineral genesis may be linked to the rise of late fluids in the fractured portions.

Fluoro-edenite is found in well-developed crystals, transparent yellow, almost millimetric; fluoro-edenitic mineralization's are well visible macroscopically as they are associated with abundant hematite (Gianfagna and Oberti, 2001).

The mineral has ideal formula $NaCa_2Mg_5(Si_7Al)O_{22}F_2$ and in 2000 it was approved by the Commission on New Minerals and Mineral Names, International Mineralogical Association (CNMMN, IMA) as an end-member of amphibole (prismatic Ca-amphibole where OH is entirely replaced by F). According to Italian legislation, it is not defined as "asbestos" although it has a similar level of danger for human health when inhaled.

A ministerial decree disciplined in 2002 the boundaries of the polluted site of Biancavilla; its territorial extension is 330 hectares including the mining area of Mount Calvario, in the eastern part of the city, where fluoro-edenite contaminated lava chippings were extracted, and also in the historical center, where construction materials of many buildings are composed by grinded lava chippings.

Since 2002, after roads remediation (Fig. 3) many urban development works where realized in Biancavilla sites; enterprises and above all Local Authorities executed several analysis to detect airborne fluoro-edenite concentration and workers' risk exposure.

Contarp carried out studies in collaboration with Local Authorities to monitor workers' exposure during remediation of Biancavilla's roads (2002-2003) and tunnelling yards (2009).

Surveys during excavations to settle internet cables were executed by Local Authority for environmental protection of Sicily Region - ARPA.

2.1.1. Sampling and analytical methods

Contarp used the methodological protocol established by Italian legislation.

In 2002-2003 surveys, the sampling and analytical methods were disciplined by legislative decree 277/91 and in 2009 surveys by legislative decree 81/08.

For the air sampling, personal samplers were placed on the workers, connected to supports with sampling points located in the breathing zone (Annex 5 legislative decree 277/91 and AIA RTM 1A method). The instrumentation

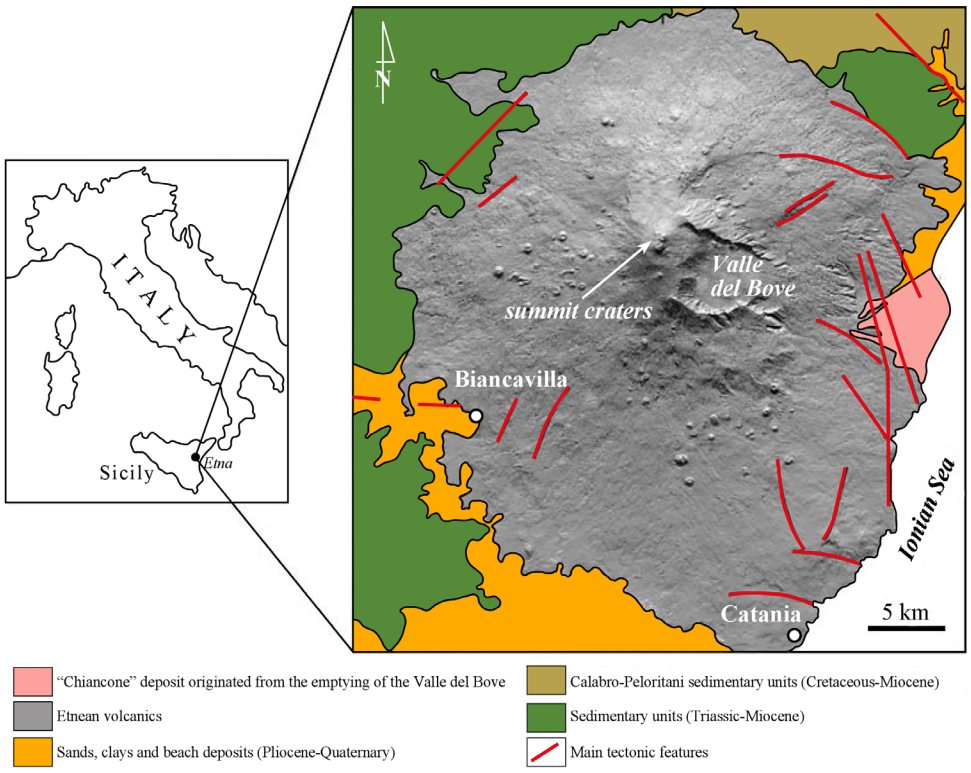

Fig. 1 - Geological sketch map of Etna Volcano, showing the location of the Biancavilla site (after Burragato et al., 2005).

Fig. 2 - Mineralized fracture (Biancavilla site, Sicilia).

and operating parameters are shown below:

- withdrawal filters: membranes in mixed cellulose esters with printed and polycarbonate lattice, with a diameter of 25 mm and a 0.8 micron porosity;
- filter holders: metal with metallic extension or plastic conductive material
- cellulose support: the sampling filter (pad) must be placed on it
- samplers: battery driven pumps (flow variation within +/-10%)
- flow rate: 2 l / min. +/- 5%
- volume: 224 - 731 l (minimum - maximum)
- withdrawal time: 114 - 369 min. (minimum maximum).

In the massive samples the research and the characterization of asbestiform fibers and other fibrous minerals, in particular amphiboles containing Ca and Mg, was performed, with analysis by Scanning Electron Microscopy (SEM).

SEM was also used to count fibers and to define morphology and chemical composition on membrane samples, analyzed the massive specimen and specifically Ca and Mg containing amphiboles.

The analysis were performed according to the method contained in Annex II of the ministerial decree 6/9/94 by the Contarp's laboratory in Rome.

2.1.2. Fluoroedenite risk assessment during remediation on the Biancavilla roads

The large use of Mount Calvario mining products and their spreading in the life and working environment caused fiber exposure and the related lung diseases in the population.

Italian Institutions carried out a remediation programme, including working procedures and monitoring surveys. The programme included urban development works to reduce airborne dust spreading, as the elimination of dirt (and dusty) roads, through:

- removal of natural contaminated soil
- building of an inactive material composed background
- paving.

In the years 2002-2003, Contarp carried out surveys concerning the potential workers' exposure to fluoro-edenitic fibers in road building yards in Biancavilla.

Sampling dealt with the following workers:

- digger conductor
- operators pours encapsulating and sealing liquid on fluoro-edenite contaminated material to avoid fibers from spreading
- manual digging operator
- mini dozer and steamroller operator
- transportation of digged polluted stone to waste

Fig. 3 - Work on removing the old paving in Biancavilla.

disposal truck driver.

Preliminary personal sampling to monitor airborne fibers, carried on a daily and then weekly basis, in each yard of the remediation area, showed a general low fiber concentration and infrequent levels exceeding the limit value of 10 ff/lt.

Contarp carried out 15 air sampling during paving in different yards.

In addition, 18 massive samplings were taken from:

- volcanic stones and sand from natural road background
- stones, sand, gravel outcropping in the contaminated area
- parts of used Tyvek overalls
- parts of used semi facial masks.

The analysis put in evidence the presence of respirable fibrous minerals (pyroxenes and amphiboles) and of morphology-like fluoro-edenite minerals.

2.1.3. Fluoroedenite risk assessment for railway building yards in Biancavilla tunnel

In 2009, Contarp carried out surveys concerning the potential occupational exposure to fluoro-edenitic fibers in railway building yards in Biancavilla tunnel.

Personal air samplings concerned with:

1) Underground yard No. 1, Est:

Workers: Miner, excavator operator: at m 138 from the tunnel entrance;

Excavator operator: at m 138.

2) Underground yard No. 2, West side

Excavator operator, miner: at m 143.40 from the tunnel entrance;

Miner: at m 143.40.

3) Underground yard No. 3, West

Excavator operator: at m 372 from the tunnel entrance;

Miner: at m 372 from the tunnel entrance.

The data obtained showed the absence of fibres in the examined samples. Chemical discrimination was not possible.

The results confirmed that fluoro-edenite presence is limited into Mount Calvario area where are the main outcrops of lava stones with hydrothermal concretions of the fibrous mineral.

2.1.4. Fluoroedenite risk assessment in excavations to settle internet cables

In 2016, the execution of broadband network in 142 municipalities in Sicily programmed a number of excavations to settle internet cables. By the consideration of the geo-mineralogic peculiarity of Biancavilla site, Local Authorities disciplined a continual air monitoring plan during working activities to take care of the population's and workers' health; the results had to be to communicated daily and in real time to Local Authorities that had to validate them. The programme included ante operam and post operam surveys in addition to monitoring during excavations into each yard.

The most hazardous monitored activities because of their potential airborne fluoro-edenite spreading were:

- excavation
- removed groundsoil handling
- packing in conform and labelled big-bags; removed soils have to be wet with encapsulating sealing liquid and packed immediately after digging. Packages have to be sealed and vacuum packed.

Analysis were carried out by SEM, using the limit value established by OMS for asbestos equal to 1 ff/lt. (WHO - Air Quality Guidelines, 2000) or twice the media value of blank concentration measured before the works were started.

Surveys were carried on according to ministerial guidelines regarding contaminated sites; they were planned and programmed depending on type of digging techniques, on digging size and yard duration. The fluoro-edenite question management was considered in the Health and Safety Co-ordination Plan (PSC).

In case the limit value was exceeding or increasing of airborne fluoro-edenite concentration, this document disciplined some technical and organizational actions to apply carefully:

- increasing yard sites and soil wetting with water or encapsulating sealing liquid to avoid fibres from spreading
- in case of increasing pollution, closing yard sites with PVC linings or geotextiles.

General actions adopted practically are:

- digger cleaning by Hepa filter vacuum cleaner wet cloth to dispose of hazardous waste according to European Waste Catalogue (CER)
- wetting asphalt with water or with encapsulating sealing liquid before smashing
- use of adequate PPE: semifacial masks with FFP3 filters, Tyvek overalls, chemical resistant gloves (nitrile rubber or PVC) , safety footwear
- decontamination procedures for workers to remove PPE
- procedures to replace filters for facial masks
- decontamination procedures for cleaning devices used by localized vacuum systems with filters.

In 2016, Local Authority for environmental protection of Sicily Region (ARPA) analyzed 53 air samples; no limit value exceeding cases were detected (http://www.arpa.sicilia.it/wp-content/uploads/2014/06/Il_monitoraggio_ambientale_nel_SIN_di_Biancavilla).

2.1.5. Final remarks

The agreement among National and Local Authorities and enterprises, established to implement urban development works in Biancavilla site, represents an operative model to take care of human and workers' health. This model should be standardized and spread to be used in other similar working situations.

Notwithstanding this, currently, the situation to remark in Biancavilla polluted site is as follows:

- Mineralogical Geo-site of World relevance, "F-edenite and F-flogopite breccias lavas in M. Calvario" was established by the ministerial decree April 15th 2015 but

it will be achieved after the environmental restoration of the Mount Calvario area;

nowadays there is a delay in the approval of the final project related to remediation and permanent safety and environmental restoration of the Mount Calvario area;

• a technical protocol is expected to be approved with the safety procedures for urban-related building work (excavation, demolition, etc.) in the National Interest Site (SIN).

Further mineralogical and environmental surveys may be needed to assess risk in the following scenarios in Biancavilla:

• old quarries (adjacent areas also used as play spaces, formerly used as an inert dump)

• plaster and mortar used in buildings (particularly old town center)

• urban activities (excavation, demolition, material handling, etc.)

• contaminated soil for agricultural activities.

In addition, it is plausible that there are other areas with F-edenite fibres occurrences for which new surveys may be useful.

2.2. Mining and processing of serpentinites: the Central Alps experience

Serpentinites are marketed worldwide as dimension and decorative stone, with remarkable mechanical properties and pleasing colors and textures.

Quarrying and processing of the stone is performed in mountain valleys mainly by small and medium size enterprises (SME); only a few of them grew up to industrialized level.

In order to pursue the aims of:

• the reduction of accidents at work

• workers' integrated protection.

INAIL provides tools to monitor continually employment and accident trends and funds, training and advice in the field of prevention, above all for small and medium size enterprises, carrying out studies and surveys on the dynamics of the injuries phenomena and of professional diseases. From this point of view, since 2004, CONTARP, with the scientific support of the Milan University - La Bicocca, Local Authorities and enterprises, carried on extensive monitoring surveys in the serpentinites quarrying sites and processing laboratories, located in the Central Alps (northern Italy) to assess workers' exposure to chrysotile fibers.

In Italy, serpentinite and greenstones are rocks crop out in several areas (Cirrincione et al., 2015; Gaggero et al., 2013, 2017; Piluso et al., 2000; Punturo et al., 2004; 2015). Before asbestos banning in 1992, these deposits were exploited for their asbestos content. In the investigated area, chrysotile asbestos was mined in the past, whereas serpentinite (dimension stone) is quarried at present time and, depending on its commercial varieties, is used for roofing and building products, paving, wood burning stoves, interior design, monumental masonry, cooking stones.

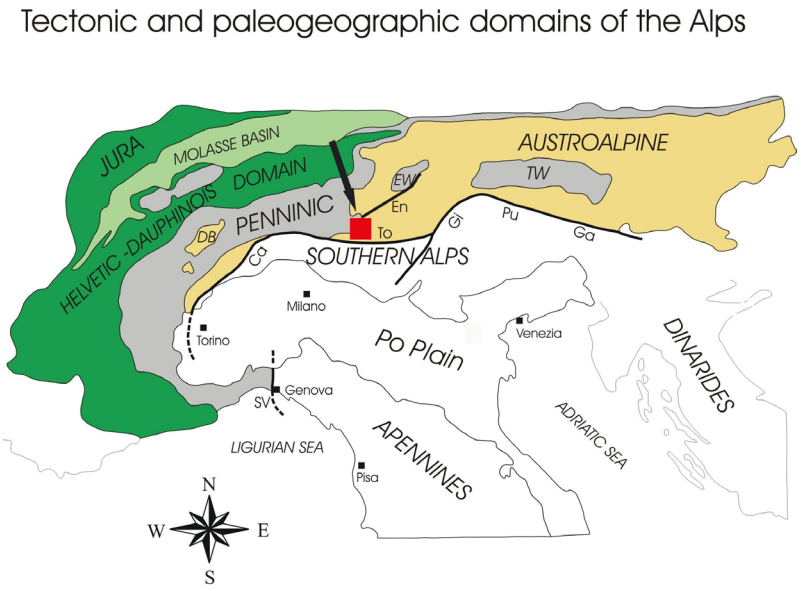

Fig. 4 - Geological map of Italian Alps (after Cavallo et al., 2004).

Generally, quarrying and excavation techniques are carried on by:

- combined use of diamond wire and explosives (detonating fuse and gunpowder)

bench splitting by diamond wire and/or by cylindrical mines

- handling by digger or Digger Derrick
- block squaring by single blade loom or diamond wire saws.

The bench is split by diamond wire and cylindrical mines (Fig. 5); diggers or Digger Derricks move blocks, later directly processed and squared in mines by single blade loom or diamond wire loom.

In the Central Alps quarrying and excavation are very difficult because of the mountainside morphology of the area that gives a complex structural set-up in which problems like waste deposits or instability are not easy to solve.

In addition, veins of asbestos, cross-fibers and slip-fibers mineralized, cross the serpentinite deposit at various angles, and cannot be easily avoided during excavation.

If mineralized veins aren't avoided during quarrying, then asbestos fibers are spread in the workplaces.

Italian legislation about asbestos and workers' exposure is very restrictive. By the adoption of European Directives, many laws were spread until legislative decree 81/08 was put into effect.

The section «Protection against asbestos related risks» of L.D. 81/08 specifies that risk of asbestos' exposure is present during asbestos contaminated equipment and devices maintenance and during asbestos remediation (removal of asbestos or of asbestos containing materials - ACM), treatment and final disposal. The decree disciplines also that the presence of asbestos or ACM requires risk assessment, continual monitoring of exposure, implementation of OHS preventive and protective actions. On this basis and in order to ensure asbestos risks' protection for workers operating in Greenstones quarries in the Central Alps, INAIL ratified an operational Agreement with Local Authorities and SME to pursue, plan, share and test the following actions:

- operational procedures to identify and map mineralized veins in the quarries
- sampling and analysis protocol for natural occurring asbestos by comparison to different analytical techniques
- best available techniques (BAT) and in-situ tests of the BAT to prevent workers' exposure and environmental contamination
- best operational techniques to assess fibers contamination of slabs and blocks before sending to further processing.

2.2.1. Asbestos risk assessment in mining and processing activities

The preliminary activity was the risk assessment; the working group (WG), composed by CONTARP consultants with the scientific support of Milan's University - La Bicocca, carried out extensive monitoring surveys in quarrying sites and in processing laboratories in order to assess workers' exposure to asbestos chrysotile fibers. The WG analyzed 254 rock samples, 87 vein

Fig. 5 - Bench splitting in Central Alps green Stones mines.

mineralizations and 23 stone cutting sludges. The WG used analytical techniques (OM, XRPD, SEM-EDS, TEM) to study "massive" and schistose serpentinite, various degrees of deformation and serpentinization, the mineralogical composition and the occurrence of chrysotile in lenses and veins, or along fractures.

It developed a specific procedure for NOA sampling and analysis (Santucciu and Somigliana, 2014)

The activities were focused on the aims to eliminate or reduce the problem of asbestos fiber concentration not only during quarrying but above all in «processing plants».

The realized solutions, planned by institutional consultants, shared with SM mines and tested by workers were divided in "main", efficient for every activity, and "specific" ones.

Main, technological, organizational and procedural, actions consist in:

- avoiding asbestos mineralized veins during quarrying
- providing dust abatement systems
- cleaning and maintenance of equipment, devices
- promoting personal hygiene
- organizing sanitary surveillance
- Protective Personal Equipment management: choosing, use, disposal.

Specific actions, technological, organizational and procedural, consist in:

- Preparation works and site manteinance: creating the first quarry front and the quarry floor, building access ramps and routes
- Organizational solutions: quarry floor and ramps manteinance
- Moving: materials handling inside the quarry and transport to processing workshops

Technological solutions:

- cab equipped with air conditioning or fresh air supply, fitted with an air filter
- spray mist dust suppression
- wet the stock mounds and quarry floor adding additive mandatory truck pass through wheel washing plant

Organizational and procedural solutions:

- product sorting before transport
- vehicles and pedestrian traffic management (speed limits, speed humps and raised platforms; separated traffic routes for working and operational areas)
- periodical cleaning and housekeeping of paved floors and haul roads
- vehicles and workwear cleaning

- Hand held drilling

Technological solutions:

- Water dust suppression systems

✓ water-powered drills: down-the-hole water suppresses dust

✓ hydraulic rock drills: better efficiency reduces exposure time

✓ water-misting controls around the hole collar

✓ local dust extraction systems

✓ water mist spraying systems

- Block squaring: bench sectioning and block squaring by diamond-wire saw

Technological solutions:

- modern cutting techniques with improvement of angular velocity/wire, chain and disk speed rates
- wastewater treatments
- presence-sensing guards to stop the machine before a person moves into a position where could be injured

Organizational and procedural solutions:

- put the stationary diamond-wire saw in the open
- keep operators isolated from sources of dust (stationary diamond-wire saw)
- residual dust removal
- cleaning and maintenance
- housekeeping: storage facilities for changing rooms (double compartment), work clothes cleaning

- Block-cutting: segregated multi-bladed frame saws

Technological solutions: enclose each sawing machine in a box connected to a suitable dust extraction system.

Organizational and procedural solutions: specific procedures for working inside the boxes and for maintenance; fitting of machines (operating modes, timing and PPE use); residual dust removal.

The Work Group planned, shared, tested block suitability check procedure, too. If the detection of chrysotile mineralized veins during the excavation with diamond wire and explosives or during block squaring cannot be avoided, that entails the asbestos spreading in the workplace in which this mineral should not occur, in particular in processing plants that usually are indoor workplaces.

The block suitability check procedure (Fig. 6) has the purpose to create a procedural barrier between the workplace «quarry» and the workplace «processing plant» against asbestos spreading; until the block is contaminated, it can't be moved out of the mine and brought to the processing plant.

3. CONCLUSIONS

Asbestos is a global question; the presence of NOA during working activities should be considered in the preliminary planning step to avoid workers' health risks and sanitary risks for the population living near asbestos sites.

The disturbance (excavations, remediation, moving) of asbestos potentially containing rocks and soils should be foreseen and planned so that adequate control measures may be carried out to avoid the spreading of airborne asbestos dust during work.

From this point of view, the ministerial decree 101/03 that regulates the mandatory mapping of NOA in Italy, represents a very operative tool that has to be used by Local Authorities and implemented with further - when necessary - geological, petrographic and environmental surveys.

Monitoring should be sized on the type of public works (roads, tunnels, building yards) or ongoing activities

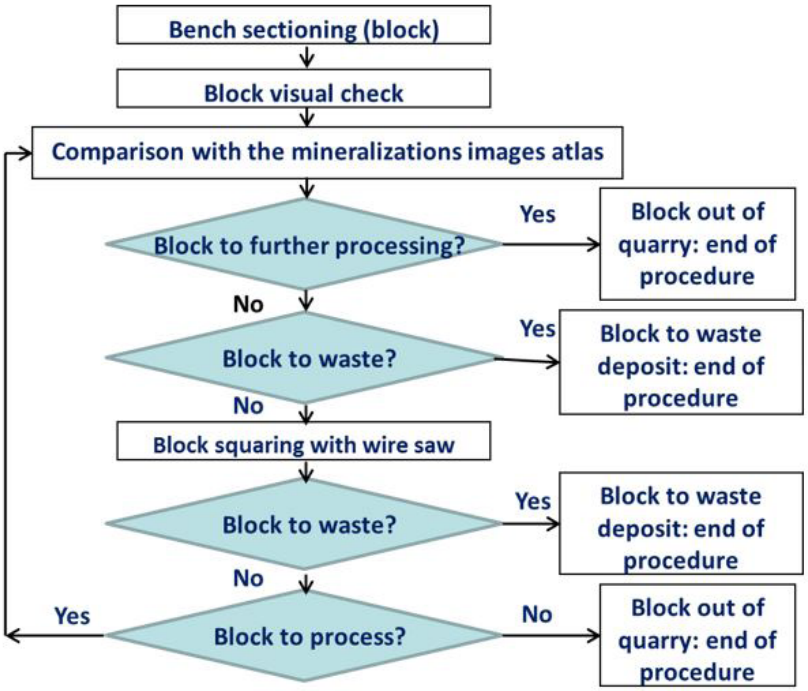

Fig. 6 - Block suitability check flow chart.

(mines, site remediation, slope stability restoration, agriculture).

Thus, the role of geologists is relevant but national guidelines should be issued to standardized surveys and implement national NOA database, as a support for consultants.

Furthermore, non - occupational exposure must also be assessed including in the analysis of the family members of workers and the peoples who live within a mile of the geological context where they are testify the presence of asbestos.

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