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Test run for odour abatement efficiency evaluation o fan ozone generator in a clothes tumble dryer refresh cycle

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Modern clothes tumble dryers offer typically, beside standard dryting functions, the so called refresh cycles, reproducing the habits of hanging dry clothes in order to eliminate unpleasant odours. Similarly, tumble dryers can flow air at room temperature, refreshing garments at some extent. Some improvements to such process are also known, e.g. by use of steam and warm air.
Main target of this work was to test the efficiency of several innovative solutions for tumble dryers garment refresh cycles.
In particular, the possibility to apply ozone for the purpose was tested: a small quantity of ozone was mixed within the air flow during refresh cycle, to increase odour removal efficiency. The study aimed to identify optimised values of ozone concetration, in order to achieve deodorisation without exceeding to possible fabric damages or decolouring events.
Literature search suggest that reference ozone concentrations between 1,5 and 3 ppm are enough to provide oxidative action on proteins, germs and in general chemical and biological agents causing malodours. Such values are in fact above TWA toxicity threshold (referred to a continuous exposure for 8 h), nevertheless they are lower than limit indicated by IDLH. (Mettlach and Rae, 2004; Rump et al., 2004; Salameh et al. 2006, Shimono et al. 1999)
Experimental activity was focused on comparative evaluation of different refresh cycle types, in terms of odour removal efficiency, namely: plain air based cycle, ozone enhanced air cycle, steam enchanced air cycle. Tests were carried out evaluating differential odour concentration, before and after refresh treatment.

1. Materials and methods

1.1 Materials

Two Indesit Company tumble dryers (Hotpoint – Ariston ASD70C EX) were used for testing, being one of the two (A2 in the following) used as reference; dryer air heater was switched off, resulting in a flow of room temperature air (flow rate: approx. 120 m^3/h) for the cycle duration.
The second tumble dryer (A1 in the following) was modified to host, inside porthole door, an ozone generating system, by which a controlled flow (23 m^3/h) of ambient air blended with a controlled ozone quantity was mixed to the main air strem inside the machine drum.

A third machine (A3 in the following), produced by a competitor, was used, to benchmark its 20 min steam enhanced refresh cycle against the others.

1.2 Methods

All experiments were carried out by using kitchen and cigarette smoke odours, from real sources (saturated environment air), to impregnate fabric patches. As the aim of the test campaigns was the measurement of odour emission from test fabric patches, odour sampling was carried out on the patches themselves, instead of analysing air form dryer drum. Sample patches odorisation process was carried out so to ensure process evenness (single patches were placed in to bags to be exposed to cigarette smoke; an exposure cell was used to submit batches of patches, regularly stirred, to kitchen smell).

Freshly odourised samples were immediately submitted to olfactometric analysis at the Department of Chemistry, Materials and Chemical Engineering - Politecnico di Milano, where a facility is available for odour concentration testing, to be performed in compliance with EN 13725:2003 and UNI EN 13725:2004.

Test facility is equipped by a Mannebeck Mod. TO8 Olfactometer, PC controlled, with four odour essay stations. Tests were performed by a four people panel by olfaction sensitivity test as described by the above described regulations.

In particular, adopted methodology is based on identification by test panel of “odour threshold”, defined as the odour level below with 50% of panel components cannot perceive anything.

To obtain such an odour sample, an “olfactometer” is needed, to dilute polluted air with clean air, in known quantity, with ratios up to 1:65536.

The dilution factor neded to reach odour threshold is taken as a quantitative index of odour concentration, can be expressed in odorimetric units per cubic meter (ou_E/m^3).

2. Results

During the first test run, two refresh cycle performances were compared, in terms of odour concentration and odour reduction efficiency:

- Ozone/Ion cycle: 5 min standard of refresh cycle plus ozone, followed by 5 min of standard refresh cycle
- Reference cycle: 10 min of standard refresh cycle

Ozone/ion cycle was obtained by using a ions/ozone generator, implemented within tumble dryer; ozone production is tuned to have, with empty drum, a concentration of 0,035 ppm. Tests were performed by activating ozone generator for the first half of cycle duration (10 min in total). Cotton fabric patches were used for this test campaign, polluted by real kitchen smell.

Odour	Fabric	Description	c_{od} (ou_E/m^3)	Efficiency (%)
Kitchen	Cotton	Baseline (odourised patches before refresh cycle)	2435	
Kitchen	Cotton	Sample after Ozone/Ion cycle	542	77.7
Kitchen	Cotton	Sample after Reference cycle	456	81.3

Second test run was meant to compare performances of three refresh cycles, different form the previous ones:

- Ozone cycle: 5 min standard refresh cycle plus ozone, followed by 10 min of standard refresh cycle
- Reference cycle: 15 min of standard refresh cycle
- Steam cycle: 20 min of refresh cycle, steam enhanced.

Ozone cycle was obtained by using an ozone generator, implemented within tumble dryer; ozone production is tuned to have, with empty drum, an istantaneous concentration of 2 ppm (25 mg/h throughput). Tests were performed by activating ozone generator for the first five minutes of cycle duration (15 min in total). Cotton fabric patches, wool fabric patches, and mixed patches (1/3 cotton, 1/3 wool, 1/3 synthetic) were used for this test campaign, polluted by real kitchen and smoke smell and by synthetic sweat smell.

Odour	Fabric	Description	c_{od} (ou_E/m^3)	Efficiency (%)
Kitchen	Cotton	Baseline (odourised patches before refresh cycle)	2170	
Kitchen	Cotton	Sample after Ozone cycle	304	86.0
Kitchen	Cotone	Sample after Steam cycle	1085	50.0
Kitchen	Wool	Baseline (odourised patches before refresh cycle)	2170	
Kitchen	Wool	Sample after Ozone cycle	180	91.7
Kitchen	Wool	Sample after Reference cycle	256	88.2
Kitchen	Wool	Sample after Steam cycle	1530	29.5
Kitchen	Mixed	Baseline (odourised patches before refresh cycle)	1820	
Kitchen	Mixed	Sample after Ozone cycle	150	91.8
Kitchen	Mixed	Sample after Reference cycle	190	89.6
Kitchen	Mixed	Sample after Steam cycle	1020	44.0
Smoke	Cotton	Baseline (odourised patches before refresh cycle)	2900	
Smoke	Cotton	Sample after Ozone cycle	360	87.6
Smoke	Cotton	Sample after Reference cycle	680	76.6
Smoke	Cotton	Sample after Steam cycle	770	73.4
Smoke	Wool	Baseline (odourised patches before refresh	3069	

		cycle)		
Smoke	Wool	Sample after Ozone cycle	1630	46.9
Smoke	Wool	Sample after Reference cycle	2050	33.2
Smoke	Wool	Sample after Steam cycle	2440	20.5
Smoke	Mixed	Baseline (odourised patches before refresh cycle)	1820	
Smoke	Mixed	Sample after Ozone cycle	580	68.1
Smoke	Mixed	Sample after Reference cycle	970	46.7
Smoke	Mixed	Sample after Steam cycle	1150	36.8
Sweat	Cotton	Baseline (odourised patches before refresh cycle)	1830	
Sweat	Cotton	Sample after Ozone cycle	340	81.4
Sweat	Cotton	Sample after Reference cycle	450	75.4
Sweat	Cotone	Sample after Steam cycle	760	58.5
Sweat	Mixed	Baseline (odourised patches before refresh cycle)	5790	
Sweat	Mixed	Sample after Ozone cycle	290	95.0
Sweat	Mixed	Sample after Reference cycle	970	83.2
Sweat	Mixed	Sample after Steam cycle	1370	76.3

Finally, odour concentrations and deodorisation efficiencies given by two refresh cycles at increasing duration were compared; ozone production is tuned to have, with empty drum, an instantaneous concentration of 2 ppm:

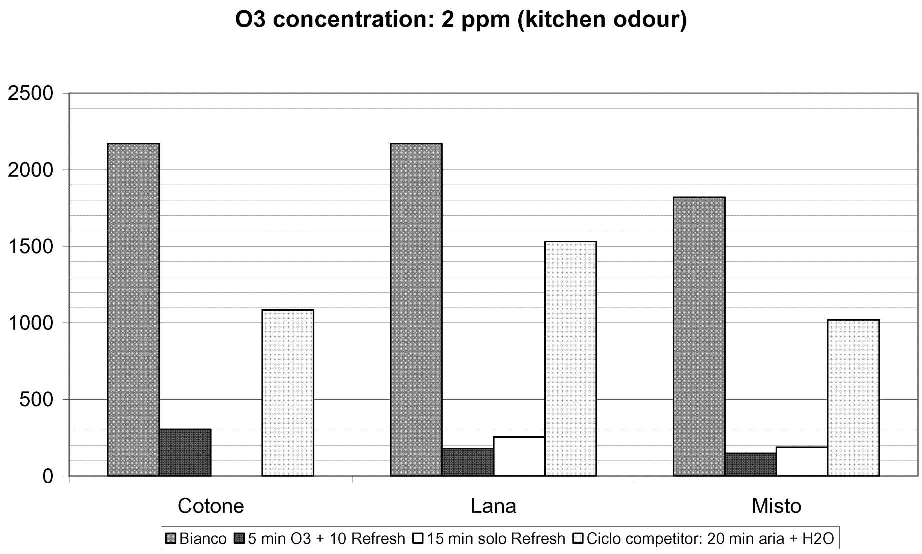
- Ozone short cycle: 10 min standard refresh cycle plus ozone
- Ozone long cycle: 20 min standard refresh cycle plus ozone
- Reference short cycle: 10 min of standard refresh cycle
- Reference long cycle: 20 min of standard refresh cycle

Odour	Fabric	Description	c_{od} (ou_E/m^3)	Efficiency (%)
Kitchen	Cotton	Baseline (odourised patches before refresh cycle)	1720	
Kitchen	Cotton	Sample after Ozone short cycle (10 min)	320	81.4
Kitchen	Cotton	Sample after Ozone long cycle (20 min)	1625	5.5
Kitchen	Cotton	Sample after Reference short cycle (10 min)	610	64.5
Kitchen	Cotton	Sample after Reference long cycle (20 min)	305	82.3

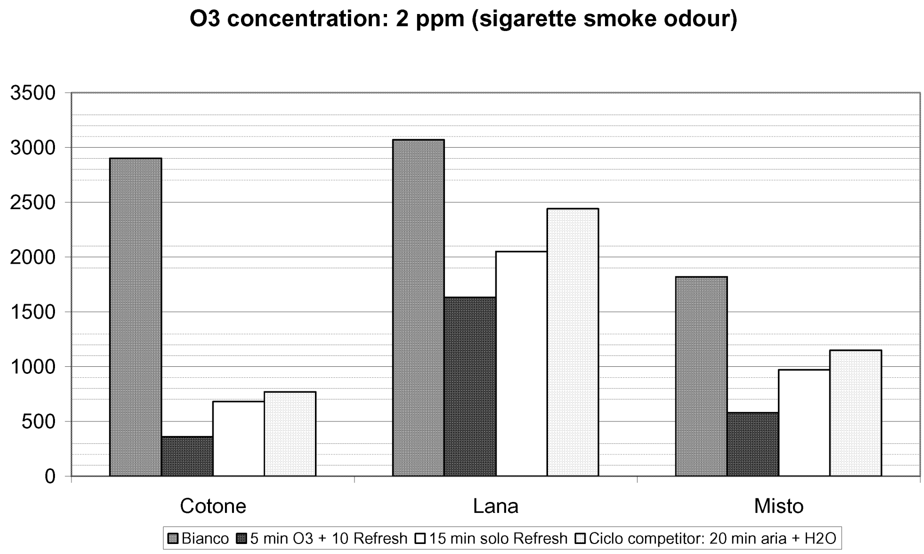
3. Discussion

Hereby a summary of the conclusions from the analysis of above described results is reported. Adoption of a high concetration of ozone (2 ppm) gave the following results:

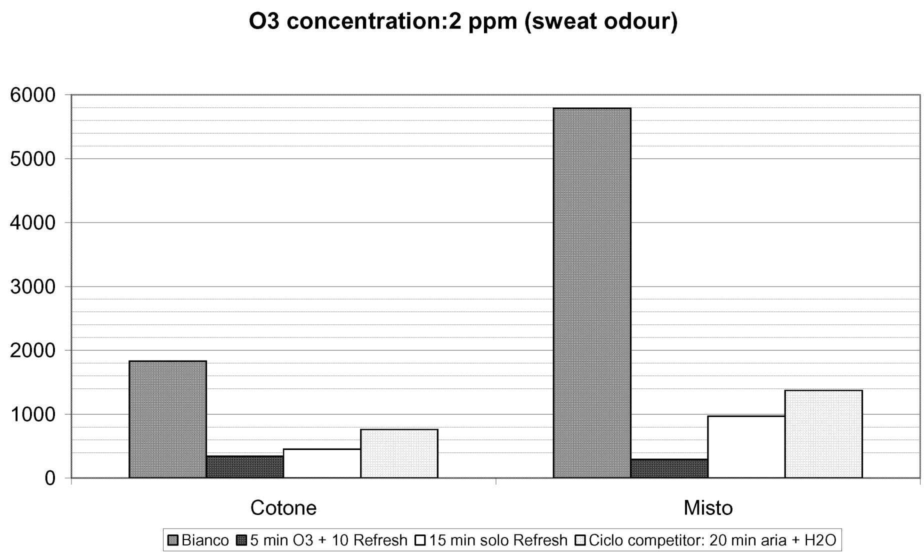
Concerning kitchen odour, the observed abatement efficiencies were:
- Ozone cycle: 86% to 92%
- Standard air cycle: 88% to 90%
- Steam Cycle: 29% to 50%



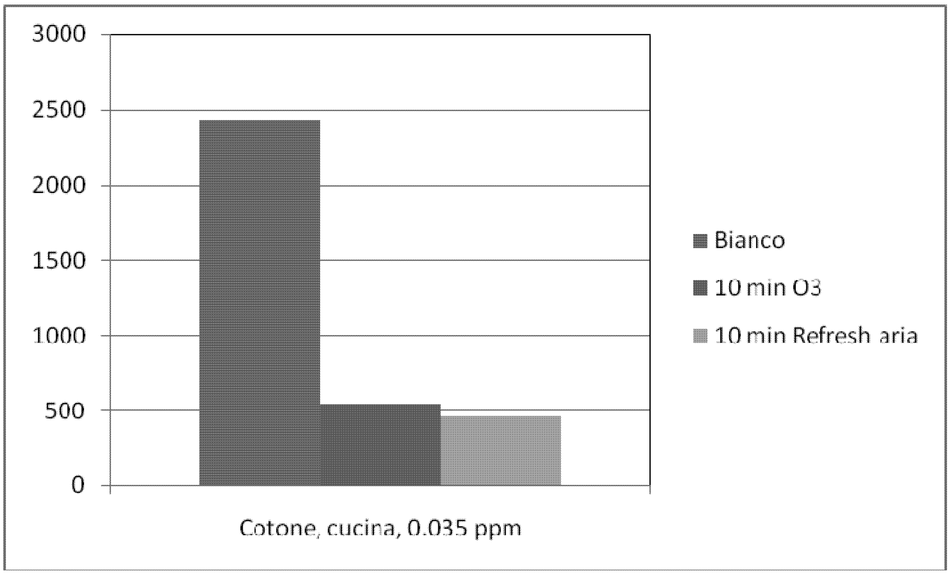
Concerning cigarette smoke odour, the observed abatement efficiencies were:
- Ozone cycle: 50% to 88%
- Standard air cycle: 33% to 77%
- Steam Cycle: 20% to 73%



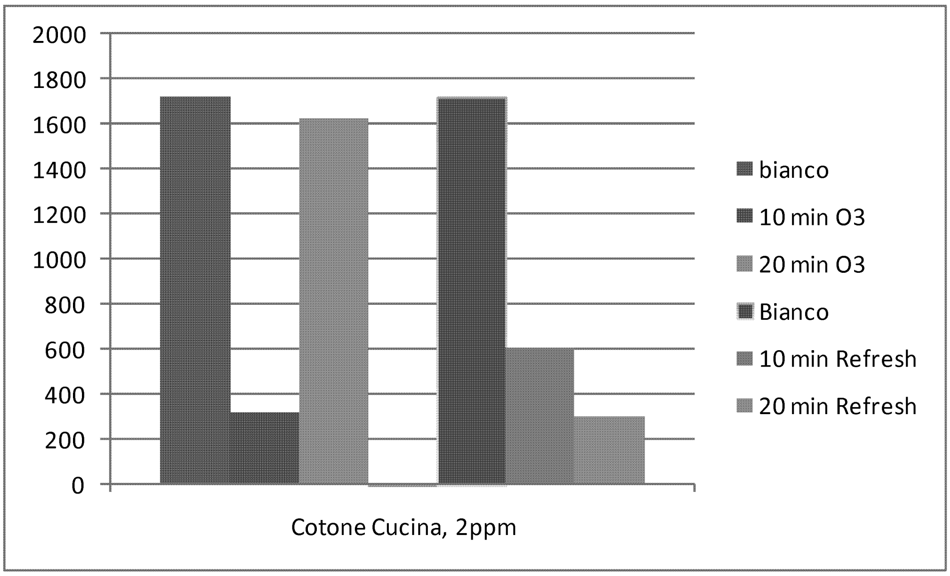
Concerning sweat odour, the observed abatement efficiencies were:
- Ozone cycle: 81% to 95%
- Standard air cycle: 75% to 83%
- Steam Cycle: 58% to 76%



Adoption of a much lower concetration of ozone (0,035 ppm), associated to ions, gave the following results, for kitchen smell on cotton:
- Ozone/ion cycle: 77%
- Standard air cycle: 82%



Increasing exposure time tests (2 ppm ozone) gave the following results, for kitchen smell on cotton:
- Ozone/ion cycle: 81% for 10 min, 5% for 20 min
- Standard air cycle: 64% for 10 min, 82% for 20 min



4. Conclusions

Main conclusions deriving from the above shown data are hereby listed:

- Cotton is the most critical fabric to be deodorised;
- Kitchen smell is the toughest pollutant to get rid of;
- Ozone concentration shall be evaluated trading off between oxidative potential and possible generation of partially degraded substances with even higher odourising power;
- Excess of exposure to ozone pollutes the fabrics by ozone odour itself; optimum appears to be 5 min at 2 ppm of ozone concentration, followed by 10 min aeration, where ozone excess is evacuated and/or decomposed. This has been proven by an undetectable odour change on clean fabric after exposure to such cycle.
- Steam appears to be possibly even detrimental in terms of odour, being worst than bare air refresh cycle.

4. References

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