Abatement and bio-digestion of airborne contamination in precision mechanics: the case study of Beretta firearms

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Abstract

The precision machining represent a crucial step of firearm production and it has, in general, a number of critical environmental issue related to the specific processing.
For about four months, an Immobilized cell bioreactors system (Bonoli et al., 2014; Borkowski 1995; Lakhwala et al. 1991) has been installed within the rifle barrel reaming area of the Beretta plant for containment of the contamination caused by specific processing involved.
Although the levels of contamination arising from emulsions used for the reaming process of the gun barrels and metal dust deriving from it proved to remain already within the limits of the law, remarkable abatements of several airborne contaminants have been detected.
The improvement of indoor environment was confirmed both by impressions of the staff and analysis performed on indoor air quality and process water of the system, carried out on the basis of standard procedures for industrial hygiene by an independent laboratory.Oil mist concentration, for instance, decreased for about 40% of baseline in the air. Volatile Organic Compounds were brought to levels below the detection limit of the portable Photoionizer used.
Residual inert dust, captured and biodegraded by the system, was found in bioreactors, in concentration up to 1700 mg/L of iron in water, for a total quantity of about 885 g during the whole testing period.
Considering the critical issues related to the production of firearms for sports use, the application of this technology appears to be particularly suitable for containment of carcinogens airborne contamination, such as walnut wood for the production of gunstock (Chemotti, 2002).

Introduction

The BerettaCompany, with its nearly 500 years of history, is a key element for the economy and employment in Valtrompia, one of the three main valley of the Brescia district, in the Northern Italy. A manufacturing company of excellence, Beretta strongly keeps a balance between tradition and innovation: "production departments are" in fact "structured on robotized workstations but also on the important presence, the human factor, as a necessary condition to obtain the levels of precision and quality requirements"[1]. The production is represented by 90% of weapons for sports use, but Beretta weapons are currently even supplied to the Armed Forces and Police of different countries.
In particular this study focused on the reaming operation of the gun barrels, a precision mechanics operation requiring a high level of specialization which determines the excellence and accuracy of the rifle.Typically, rifle's barrel is produced by high-precision drilling of high alloy Chromium-Molybdenum Steel, with high resistance to pressure (since the peak pressure developed into the discharge operation reach 345 MPa) and mechanical stress, and the reaming phase represent the final refinery of the barrel.
This particular production phase has proved to involve two main families of contaminants: metal fine and ultrafine dust, coming from mechanical friction of the gun barrel and the reamer, and oil mist, arising from the fluids used to cool and lubricate tools and pieces in the metalworkingprocess. They are turned into fine mist by mechanical friction of the reaming machinery on the rough-cut barrel and consequent heat dissipated. The lack of localized aspiration on workstations favors an indoor accumulation in of aerosols and oil mists, not always sufficiently removed from

workstations through the general ventilation system, even though the general indoor air quality tested by the industrial medicine authority proved to remain consistently compliant with the European regulations limits.
The oil mist is defined as [2] "Aerosols of liquid particles of size less than 1 micron dispersed in the air, generated by the processes of evaporation and condensation, atomization, nebulization etc. (aqueous, oily, solvent)". Airborne contaminants particles have specificproperties, due to their size and nature: oil mist falls, in fact, in the submicron contaminants class. In particular, the average size of oil mist has been defined as belonging to the accumulation mode ranging from about 0.05μm to 2μm [3]. Particles of this kind are known to be among the most stable particle size range, accordingly to Morawska [3], deriving from gas to particle conversion, chemical reaction or physical phenomena as condensation and coagulation. They are doomed to remain airborne for long period of time as, as stated by Morawska [3], the removal mechanisms are least efficient inthis regime, thus increasing the potential exposure for workers. Depending on the size of the particles, they will tend to settle in specific sections of the respiratory tract: particles of smaller size are, therefore, carriers of the major size-related risk of exposure, since they can reach the pulmonary alveoli and enter into direct contact with the blood circulation.The combination of tendency to linger in indoor air for long periods and ability to penetrate deep into the respiratory tract (particle size range of 0.1 to 1 μm are easily deposited in the lungs. Morawska [3]) makes this class of particulate carrier of the major health risk for humans. As stated by Seaton et al. [4], adverse health effects can be caused by ultra-fine airborne particles, such as exacerbations of lung disease and increased blood coagulability, leading to the observed increases in cardiovascular death associated with urban pollution episodes can be ascribed, in susceptible individuals, to alveolar inflammation, thus suggesting an extra precaution even in working place. This assumption is consistent with several epidemiological studies showing correlation between elevated levels of airborne particulatesand increased rate of morbidity and mortality [5].
In parallel with oil mist, but with a strong correlation for the generating mechanism and fate, indoor air of gun producing facilities is affected by metal dust, deriving from mechanical friction and, thus, consumption and volatilization of particles of metal under processing.
The direct health impacts of trace metal contamination are complex to assess due to the complexity of the medical factors involved [6, 7], but it is known that exposure to high concentrations of heavy metals would lead to their accumulation in environment and, therefore, in the human body, since they are non-biodegradable. This represent a peculiar characteristic of heavy metal, which can accumulate particularly in fatty tissues,potentially affecting crucial system like the central nervous system, or circulatory system with consequent disruption of the normal functioning of the internal organs [8, 9, 10]. In addition to this, when inhaled, they can trigger inflammatory process of inflammation, sensitization and even damaging of lungs and tissue, coming potentially into direct contact with blood stream and, therefore, other organs [6, 7].
Even in facilities like Beretta, where all regulation to protect workers' health and safety of the working environment are completely fulfilled, with adequate prevention measures against other risks related to airborne metal dust concentration (for example, explosion), improvement should be pursued both for the sake of safety as well as for the quality of product, which, in an excellence framework, could be negatively affected by airborne contaminants.
The aim of the study was identified according with the Company, in the improvement of the quality of the working environment beyond the standards required by the regulations. In particular, the removal of oil mist and metal dust in the indoor air have been identified as specific targets for the application and verification of U-Earth AIRcel system [11, 12, 13, and 14]. Experimentation in the reaming barrel area allowed the Company to evaluate the effectiveness of the biotechnology addressed to the possible application to other potentially critical areas of the same facilities of the Beretta group.

Materials and methods

The experimental application of AIRcel biotechnology in the Gardone Valtrompia (Italy)Beretta facility involved the department of gun barrels reaming for a period of three months between November 2013 and February 2014. The oil mist have been identified as specific target to be abated, verified by indoor air monitoring.
The testing period has coincided with a period of renovation of the building in which the barrels reaming area is located, with the full implementation of the productive area only since January 2014.
The contamination issues involved into the present study, i.e. oil mist and metal dust, are closely related to the kind of work carried out within the plant and, therefore, past air quality tests were verified and they showed that facility is consistently within the regulatory limits for safety of the working sites [15]. The Company has shown, however, a

strong interest in establishing a new environmental quality standards within their facilities in order to prevent health risks for operators.

During the three months trial period, three independent tests on indoor air quality and process water were performed. Oil mist and polycyclic aromatic hydrocarbons (PAHs) have been checked in indoor air, while heavy metals content in process water have been measured. These investigation have proved that Threshold Limit Value (TLV), i.e. the concentration level at which a worker could be exposed throughout his working life time - for no more than 15 minutes for TLV-STEL(short-term exposure limit) to be repeated no more 4 times per day with at least 60 minutes between exposure periods and on an average exposure on the basis of a 8h/day, 40h/week work schedule for TLV- TWA (time-weighted average proposed by the US National Institute for Occupational Safety and Health,NIOSH [16]) applied in Italy for mineral oil in indoor air (5 mg/m^3)was always respected and no presence of PAHs was detectable.

Analysis of the process water of the bioreactors was carried out to completion and confirmation of the results obtained on the indoor air.

The area selected for experimentation,where the reaming of the rifle barrels is performed, was constituted of an open space within a building body, partially dedicated to other processing.A total number of 7 AIRcel bioreactors were placed in the area: n. 5 Aircel 5000 around the reaming machines, in order to contain the contamination source and n.2 Aircel 600 as sentinels on the main openings of the building, with the intent to prevent cross-contamination (in fact, the area isconnected to different working areas through a covered walkway between different buildings).

At the time of installation of AIRcel system, the department was under renovation, with a progressive replacement of the pavement and under pavement, being soaked with mineral oil during the years. This condition implied a reduced processing rate in the sectors complementary to the reaming one, which lasted until January 2014when the facility came in full operation again. Thus giving rise to the operative worst case scenario conditions in the final stage of the testing period, while the first months were characterized by potential risk related to PAH and mineral oil volatilization related to renovation.

Exposure to aerosols and oil mists for operators is only partially contained on most modern machines equipped with localized aspiration, even though survey data highlightedairborne concentrations below the TLV reference provided by NIOSH [16].Lubricant oils used for the reaming process are, in fact, numerous and variously defined as synthetic base oils with additives, hydraulic fluid, gear oil, oil for machinery, cutting fluid for machining, highly refined mineral oil, not classified as dangerous for UE regulation and non-carcinogenic. The regulatory limit for working environment for the oil mist generated by them is, therefore, set at 5 mg/l.

The bioreactors used, provided by U-Earth Biotechnologies, are classified as "Immobilized cell bioreactors" and they work through a combination of convection (for handling oxygen and larger particles) and, as a main driving force, the biological digestion of hazardous materials captured. These miniaturized air treatment plants, in fact, use the bio-oxidation mechanism to destroy gases, volatile organic compounds (VOC), odors, and remove particulates [17, 18]. Noionization, nor electrostatic charging (which increase the danger of airborne components), is generated by the AIRcel bioreactors, whilethe natural surface charge of the particles is exploited as capturing principle.

The correct sizing and positioning of bioreactors contributes to the superposition of the individual units, increasing the overall effectiveness of the system.For the nature of the technology, which treats indoor air recirculating it inside the industrial facility, it was not necessary to complete the installation with pipes for exhaust air, preventing problems typically related to the ventilation, such as high energy consumption for forcing air inside and outside the building and consequent air conditioning, as well as the difficulties in capturing fine and ultrafine airborne contaminants, on which the surface forces play a major role compared to volume ones.

Sampling of air quality were made by vacuum gauge with subsequent adsorption on inert support, a technique that allows the detection of even small amounts of contaminants like oil mist (0.1 mg/L). The samples were taken at different locations of thefactory body, kept identical in every subsequent monitoring for sufficient time to permit the analysis of more than 1000 L of air.

Sampling of VOC, particularly dangerous for operators' health and often carried by airborne particulate of breathable size, have been achieved through the use of a portable Photo-Ionization Detector(PID), which provided instantaneous reading of the overall VOC concentration within the building.

Results and discussion

In order to provide a comprehensive report of the results, they have been divided into two different paragraphs, related, on one hand, to direct measurement performed on indoor air quality inside the facility and, on the other hand, to the inference deduced from indirect measurements carried out on process water into the bioreactors.

Indoor air quality tests

The verification of VOC usingportable PID, has confirmed the fall of such compounds from various concentration (the device provides, in fact, instantaneous readings and, therefore, they can vary in different spots) in a range between 0,5 and 0,9 ppm to concentrationssteadily below the detection limit of the instrument in the entire area treated with AIRcel system.

It was found evidence of part of the fine and ultrafine iron dust attracted by bioreactors and retained in the compartment of the fan, therefore, apparently busy in countercurrent to the flow of exhaust air. This was considered an example of the attraction due to electric charge, which is prevalent on ventilation for particulates of this size.

In the evaluation of the results it's important to consider how:

1. the *baseline* for comparison was carried out during *summertime,* that is, when natural ventilation is more favorable for the containment of the specific issue (on the contrary, a baseline performed in wintertime would have, presumably, provided higher data);
2. processing within the factory was running at a reduced intensity during detection of baseline, while the *final sample,* carried out, on the contrary, with *machinery at full capacity***.**

In the following Table 1, analytical results of oil mistconcentration aredisplayed: the indication of the values below the detection limit (0.1 mg/l) was reported and considered, conservatively, in the assessment of abatement rates as corresponding to the 95% of this limit (^{1}) or, more likely, corresponding to half the detection value (^{2}).

Sampling point identification code	t_0 08/08/2013	t_1 01/31/2014	t_2 02/28/2014	abatement rate compared to t_0^{1}	abatement rate compared to t_1^{1}	abatement rate compared to t_0^{2}	abatement rate compared to t_1^{2}
A25	0,17	0,27	<0,1	44%	65%	71%	81%
A32	0,21	0,27	0,15	29%	44%	29%	44%
A12	0,13	0,15	0,1	23%	33%	23%	33%
A47	0,23	0,13	<0,1	59%	27%	78%	62%
average abatement rate				39%	42%	50%	55%

Tab. 1 - Analytical results abatement of oil mist in t_0 (baseline), t_1 (about 90 days after installation) and t_2 (130 days after installation). Where the concentrations observed were below the detection limit, two different scenarios have been outlined to define the abatement rate: (^{1})= the concentration value in t_2 has been assumed conservatively equal to 95% of the detection limit value; (^{2})= the concentration value in t_2 has been assumed equal to 50% of the detection limit value

Process water quality tests

The sampling of process water were carried out after about 60 days of installation (01/02/2014), after about 90 days of installation (01/31/2014) and after 120 days of installation(at the end of the test02/19/2014)

The main purpose of water testing was to identify and quantify elements and compounds not degraded (or under degradation process, i.e. intermediate metabolites) by the biomass, especially metals. The AIRcel machines were supplied with water from the public distribution network, so contamination from metals and oils is supposed to be found occasionally and only in traces, not harmful for human health. The chemical quality of supply water was, therefore, known and, since non chemical compounds are included into U-ox biomass, the contamination to be found in water samples is assumed to come from the capturing activity of the AIRcel system. Airborne contaminants are, in fact, attracted and captured by the AIRcel system and, then, U-ox biomass metabolize degradable compounds, while inert or non-degradable compounds and elements (e.g. metals) should be found into water in form of residual material at the bottom of the tank.

The samples showed a remarkable presence of the following:

1. metal dust from processing of gun barrels,
2. suspended solids presumably coming from airborne particulates,

3. COD (chemical oxygen demand) deriving from the presence of compounds captured by the system and in course of degradation ; at the same time also BOD (biological oxigen demand) is increasing,
4. oils deriving from lubricant oils used into reaming process.

Water quality parameter	**S. time**	**pH**	**Suspended solids**	**BOD5 (as O2)**	**COD (as O2)**	**Cd**	**Cr (tot)**	**Ni**	**Pb**	**Cu**	**Fe**	**Oils**
Unit of measure		pH units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
AIRcel 5000-SN 13070003	t_1	8,3		<5	<10	<0,002	0,02	<0,02	0,02	0,02		0,9
	t_3	8,1	52400		10200		0,3	0,19			45	0,8
AIRcel 5000-SN 13070004	t_1	8,4		<5	<10	<0,002	0,02	<0,02	<0,02	0,01		0,2
	t_3	9,2	39180		9000		1,8	0,9			300	0,9
AIRcel 5000-SN 13070005	t_1	8,4		<5	<10	<0,002	0,02	<0,02	<0,02	0,01		<0,2
	t_3	7,9	108800		14800		2,5	1,1			1728	1
AIRcel 600-SN 13070007	t_1	8,3		15	39	<0,002	0,02	<0,02	<0,02	0,02		0,3
	t_3	8,2	32560		13100		3	2,2			468	0,9
AIRcel 600-SN 13070008	t_1	8,5		<5	23	<0,002	0,03	0,02	<0,02	0,02		1
	t_3	8,9	53760		8200		1,8	0,8			456	1
AIRcel 5000-SN 13070001	t_1	8,4		12	32	<0,002	0,02	<0,02	<0,02	0,01		0,1
	t_3	8,1	48560		10400		0,6	0,3			99	0,7
AIRcel 5000-SN 13070002	t_1	8,1		<5	<10	<0,002	<0,02	<0,02	<0,02	<0,01		0,2
	t_3	7,9	39020		12900		4,2	3,1			1050	0,6

Tab. 2 - Analytical results on process water in different sampling time: t_1 (60 days after installation) and t_3 (120 days after installation).Lead, copper and cadmium, found in traces (in concentrations around the detection limit values) in the first samplings in t_1, were not detectable in the following monitoring. Ironwas detected in remarkable quantities, exceeding the maximum allowed content for drinking (and, therefore, tap) water.

On the basis of the contaminants detected within the process water, it has been carried out an evaluation on the amount of the compounds of interest related to the specific working environment, in particular heavy metals and oils, captured, treated and immobilized by the AIRcel system in the form of residual material on the bottom of the bioreactors tanks. Metals found in process water were evidently deriving from the reaming of gun barrel, during which they are volatilized, but cannot be totally degraded by the biomass, remaining as residual material. Lead, copper and cadmium, found in traces (in concentrations around the detection limit values) in the first samplings in t_1, were not detectable in the following monitoring, probably due to uncertainties in the first instance analysis. Iron, on the other hand, was detected in remarkable quantities, from 225 times to 8640 times the maximum allowed content for drinking (and, therefore, tap) water. Provided that analysis periodically performed on tap water by the water supplier public company gives no evidence so far of the presence of iron, it can be assumed that the whole amount of the metal found into bioreactors had been captured from airborne dust.Even though air quality monitoring had not been able to detect airborne metal particles, confirming the compliance to regulation on safety in working place, evidences of the presence of iron dust were clear, as displayed in Fig. 1 and in Fig.2 (note that the triangular shaped grid at the top of the machinery had been perfectly replicated by the iron dust deposit at the top of the electrical box below).
Inferences have been made on the total content of contaminants captured by the system, calculated on the basis of the concentration detected into the samples. The quantified amount of pollutants have been projected to the minimum water content inside the bioreactor (see Tab.3), below which the machines indicate a low level alarm and stop, since the activity of capture and digestion is compromised. This assumption is, therefore, conservative, since the minimum level value corresponds to about 40% of the maximum potential content of water. Thus, in the perspective of a potential recovery of the iron that can be present in the residual material, it is possible to assume a quantity between 7 and 17 g per day of fine and ultra-fine iron dust.

Contaminant	Chromium (tot)	Nickel	Iron	Oils
Aircel 5000 - SN 13070003	0,0765g/l	0,0485g/l	11,4750 g/l	0,2040g/l
Aircel 5000 - SN 13070004	0,4590g/l	0,2295g/l	76,5000g/l	0,2295g/l
Aircel 5000 - SN 13070005	0,6375g/l	0,2805g/l	440,6400g/l	0,2550g/l
Aircel 5000 - SN 13070001	0,1530g/l	0,0765g/l	25,2450g/l	0,1785g/l
Aircel 5000 - SN 13070002	1,0710g/l	0,7905g/l	267,7500g/l	0,1530g/l
Aircel 600 - SN 13070007	0,2040g/l	0,1496g/l	31,8240g/l	0,0612g/l
Aircel 600 - SN 13070008	0,1224g/l	0,0544g/l	31,0080g/l	0,0680g/l
Content into the whole system	2,7234 g	1,6295 g	884,4420 g	1,1492 g
Avg. daily abatement	0,0227 g	0,0136 g	7,3704 g	0,0096 g

Tab. 3 - Total quantity of main contaminants found in the residual process water at the end of the test period

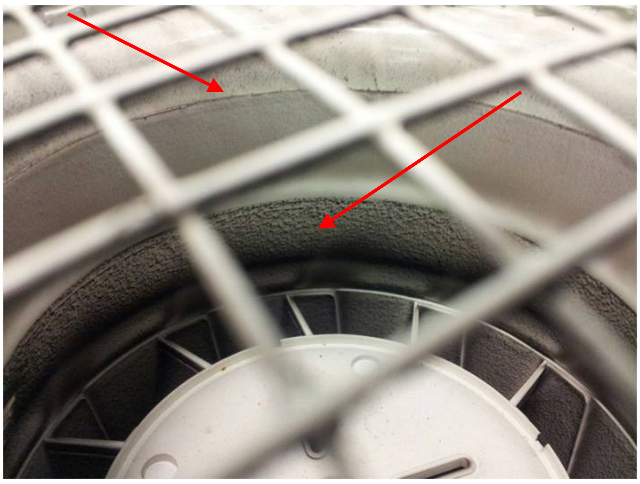

Fig.1-Iron dust deposit at the outflow side of the fan

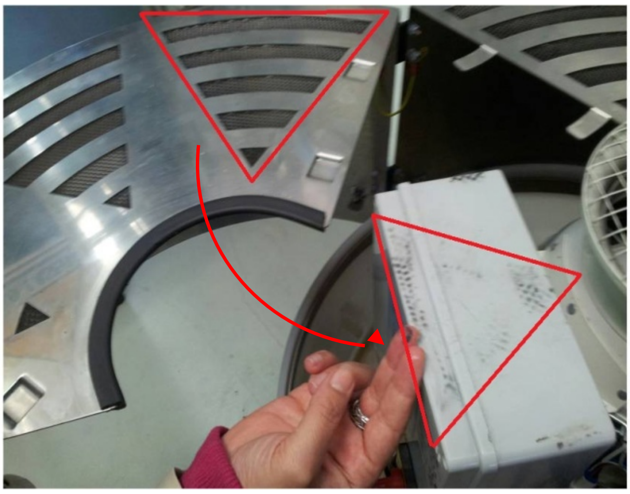

Fig.2 - Iron dust deposit at the top of the machinery, replicating the triangular shape of the protection grid

A backward assessment of the average pollutants concentration abated has been performed, particularly interesting for metal dust, for which the air quality monitoring had proved not efficient, due to the low concentration. The building size was known and a conservative assumption was made regarding the ventilation: since no forced environmental air venting system is implemented, natural ventilation has been imputed for a single total air volume exchange per day. The obtained results were remarkably below the Threshold Limit Values by American Conference of Governmental Industrial Hygienists (ACGIH): Chromium and Nickel's projected average concentration in indoor air were calculated as compliant to the regulation by more than two orders of magnitude, while iron's projected concentration, as expected, resulted around 10% of the TLV-TWA of 5 mg/m^3, i.e. around the lower detection level of the monitoring instruments.

The obtained results suggest the opportunity of an in-depth analysis dedicated to the possible recovery of metal dust from process water and residual material, both to address the final disposal issue correctly and to verify the feasibility of a recovery chain, at least for iron.Several different treatment technologies are currently available to remove metal ions from water (wastewater in particular), such as membrane separation, ion exchange reverse osmosis, solvent extraction, evaporation and precipitation [19-24]. Since, in this case, metal dust appears as a precipitate at the bottom of the bioreactors' tanks, as expected from the conclusions presented by Rus et al. [25], a final filtration stage or magnetic separation (like High Gradient Magnetic Separation - HGMS – proposed by Los Alamos National Laboratory, Du Pont and New Mexico State University [26] and Osaka University [27])would be sufficient to close the cycle, solving the residual sludge issue with reduced costs due to the relatively limited quantities involved.The application of a final stage of treatment for process water could involve a magnetic filtrationsystem aimed to the removal of both iron dust and possible residual surfactants and oil [19] not yet digested by the biomass at the time of the required discharge.

Conclusions and outlooks

For about four months, an immobilized cell bioreactors has been appliedin the rifle barrel reaming area of the Beretta manufacturing plant of Gardone Valtrompia(Italy) for containment of the airborne contamination related to the specific processing involved.

The sizing of the system has been calibrated as to treat only part of the plant building where the reaming process is performed, in order to contain the test to a pilot scale level, even if applied already on field conditions.

The airborne contamination arising from emulsions used for the reaming process of the gun barrels and metal dust related to it proved to comply with the regulations for health protection and safety in working placealready in the baseline, a remarkable reduction was found in the monitoring of oil mist, which is around 40% (despite the already low baseline values), and in Volatile Organic Compounds content (brought below the detection limit of the photoionizator used). Contextual verification of process water has also highlighted the capture of airborne oils and metal particles resulting from the specific processing carried out in the treated area. Thus proving the system to have captured large quantities of airborne iron dust, even if it had not been detectable by sampling systems conventionally used in hygiene labor.The removal of these contaminants (i.e. oil mist and metal dust) is particularly important in order to decrease the health risk for operators, given the size of the particles, belonging to the breathable fraction.

The airborne contamination has been contained below the baseline values, even in the presence of a greater working intensity in the treated working environment: a partial renovation of the building was in progress during the setup phase, while full working capacity had been recovered during the last two months of experimentation, potentially aggravating the indoor air pollution conditions. In addition to this,it must be noted how the reduction was achieved despite the baseline sampling period has coincided with summer, when favorable condition of air quality due to natural ventilation are expectable. In this regard, the area of rifle barrels reaming has been treated with the formation of an area of clean air in an unconfined environment (different process are, actually, carried out in the same open-space building) and with satisfactory results in the entire body of the building.

A key element to demonstrate technology effectiveness applied in the specific environment of precision mechanics was the monitoring of process water quality inside the bioreactors. A highsuspended solids concentration,more than 100 g/lof was found into samples, attributable to the capturing activity and bio-oxidation of the corpuscular airborne compounds. Oils deriving from lubricant additives used in the reaming process were found into samples, but still compliant with standard concentration required, for example, for discharging in water bodies. A remarkable amount of metal dust, especially iron, was detected into the bioreactors at the end of the testing period: inferences have been made on a backward assessment of airborne metal dust captured, on the attempt of supplementing indoor air monitoring, which proved to be insufficient to characterize the specific working environment and, therefore, the effectiveness of the technology applied. In the full-scale application perspective, the feasibility of metal dust recovery from the process water must be addressed as an opportunity, rather than an issue and several studies prove its applicability in different contexts.

In relation to the specific industrial sector, i.e. the production of firearms andin particular rifles for sport use, the most critical issues to be addressed by future possible application of the AIRcel technology is for sure the containment of airborne contamination by carcinogens, such as walnut wood for the production of stocks [28]. The Italian Legislative Decree 66/2000, in fact, introducing changes to Legislative Decree 626/1994 regarding carcinogens, included the hardwood dust among substances, preparations and processes that expose workers to carcinogens. According to IARC (International Agency for Research on Cancer) available data and information are sufficient to relate the processing of hardwood with 'increased incidence of tumors in workers paranasal sinuses and, generally, the incidence is higher in the finishing process, where the dust generated is finer (as, for example, in the operations of finishing and etching the rifle stocks). Despite being implemented all measures to protect workers within the production plant of Gardone Val Trompia, the principle of prudence would suggest the application of the technology successfully tested to airbornepollution containment in that area where an adjustment to probabilistic factor associated with cancer risk could be strategic.

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Bibliography

1. Beretta firearms website. http://www.beretta.com/it-it/world-of-beretta/today/
2. University Hospital “Federico II”, Department of Hygiene, Occupational Medicine and Community: Regional Training Course for operators of the Departments of Prevention. (2010).
3. Morawska L.:Environmental Aerosol Physic - Queensland University of Technology Brisbane, Australia. International Laboratory for Air Quality and Health, Aerosol Physics.
4. Seaton A. et al.: Particulate air pollution and acute health effects - The Lancet, Volume 345, Issue 8943, 176–178 (1995).
5. Pope, C.A. Review: epidemiological basis for particulate air pollution health standards. Aerosol Science and Technology 32, 4-14 (2000).
6. Gbadebo, A.M., Bankole, O.D.: Analysis of potentially toxic metals in airborne cement dust around Sagamu, Southwestern Nigeria. J. Appl. Sci., 7(1). 35-40. (2007).
7. O.E. Popoola et al.: Heavy Metals Content in Classroom Dust of Some Public Primary Schools in Metropolitan Lagos, Nigeria. Research Journal of Environmental and Earth Sciences 4(4): 460-465(2012) ISSN: 2041-0492.
8. Hassan S. K. M.: Metal concentrations and distribution in the household, stairs and entryway dust of some Egyptian homes - Atmospheric Environment 54, 207-215(2012).
9. Waisberg, M. et al: Molecular and cellular mechanisms of cadmium carcinogenesis. Toxicology 192, 95-117 (2003).
10. Bocca, B.: Quantification of trace elements by sector field inductively coupled plasma spectrometry in urine, serum, blood and cerebrospinal fluid of patients with Parkinson’s disease. Spectrochim. Acta, B 59, 559-566 (2004).
11. Borkowski T.: Quantitative studies of an Immobilized Cell Bioreactor-MS Thesis, Environmental Science, New Jersey Institute of Technology (1995).
12. Sofer S.:The Clean Air Resource Guide: Bio-Oxidation Controls Lab Odors. Pollution Engineering (2006).
13. Lakhwala F., Sofer S.: Design consideration for an Immobilized Cell Bioreactor Operating in a Batch Recirculation Mode, J. Chem. Tech. Biotechnologies 52, 499-509 (1991).
14. Jeong Seop Shim et al.: Oxidation of Ethanol Vapors in a Spiral Bioreactor. J. Chem. Tech. Biotechnologies 64, 49-54 (1995).
15. Italian Institute for prevention and safety on working places:Working risk profile for precision mechanics. (2001)
16. NIOSH Pocket Guide to Chemical Hazards - http://www.cdc.gov/niosh/npg/pgintrod.html
17. Bonoli A., Zanni S.: Air pollution treatment in modern segregated waste treatment facilities. Recent advances in urban planning, sustainable development and green energy. 50-57. (2014). ISBN: 978-960-474-404-6.
18. A. Bonoli, S. Zanni.: Indoor air quality in waste treatment: environmental issue and biotechnology application for air pollution containment, a case study. WSEAS transaction on environment and development (2014).
19. C.C. Borghi et al.: Magnetic removal of surfactants from wastewater using micrometric iron oxide powders. Separation and Purification Technology 83, 180–188, (2011).
20. Y.F. Shen et al.: Preparation and application of magnetic Fe_3O_4 nanoparticles forwastewater purification. Separation and Purification Technology 68, 312–319(2009).
21. Jha, M.K. et al.: Treatment of rayon waste effluent for the removal of Zn and Ca using Indion BSR resin, Desalination 228, 97–107(2008).
22. Jha, M.K. et al.: Studies on leaching and recycling of zinc from rayon waste sludge, J. Ind. Eng. Chem. Res. 43, 1284–1295(2004).
23. Kentish, S.E., Stevens, G.W.: Innovations in separations technology for the recycling and re-use of liquid waste streams, J. Chem. Eng. 84, 149–159(2001).
24. Icopini, G.A., Long, D.T.: Speciation of aqueous chromium by use of solid-phase extractions in the field. Environ. Sci. Technol. 36, 2994–2999 (2002).
25. E. Rus et al.: A spiral bioreactor for removal and recovery of metals from aqueous wastes. Bioprocess Engineering 13, pp.13-17. Springer-Verlag (1995).
26. Waynert, J. et al.: Wastewater Treatment with Magnetic Separation - Superconductivity for Electric Systems Program Review -July 23-25 (2003).
27. Nishijima, S., Takeda, S.: Superconducting high gradient magnetic separation for purification of wastewater from paper factory, IEEE Trans. Appl. Supercond. 16(2), 1142–1145(2006).
28. B. Chemotti: Risks related to exposure to wood dust: main information. University of Trento (2002).