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DUST BUSTER

TURIN POLYTECHNIC
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MATERIAL SCIENCE AND CHEMICAL ENGINEERING DEPARTMENT

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Reference: Final report on studies carried out on behalf of ECOSERVICE Office srl

INTRODUCTION

In order to set in a context all the issues for which the present research has been carried out, we wish to make a short introduction relevant to the quality of air in confined areas and to the ever more topical question of nanoparticles present in work environments.

The normal composition of air that we breath in confined surroundings can be altered by various elements some of which release odours, others cause irritation while others still may be cause of serious disease.

These substances are ordinarily referred to as "pollutants" or "contaminants". The higher the polluting quantity, the worse the air quality.

The terms of exposure to polluting agents are defined by the product of concentration and time in which one is submitted to that specific pollutant.

Exposure = Concentration x Time

The ensuing consequences can be: physiological and psychological changes, mutagenic or carcinogenic effects, building materials and furnishing damage.

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Table 1. Survey of time spent indoors and outdoors.

Survey	Percentage of time spent in the house	Percentage of time spent in other closed surroundings	Percentage of time spent in means of transport	Percentage of time spent in the open air
EPA-USA (1)	60	30	5	5
ISS/ANPA - Italia (2)	53-64	13-28	-	17-24

(1) Environmental Protection Agency
(2) Istituto Superiore di Sanità/Agenzia Nazionale Protezione Ambiente

Table 1 shows interesting data relevant to a survey of time spent inside and outside buildings by persons in Italy and USA. The following criticality has been highlighted:

- time spent within confined areas is between 76% to 90% of the total;
- outdoor air pollution increases as well as indoor air pollution;
- new polluting materials are being used in the building industry as well as the furnishing and office equipment industry (Copiers, printers etc.);
- Doors and windows made of ever improving sealing quality, reduce the natural air exchange.

We wish to add to the present data a specific research that Ecoservice Office srl has financed and published under the title :"Evaluation of the impact created by peripherals that transfer computer digital information on paper (laser printers) on the quality of air within confined areas. "
It is a well known fact that copiers and printers produce various emission: ozone, ultraviolet rays, noise , dusts (paper, environment and toner dusts) the quantity of which depending on the type of the equipment and its use (frequency, location, etc.).
Lampblack nano-particles contained in toner present potential health hazard.
Risks involving the humans organism have not yet been quantified in definite and reliable manner.
The means of penetrating the human body are, on the other hand, well known:
inhaling, ingestion or skin absorption.
Toner powders are a mixture of different components. According to up-to-date knowledge, two components of toner are to be considered toxic: lampblack (that can cause urinary tract tumour and lung complaints) and styrene (that can cause blood disease and tumour).

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Toners are normally supplied with Technical Specifications that indicate their components.

These data though, come with omissions and shortcomings (powder dimensions are not indicated; components CAS Code, used to check possible teratogenic effects, is not indicated; nor usage precautions are provided).

Further consideration regarding toner lampblack components concerns the organ that more than others is attacked by polluting particles: the respiratory system.

The most important information in studying the effects is probably the particle dimensions as these determine the penetration extent of the respiratory tract as shown in Fig. 1

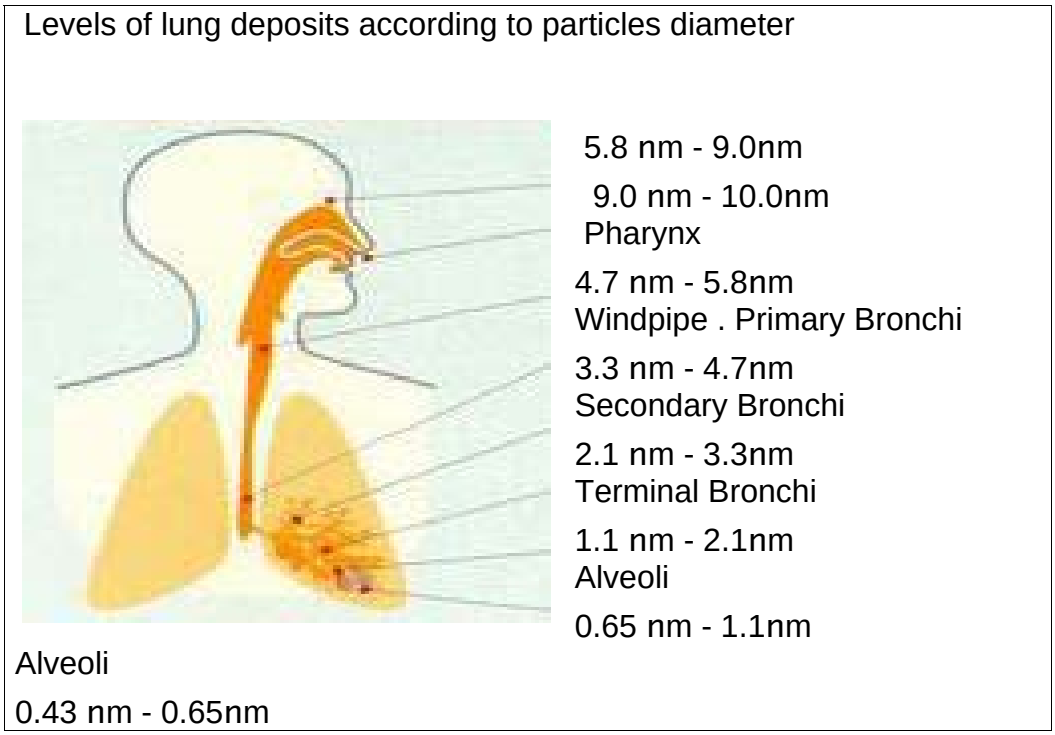

Fig. 1 Levels of lung deposits according to particles diameter.

Before reaching the lungs, the particles must pass through natural barriers provided by the respiratory tract (winding ways, damp piliferous zones, etc.) Such barriers effectively stop some of the particles. We can in fact state that all particles with diameter higher than 5 nm are blocked in the nose and the throat. Particles between 0.5 nm and 5 nm may lodge in the bronchioles and by the cilia action are removed within two or three hours and pushed back toward the throat.

The actual danger refers to the number of particles of diameter 1nm or lower that reach the alveoli where they tend to be eliminated in a much slower and less complete way, thus allowing blood and

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lymph to absorb them, causing subsequent poisoning and flowing, through the vascular or lymphatic system, into other organs. Recent studies have shown that nanometric size particles can reach the brain itself.

Research methods

In order to better understand the effect of dust emissions generated by printers (particularly those operating out of confined areas and vulnerable premises like offices or print shops) it is necessary to ascertain the quantity and distribution of toner particles dimensions released during working or printing hours in premises with little change of air.

The research carried out by CRE 2 of the Turin Polytechnic on behalf of Ecoservice Office srl (hereinafter referred to as Ecoservice) focus on the study of solid emissions from a laser printer, supplied by Ecoservice and the effectiveness of abatement of those emissions accomplished by a filtering device designed and manufactured by the same Company. (Fig.2).

During this study, two different methods of analysis have been applied:

-) The study of dispersed flows sucked up along several points of the printer carried out with a Scanning Mobile Particles Sizer (SMPS);

-) The study of paper filter samples placed upstream the laser printer, carried out by means of electronic microscopic scanning (FESEM).

1. Dispersed Flows Tests (SMPS)

In order to monitor solid mobile emissions, continuous tests methods have been applied on the printing machine: these tests were carried out with the device turned both on and off, during the printing process, both upstream and downstream of two different filtering devices supplied by Ecoservice.

The testing equipment is a SMPS (Scanning Mobility Particles Sizer Spectrometer) supplied by TSI (Fig.37).

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Fig. 2 ECOSERVICE Filtering Device

Fig. 3 Scanning Mobility Particle Sizer Spectromter

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With this highly technical instrument it is possible to evaluate contents and particle-size distribution of nanometric powders, scattered in a gaseous pattern aerosol. The interval of test detection vary from 2 nanometrs to 1 micron, a surely interesting interval to enable the application of the study.

Tests have been executed at the Turin Polytechnic in the following operating conditions:

- Work environment test (the trial has been called 'white")

- Test conducted with a printer operating under standard conditions, without the Ecoservice filtering device, in order to check environmental conditions with a printing machine in operation.

- Test conducted with a printer operating under standard conditions, alongside an Ecoservice filtering device, fitted with a standard filter, in order to check environmental conditions with a printing machine in operation. This filter shell be referred to hereafter as "commercial ". Two tests, one upstream and one downstream the filtering device have been carried out.

- Test conducted with a printer operating under standard conditions, alongside an Ecoservice device, fitted with a better performance filter compared to the standard type formerly employed, in order to check environmental conditions with a printing machine in operation while providing a best performance reference during the filtering time. This filter shall be referred to hereafter as "Ecoservice " Two tests, one upstream and one downstream the filtering device have been carried out.

- The test has been carried out after a long lasting printing activity (Approx 20,000 sheet were printed continuously)

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2. Results obtained by means of SMPS

One can notice on Table 2, how the filtering device turned on while printing is underway, produces a particle increase of averagely 500% compared to previous values of particles present in the premises when the printing machine was turned off: the different values of particles recorded upstream employing both different filters may be depending on the different head of the filters which in turn implies a change in the system motion fields and possibly a higher or lower concentration of particles released by the printer in an air flow which does not appear to be strictly the same.
Downstream the filtering device the particle concentration decreases by 49.7% with the Ecoservice unit and 24.1% with the Commercial unit respectively as proof of the good, though not excellent, effectiveness of the filtering devices (Table 2)

Table 2. Mean concentration of particles between 2 and 1000 mm

	Turned off Printer	Turned on Printer and printing underway			
		Upstream the filtering device		Downstream the filtering device	
		Commercial	Ecoservice	Commercial	Ecoservice
Particles mean Concentration (#/cm³)	8,538.91	40,452.67	48,345.67	23,455.32	24,349.63

It is moreover interesting to observe the modal concentration (namely the maximum value recorded during a trial lasted at least 30 minutes) in various conditions of testing (Table 3). The reading recorded upstream the filtering device increases at least by 150% approx. while downstream the same device the increase is only 50%: this effect is a further credit for both filtering devices (Table 3).

Table 3. Particles Modal Concentration between 2 and 1000 mm

	Turned off Printer	Turned on Printer and printing underway			
		Upstream the filtering device		Downstream the filtering device	
		Commercial	Ecoservice	Commercial	Ecoservice
Particles mean Concentration (#/cm³)	10,855	99,900	98,445	39,145	31,800

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All data shawn on Table 2 and 3 can be evaluated in Fig. 4

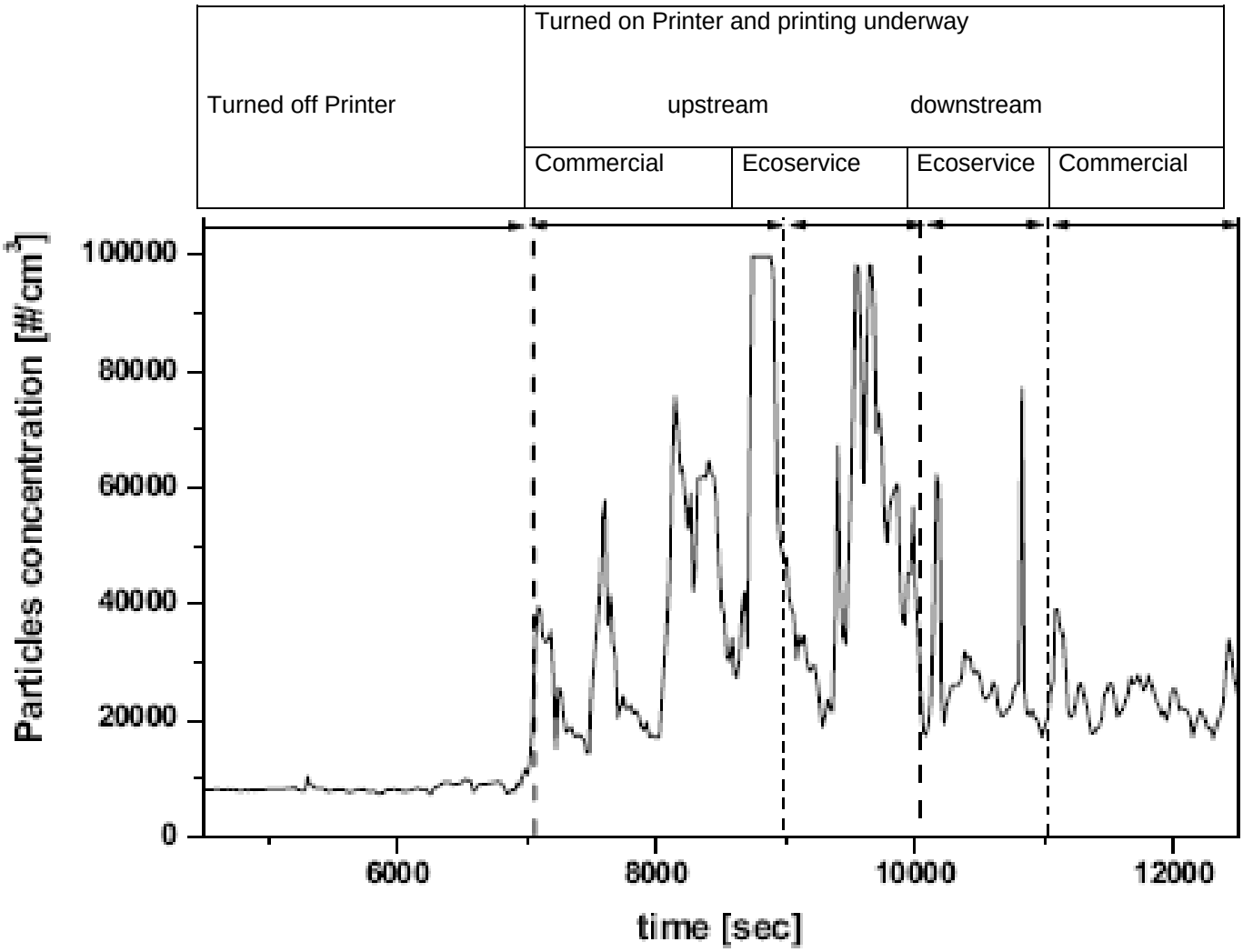

Fig. 4 Mean Concentration of Particles between 2 and 1000 mm. First batch of trials.

In the process of improving effectiveness of the "Ecoservice" device (Fig.4), the paper filter has been changed, during a second series of trials, and every care was taken to achieve effectiveness of nanopowders abating higher that 50%, producing a load loss compatible with the filtering device. The tested filter was chosen among various paper supports with better performances than those of the filter used during the first test run while preserving a cost compatible with the present filtering unit. Moreover, a series of trials has revealed the extra consumption as being caused by load losses originating from the Ecoservice filtering device. A new filter was chosen, which could compromise between filtering effectiveness and load losses.
The results are shown in Fig. 5

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The results found on this second series of trials are definitely interesting. Two second generation filters have been compared: "Filter 1" proved an abatement effectiveness of nanopowders released from the printer of 55%. The second filter ("Filter 2") has shown an effectiveness of abatement of 70% (Fig. 5)

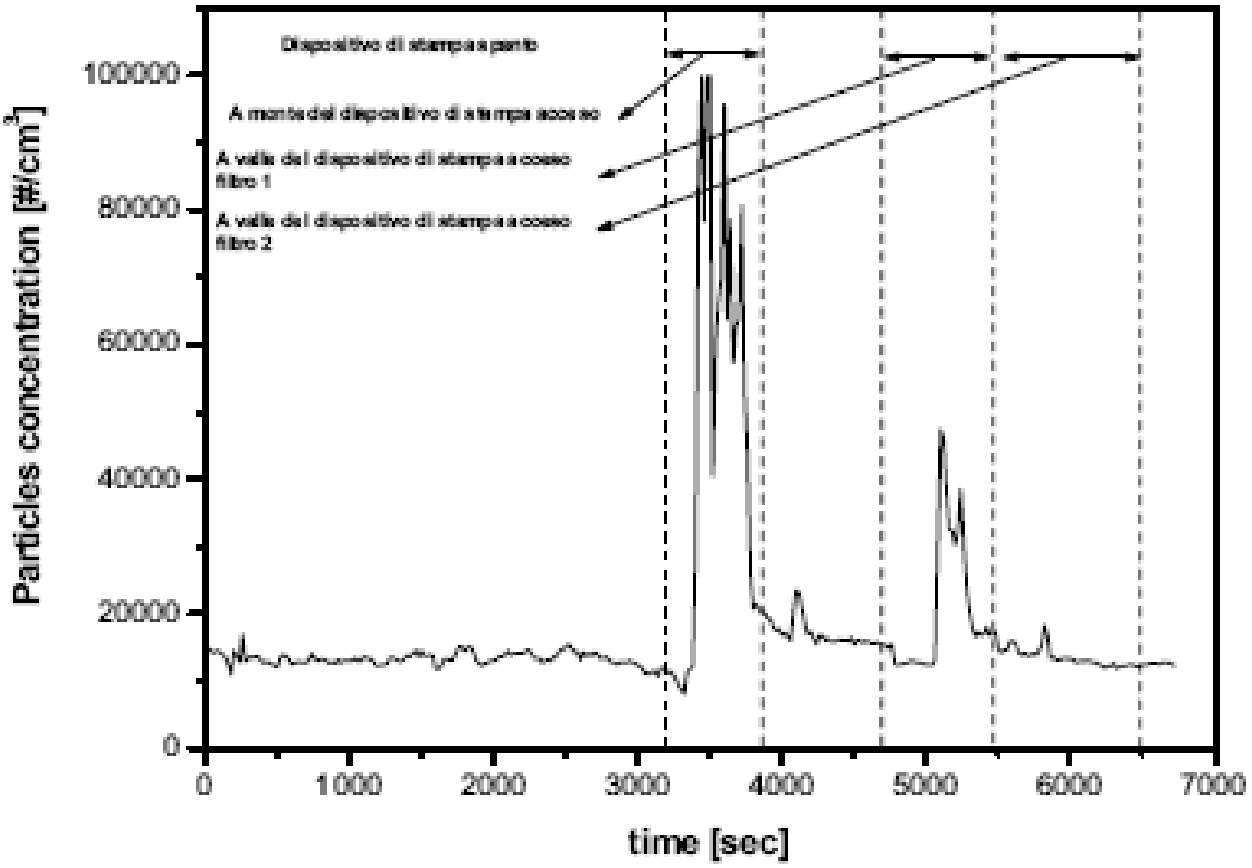

Fig.5 Mean concentration of particles between 2 and 1000. Second series of tests.

2. Electronic microscopic scanning (FESEM).

The use of electronic microscopic scanning (FESEM - Fig.6) enabled morphological observation of particles and possible clusters captured by the paper filter and also produced indications as to their chemical composition.
Enlargements of up to 100000 times allow observation of particles not larger that a few tens nanometers.

Electronic microscopic scanning studies have been carried out on paper samples used as filters during solid emissions of laser printer machines. The instrument employed during this test is a Field Emission SEM- FESEM -Leo50 fitted with a GEMINI column (Fig. 6). All examined filters were taken from three different Ecoservice filters:
one clean filter not yet used (Fig.7)

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one partially used filter (following 3000 page prints -Fig.8 left) and one used filter following 20000 page prints (Fig.8 right)

Fig. 6 Electronic microscopic scanning

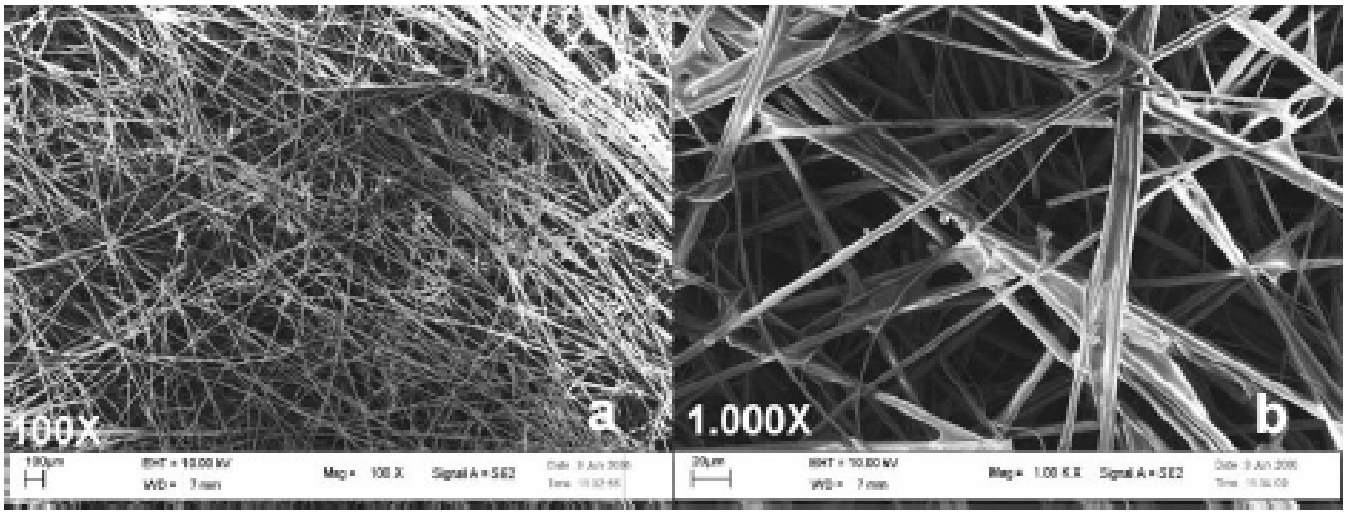

Fig. 7 FESEM Micrography with various enlargements (a) 100 times and (b) 1000 times of a clean Ecoservice filter.

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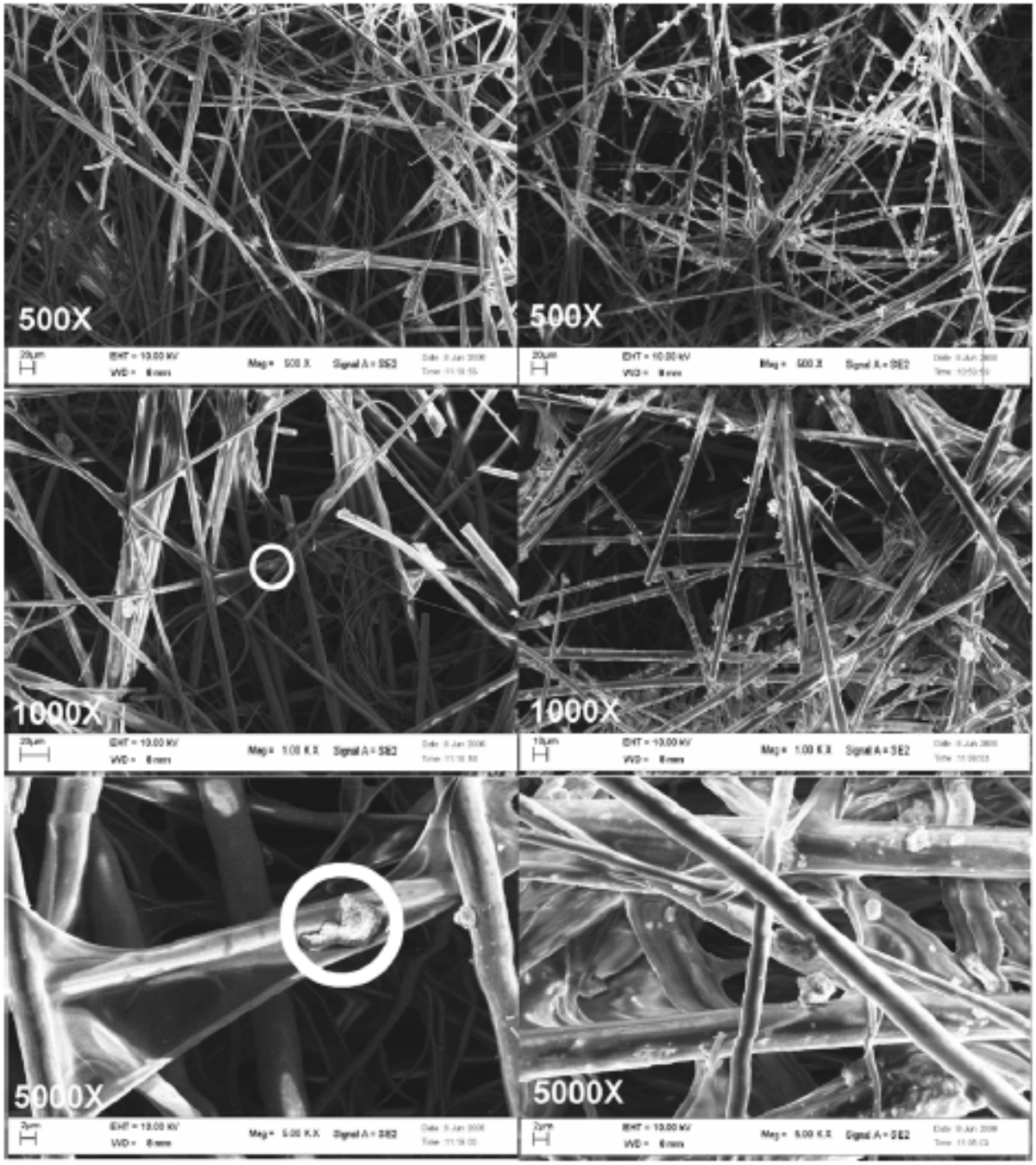

Fig. 8 ESEM micrography: Enlargements 500 time, 1000 times and 5000 times.
Left: an Ecoservice filter following 3000 page prints; right: an Ecoservice filter following 20000 page prints.

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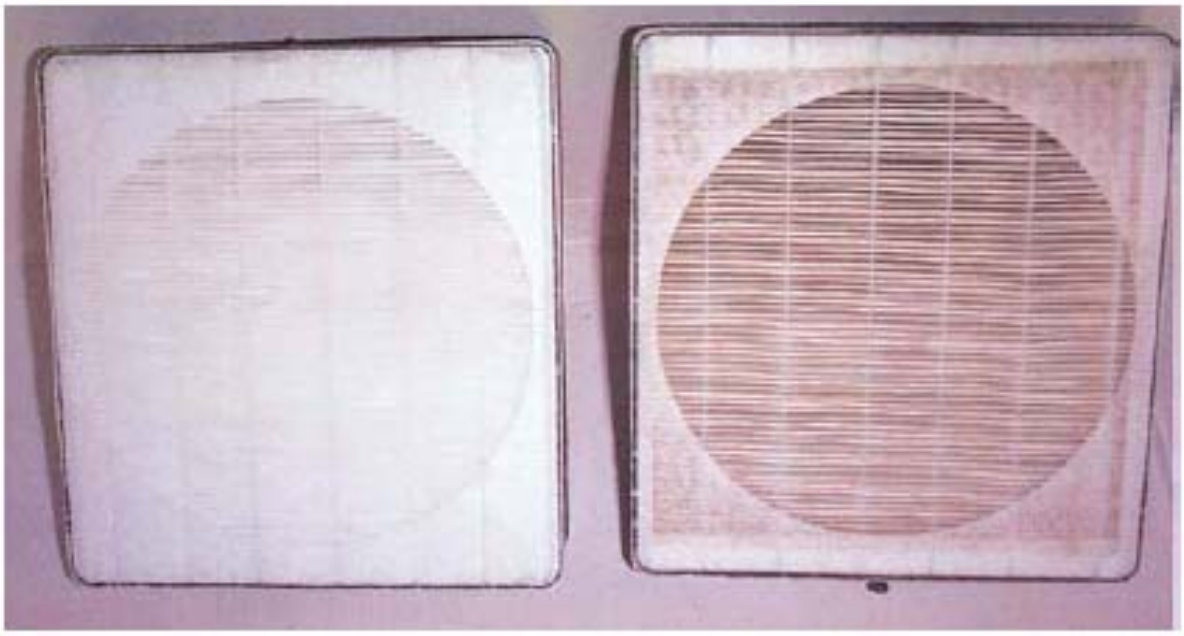

Fig. 9 Examined filters. Left clean commercial filter; right Ecoservice filter following 20,000 page prints

These encouraging results as shown in Fig. 8 with three different enlargements, indicate that several micron large carbon deposits appear on the fibrous pattern filter(highlighted by a white circle). These events are greater, as expected, in the filter used for 20,000 page prints. In Fig. 9 the dirt produced on the filter is also noticeable with the naked eye.

Given the nanometric dimension of toner particles (Fig. 4 and 5) it is to be expected that filters, while operating, produce agglomeration of nanometric particles that in turn form microbial particles, much less dangerous than the former, should these, due to possible filter malfunctioning, be released in the environment. At this level of particle dimensions, agglomeration is to be considered virtually irreversible thanks to the action of the Van der Waals forces that prevent the breaking of the agglomerations that have built up.

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3. Conclusions

In light of the results that we have discussed it is possible to confirm that:

-) Last generation Ecoservice paper filters guarantee abatement (50-70%) of toner particles released by the copier used during the experimentation
-) performances are better than those of other commercial filters or older generation Ecoservice filters and do not entail unacceptable power losses.
-) filters, most likely, operate according to both interstitial and superficial filtering mechanisms, causing penetration of particles within the filtering tissue and producing relative agglomeration that form much less dangerous microbial particles.
-) it is presumable that more detailed engineering, that may limit the aestethic effect, and possibly a further evolution of the filtering material may improve the performance of the product in view of a desirable introduction in the market of an item of highly commercial interest

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