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Asbestos reclamation at a disused industrial plant, Bagnoli (Naples, Italy)

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Abstract

Asbestos reclamation works were carried out at a disused industrial plant (157,000 m^2) in Bagnoli, a high population density area of Naples. The case-study here presented recommends a new reclamation procedure that is not usually provided for by current international standards. To this purpose, a specific innovative cleaning machine (Safecar) was built in order to control the reclamation procedures also in non-confined areas.

An accurate identification was planned and worked out of the various types of materials (10,111 t) present within the area, and this allowed a thorough mapping of the site to be decontaminated. Besides these reclamation activities, which were carried out in both confined and open sites, each material was cleaned, collected and encapsulated following diversified procedures, according to their characteristics. Moreover, the evaluation of airborne asbestos fibre concentrations, both within and outside the decontaminated area, assured a strict respect of environmental safety level.

Keywords: Asbestos; Decontamination; Reclamation; Disused industrial sites

1. Introduction

The reclamation of buildings with presence of asbestos, in connection with the kind of material that is present, whether of a compact or friable matrix, must be carried out under confinement. In the case of friable materials containing asbestos, like for instance spraying insulation, confinement must be dynamic, that is the operations must be carried out within a completely confined and sealed area where a depression is created through intake systems provided with absolute filters. This is to make sure that fibre pollution won't take place during the abatement operations outside the area to be abated.

When the reclamation of a disused industrial plant is particularly complex, it is necessary to check beforehand the most hazardous situations for which dynamic sampling must be used as well as more innovative procedures than those provided for by international reference standards (which refer exclusively to confined areas). These innovative procedures concern both removal of material and cleaning operations, which guarantee a safe environment also in non-confined areas.

Therefore, the present work adopts an reclamation plan which reduces dynamic confinements as much as possible as well as resorting to rigorous procedures in the case of interventions in non-confined areas. To this purpose, a specific innovative cleaning machine (Safecar) was built that made sure pollution levels – both inside (confined and non-confined areas) and outside the whole area to be reclaimed – were very low, as this work clearly shows.

1.1. The case study

Decontamination and removal of materials containing asbestos fibres are a direct consequence of the following laws in force in Italy:

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- legislative decree no. 277 of 15 August 1991 (originating from the relevant EU Directive), prescribing the need to protect workers from exposure to asbestos during work [1];
- law no. 257, of 27 March 1992, establishing the rules for the termination of use of asbestos [2];
- the law by decree of the Ministry for Health promulgated on 6 September 1994, concerning the termination of use of asbestos [3];
- the law by decree of the Ministry for Health promulgated on 14 May 1996, prescribing reclamation of disused industrial plants [4];

Fig. 1. The study area, Bagnoli, Naples.

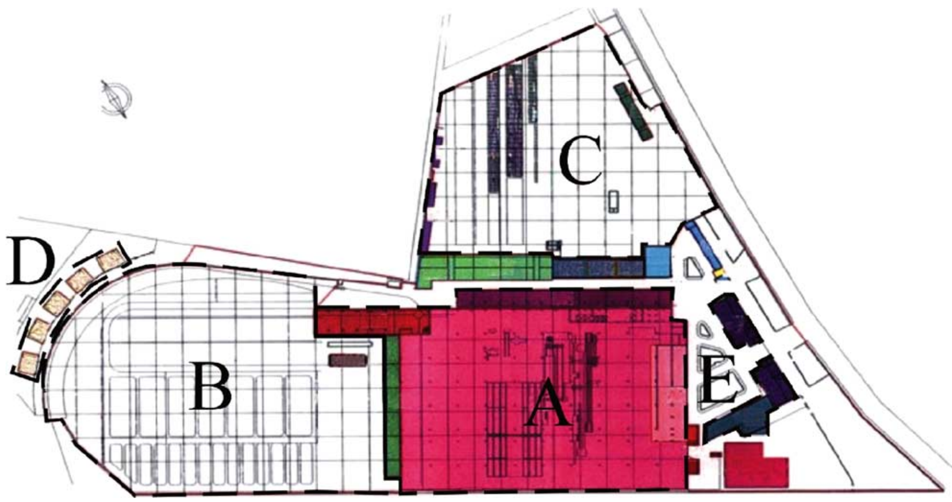

Fig. 2. The reclaimed area of Bagnoli (157,000 m^2). The whole site was divided into grids large 20 × 20 m. A = old plant area; B and C = external areas, used to store of plant products; D = worker's residence; E = management area (administration offices and residence).

- law by decree no. 22, promulgated on 5 February 1997, prescribing the management of waste matter [5]; and the legislative decree no. 36 of 13 January 2003 that implements the EU Directive 1999/31/CE pertaining waste-dumps [6] and the Decree of the Ministry of the Environment of 13 march 2003, laying down the criteria for the acceptability of wastes in dumps [7].

The former activities of the disused plants concerned the production of asbestos-cement items (i.e., pipes, slabs and joints, [8,9]). The aim of the decontamination works was that of eliminating every trace of asbestos in conditions of complete safety, as prescribed by the above mentioned laws.

The reclamation activities on the site consisted in collecting solid asbestos–cement materials, dismantling asbestos–cement slabs and tiles, cleaning up sprinklings of raw material containing asbestos on walls and hoppers, and packing both dangerous and non-dangerous waste material containing asbestos. The area to be reclaimed (Bagnoli, Naples, Figs. 1–2) is approximately 157,000 m^2 divided as follows:

- yard areas: 26,000 m^2;
- indoor areas: 36,601 m^2;
- shedded areas: 5609 m^2;
- roads and large square areas: 78,040 m^2;
- greens: 10,750 m^2.

2. Reclamation phases

2.1. Materials and methods

Analytical controls in the environment and in workroom has been conducted with fixed samplers for the environmental controls and personal samplers for the workers exposition control.

Analyses were carried out by using either an optical phase-contrast microscope (PCOM) and by scanning electron microscope (SEM) (Philips XL30FEG) equipped with an energy dispersive X-ray (EDX) analyser [10–12].

For the analysis with PCOM a sample is collected by drawing a known volume of air through a membrane filter by means of a sampling pump. The filter is rendered transparent ("cleared") and mounted on a microscope slide. Fibres on a measured area of the filter are counted visually using phase-contrast optical microscopy (PCOM), and the number concentration of fibres in the volume of air is calculated.

The use of SEM-EDX to assess the final result of the reclamation is compulsory by law [4], while the PCOM method is required for monitoring the work in progress. In this work, the detection limit of 20 ff/L established by AIA RTM 1 method for PCOM was considerably enhanced (n = 10) by the increase of the sampling flow level (9 L/min) and the number of fields analyzed (grid areas).

The SEM-EDX analysis has been performed after carbon or silver coating. The detection limit was 0.27 fibre/L (for an 8-h flow).

2.2. Monitoring of background values of airborne asbestos fibres

By way of preliminary analysis, it was deemed right to monitor the ambient air in the area immediately surrounding the site to be reclaimed, in order to gain information as to the concentration levels of airborne asbestos fibres in that area before the intervention. Therefore some monitoring stations were fixed around the area to be controlled, taking into account:

(a) wind direction;
(b) built-up areas in the vicinity of the site;
(c) technical difficulties in the implementation and control of the monitoring units.

At every monitoring station, constant-flow isokinetic samplers were positioned equipped with airometers and thermometers and automatic compensation of depression.

The duration of the sampling sessions consisted of a number of sampling periods lasting 8 h each and occurring on a daily basis; of course, each 8 h cycle happened within the time scheduled for the daily work of decontamination.

Each sampler was adequately protected from the outside environment by the implementation of appropriate coverings. Each extractor unit was implemented with a cellulose nitrate screen membrane filter**,** having a porosity ranging from 0.8 to 1.2 μm and a diameter of 25 mm. The filter was seated on a filter holder equipped with a 33 mm wide metal cover. The filter holders, propped up on special supports, were hung at approximately 1.5 m above the ground, tilted downwards and facing the disused industrial area.

The sampling flow rate was 9 L/min ± 0.5%, which was enough to keep the minimum face velocity of 0.35 m/s prescribed for samplings occurring in the presence of high-speed air in the sampling station, as is the case, for instance, of samplings occurring in the open air. Before each sampling, the flow rate and the intake volumes were assessed using a standard flowmeter and a chronometer. Before the actual decontamination works, a number of monitoring activities were carried out in order to assess beforehand background values.

Table 1 shows the mean sampling results obtained in the external sampling stations, meant to evaluate the background values. The sampling cycles took place on a daily basis (8 h/day during the working period). Mean values (Table 1) are the result of a sampling activity of 30 days distributed throughout the year to allow for the influence of seasonal variations. Fig. 3 shows the plan of the area to be reclaimed and the location of the external monitoring stations.

Table 1
Background values of fibres at external monitoring sites

External monitoring stations	Mean concentrations (fibres/L) ($n = 30$)
A	0.6
B	0.4
C	0.4
D	0.4
E	0.5

All measures are below of R.S.D.% = 20.

A weather station was set up as well, which enabled us to collect the following data on a daily basis: direction and strength of the winds, air temperature, relative humidity and raininess.

2.3. Site identification and analysis of all materials—grid mapping of the site

Materials were identified after dividing the area of the whole site (yards, sheds, buildings, etc.) into grids large 20 m × 20 m; materials in each grid were analyzed on one or more appropriately chosen samples using the Dropout Index (DI) (see Fig. 2). The dropout index is defined as the proportion between the asbestos percentage present in the sample and the percentage of the material's specific gravity;

$$\text{dropout index} = \frac{\%\text{asbestos}}{\%\text{specific gravity}}$$

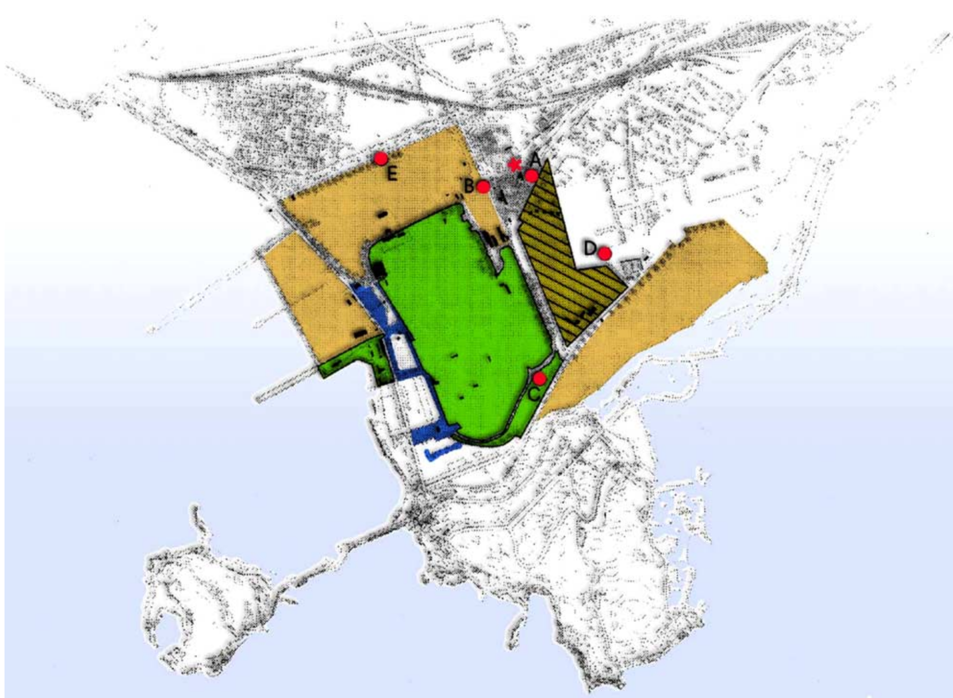

Fig. 3. External sampling monitoring stations (A–E). The plant area is marked with transversal lines.

Table 2
Types and quantities of materials reclaimed

Types of materials	Microactivity	Definition	Length (m)	Surface (m^2)	Volume (m^3)	Weight (kg)
Piled up materials	Joints				576	1325511
Piled up materials	Panels	130 sandwiches		9385	488	439161
Piled up materials	Panels	339 slabs		6152	74	183607
Piled up materials	Pipes				2073	4787271
Scraps	Scraps			22986	433	693245
Materials still used	Ceilings			14981	17	15807
Materials still used	Covering slabs	87 covering slabs (m^3)		48700	485	1023420
Materials still used	Covering slabs	111 covering slabs (m^3)		21023	102	10015
Materials still used	Panels still used	143 panels (m^3)		127	3	8942
Materials still used	Panels still used	92 sandwich-type panels (m^3)				
Dusts	Dusts				200	240184
Friable asbestos	Friable asbestos			20655	185	56607
Pipes' covering	Coverings				18	6187
Ground				6548	954	850200
Safecar				97106	57	126100
Sewerage			3130		257	345500
Total weight						10111757

which is defined as the proportion between apparent density and absolute gravity. The dropout index is a bill which is being promulgated in Italy, in order to classify waste materials containing asbestos:

DI < 0.6 = non-dangerous waste matter; DI > 0.6 = dangerous waste matter.

The total weight of reclaimed materials was 10,111,757 kg. Table 2 shows the identification data relating all materials.

3. Decontamination works

The reclamation plan was carried out by removing all materials (i.e., slabs, pipes, joints), scraps, and dusts containing asbestos, so as to reduce to the lowest terms the risk of fibres' dispersion.

To that end, a number of confined yards were set up in advance; a Safecar [9] was used, that is a specially constructed mobile decontamination unit; before reclamation, all materials were washed and encapsulated with a special encapsulating liquid; the same materials were prepared for disposal into suitable polythene packs or big bags specially sealed. Fibres' concentrations were kept under control in real time, in order to both evaluate the exposure of each worker [8] and to characterize the pollution of each yard.

During the decontamination activity, the concentration of asbestos fibres was monitored in the external stations of the monitoring network.

Decontamination works involve the site reclamation with ensuing removal of superficial ground down to a depth of 20 cm from natural surface level.

3.1. *Implementation of decontamination units*

The preparation of the yard involved the setting up of sheds, electrical system and waterworks, limits and signs e sign boards showing safety exits and escape routes, pedestrian walkways, routes for work vehicles and routes for lorries, danger signals warning about asbestos presence, and instructions for the use of individual safety devices. After setting up the yard, the following units were arranged:

(a) one general decontamination unit for workers, which was used by all those working in open yards. This unit had:
 - one clean, civil dressing room;
 - one filter room;
 - one shower room;
 - one room for dirty equipments;

(b) one Safecar decontamination unit, this room was built partly by using the walls of a building to be reclaimed. This room is approximately 13.95 m × 7.95 m large and 5.40 m high. Externally, the wall is made of bricks, the other three are consist of a metal framework made of iron tubes padded with fylon sheets. The room is covered with fylon sheets secured to iron girders and it is divided in two by an iron wall padded with fylon sheets: room no. 1 (prechamber) and room no. 2 (depression room). It has a cement floor treated with a waterproof enamel; in order to gather water, a small blind end well 40 cm × 40 cm × 50 cm large was built at the maximum slope point of the floor. The gathered water was sucked up and filtered. The area immediately outside the entrance to the room was enclosed.

 Along with the Safecar decontamination room, another decontamination unit was arranged for the staff, having the same characteristics as the general unit described in point (a). Beside this unit, another decontamination unit was arranged for materials, consisting of one dirty room, one washing room for polythene bags containing the materials collected by the Safecar, and one clean room;

(c) confined yards, these yards were set up with dynamic closure and with air extractors equipped with absolute filters; closure checks were carried out through smoke tests. By the yards' exits there were built decontamination units for materials and decontamination units for workers; authentication proofs of decontamination were carried out by controlling environmental concentrations of residual airborne fibres through SEM measurements [11], and by recovering the reclaimed areas through compliance certificates issued by relevant local health bodies.

4. Reclamation procedures

The following types of materials were identified: manufactured articles, fragments and scraps of coarse asbestos-bearing materials (ABM), dusts and ABM residuals, residuals of friable paste containing asbestos, pipes, pipes containing scraps of friable asbestos, asbestos–cement roofings and panels, waters and muds containing asbestos, soil containing asbestos.

A specific procedure was arranged for each of these types of materials. By way of an example we hereby describe the reclamation procedures of asbestos–cement roofings and panels and of soil containing asbestos.

4.1. Procedure of reclamation of asbestos–cement roofings and panels

Waste materials following within this category are:

- roofing slabs 0.7–1 cm thick;
- roofing or padding tiles;
- sandwich panels;
- slabs or panels in false ceilings.

4.2. Reclamation methodology

4.2.1. Roofings and false ceilings

Eaves gutters and special iron pieces still in use were sucked up and encapsulated, and dusts were bagged before removal. The surfaces of roofing slabs, false ceiling panels and roofing tiles to be removed were first dampened with water and diluted vinyl glue and then they were wholly recovered. After placing them on the ground, the packs of slabs were encapsulated on all of their sides. After removing the slabs, all frameworks supporting tiles or both vertical and horizontal slabs (i.e., floors, girders, pillar brackets) were sucked up either by aspirators with absolute filters or by the Safecar's draft tube and subsequently encapsulated.

4.2.2. Mechanical vehicles

Lifting-gears were used supplied with forks on which were placed packed slabs on pallets. Moreover, lift bridges were used with travelling platforms for the operators. The means employed and their use were described in each detailed working plan. At the end of their work-shifts, the operators had to walk into the workers' general decontamination unit located at the site's entrance, in order to take a shower and to follow the exit instructions from the decontamination unit.

4.3. Procedures of reclamation of ground containing asbestos

Wastes following within this typology are:

- soil containing asbestos-cement fragments;
- soil showing friable asbestos on its surface.

4.4. Reclamation methodology

The mapped area, which was considered polluted, was treated with suction performed by the Safecar, allowing the removal of the superficial layer of dislodged material. The other layer was decontaminated as follows:

(a) Soil containing only asbestos-cement fragments (0–20 cm layer). Using a mechanical shovel, a layer of about 20 cm was removed. Before removal, the soil was soaked with an encapsulating product and it was left to soak in the bucket. This waste material was poured directly into the big bags, by using nebulized water. At the end of each work-shift, both the bucket and the Safecar were abundantly washed according to the following procedure: some polythene sheets were placed on the floor, the Safecar was then positioned on them, the parts to be cleaned were sprinkled with water and encapsulated and at the same time fluids were sucked up. The fluids were then placed into containers which were subsequently emptied into the vat used to wash the bags inside the Safecar decontamination unit, so that they could be filtered.

(b) Soil with fragments and traces of superficial coverings containing friable asbestos. A confinement shed 12 × 12 m large and 6 m high was built in two stages; the framework consisted of iron and wooden girders, and all its sides and the roofing were covered with two layers of polythene. Beside the shed, the workers' decontamination unit was built, as described in Section 3.1 point (a).

5. Results of environmental controls

5.1. External monitoring network

During reclamation activities, accurate environmental monitorings were implemented (January 1999–February 2000), both within and outside the disused site area. The methods employed are described elsewhere [1,2,9]. Outside the area, a monitoring network was used consisting of the five stations described above. Table 3 shows the results of the external monitoring activity (Sites A–E, Fig. 3). Table 3 clearly shows that mean values measured outside the plant had an upward trend up until April 1999 and then began to

Table 3
Results of the outside monitoring activity

Station	January 1999 (ff/l)	February 1999 (ff/l)	March 1999 (ff/l)	April 1999 (ff/l)	July 1999 (ff/l)	September 1999 (ff/l)	October 1999 (ff/l)	November 1999 (ff/l)	December 1999 (ff/l)	January 2000 (ff/l)	February 2000 (ff/l)
A	0.9	0.9	1.0	1.3	0.8	0.8	0.8	0.6	0.7	0.7	0.7
B	1.0	0.8	1.3	1.4	1.0	0.9	0.8	0.7	0.8	0.8	0.8
C	1.0	0.9	1.1	1.3	1.0	0.9	0.8	0.7	0.8	0.8	0.7
D	1.0	0.6	1.0	1.2	0.6	0.6	0.8	0.7	0.8	0.9	0.8
E	1.5	1.6	2.0	1.6	1.0	1.0	0.9	0.7	0.8	0.7	0.8

All data represent a mean of at least 20 determinations for every month considered. For all data the R.S.D.% was below of 20%.

level off at mean values of 0.7–0.8 ff/L by the end of the works (February 2000): these are more or less level with the values detected before inception of decontamination works.

In 1987, the World Health Organization (WHO) fixed a limit value of 1 fibre/L for air quality protection [13] considering the use of a methodology comprising SEM analysis and 0.5 fibre/L if optically measured. The Italian Ministerial Decree of 1994 [3] states that concentrations of 20 ff/L detected through PCOM and 2 ff/L detected through SEM must be considered a sign of pollution. This set of rules also considers it a warning signal when there is a firm upright tendency in the number of airborne fibres; it is a downright alarm when concentrations are higher than 50 ff/L.

Our results concerning life environment (Table 3) are in agreement with those proposed by WHO, and markedly lower than the above mentioned safety levels fixed by Italian legislation. We can therefore conclude that the decontamination works were correctly conducted.

5.2. Controls in working places

Each yard, both confined and open, was controlled by monitoring the possible dispersion of fibres in the environment (inside the plant) and the exposure of those who worked during the reclamation phase.

The duration of the sampling was normally 8 h or, in some cases, fraction of this period, whenever it was necessary to obtain different information on same phase of reclamation. In all phases of reclamation, workers were equipped with respiratory masks, particularly demi-mask with P3 filters and tyveks clothing. For the workers exposure measurements, the sampling pumps and devices were carried by the workers themselves and all samples were taken outside the masks.

The results of this study are reported in Table 4. As we expected, it is to be noted that the values of environmental (inside) samples are clearly lower than those concerning the workers. Also, the standard deviations were, of course, generally high and in some cases extremely high (i.e., November 1999, monitoring of workers, Table 4). This example corresponds to an R.S.D.% of 339 and of a maximum value of 24 ff/L that is however largely below the safety limits in force in many countries (see Table 5).

If we compare our data with the occupational exposure limits in force in some countries (Table 5), we can observe that our results are largely below these limits. We can conclude that the reclamation process was conducted according to high quality safety standards and procedures.

6. Removed and disposed of materials

Materials containing asbestos were disposed of according to the classification prescribed by certifications. Cement materials were disposed of in two different authorized sewage disposal plants, both located in the Province of Latina (central Italy). Friable materials declared to be dangerous were disposed of in a centre for thermodestruction located in France, which makes use of a fritting of waste materials containing asbestos (Inertam process).

This process involves the destruction of the crystalline grating of silicate minerals constituting asbestos fibres at very high temperatures, and their transformation into a fritted,

Table 4
Results of asbestos monitoring activity at working places (inside the Plant and also on workers)

Month	Environmental monitoring		Workers monitoring	
	Environmental mean, ff/L ± S.D.	Number of samples	Worker's mean, ff/L ± S.D.	Number of samples
January 1999	1.23 ± 1.61	65	3.01 ± 3.91	28
April 1999	1.50 ± 1.81	62	2.06 ± 1.69	35
September 1999	1.20 ± 1.11	89	1.58 ± 1.75	53
October 1999	1.06 ± 1.18	102	2.52 ± 3.10	82
November 1999	3.38 ± 0.89	116	7.09 ± 24.05	71
December 1999	1.72 ± 1.07	80	1.86 ± 1.91	47
January 2000	1.13 ± 0.76	85	2.74 ± 3.01	51
February 2000	1.10 ± 0.85	49	2.55 ± 1.32	48
Total (mean)	1.54	648	2.92	415

Table 5
Occupational exposure limits for asbestos in air in some countries

Country	Limits	Concentration
USA (ACGIH)	TWA	0.1 ff/mL (100 ff/L)
USA (NIOSH)	REL	0.1 ff/mL (100 ff/L)
USA (OSHA)	PEL	0.1 ff/mL (100 ff/L)
AUSTRALIA (NOHSC)	TWA	0.1 ff/mL (100 ff/L)
CANADA (TBS)	TWA	0.2 ff/mL crocidolite (200 ff/L), 0.5 ff/mL amosite (500 ff/L), 1 ff/ml other forms of asbestos (1000 ff/L)
EUROPEAN COMMUNITY (Directive 2003/18/CE)	TWA	0.1 ff/mL (100 ff/L)
ITALY (Law no.257, of March 1992) (Directive 2003/18/CE is still not implemented in Italy)	TWA	0.6 ff/mL crysotile (600 ff/L), 0.2 ff/ml other forms of asbestos (200 ff/L)

ACGIH TWA: American Conference of Governmental and Industrial Hygienists' threshold limit value expressed as a time—weighted average; the concentrations of a substance to which most workers can be exposed without adverse effects; NIOSH REL: National Institute of Occupational Safety and Health's recommended exposure limit; OSHA PEL: Occupational Safety and Health Administration's permissible exposure limit expressed as a time–weighted average; NOHSC TWA: National occupational health and safety commission's time–weighted average over a given work period (e.g. 8 h workday); TBS TWA: Treasury Board of Canada's time–weighted average over a given work period (e.g. 8 h workday).

amorphous, inert product, characterized by a volume 20 times lower. The transformation occurs in a very high-temperature oven (about 1600 °C) fed by a plasma torch (about 4500 °C). The oven and the loading system are completely automated and suitable to hold containers kept sealed from arrival up until destruction, so as to avoid asbestos fibres' dispersions in the environment. The relevant instruments – such as the post-combustion chamber, which assures secondary combustion of gases contained in smokes at about 1200 °C, and filtering systems reducing dusts – eliminate the environmental impact of emissions into atmosphere.

Reclamation involved disposal of the following quantities of material containing asbestos:

- 3,643,780 kg of processing products, and asbestos–cement residues and coverings;
- 584,700 kg of various waste materials;
- 141,000 kg of shrubs and brushwoods;
- 400,000 kg of asbestos materials sent to Inertam (France).

7. Conclusions

It was possible to implement the decontamination of a very large disused site, in a high population density area of Naples, where there were a considerable amount of items containing asbestos, waste materials from processing, as well as plants and buildings containing asbestos or polluted with the asbestos cement sprinkled on the walls as a consequence of the cleaning methods used during work activities.

An accurate identification of all materials present and the arrangement of the whole area in detailed grids allowed a thorough mapping of the site to be reclaimed. This monitoring activity was indispensable for the preparation of the reclamation plan, which was carried out by preparing a limited number of confined yards.

Therefore, a large part of the activity was carried out in open yards, and each material was cleaned, collected and encapsulated following diversified procedures according to their characteristics, as well as to the surface ground to be removed where asbestos residues were found.

Frequent controls of the dangerousness of waste materials through the evaluation of the fibres' dropout index were essential to fix different procedures according to each single type of material. The assessment of environmental pollution around the area during reclamation activities and the constant monitoring of workers and yards allowed us to control fibres dispersion and, therefore, to work according to the necessary safety requirements.

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