ODOR REDUCTION THANKS TO TEXTILE MATERIALS

CETI
Thierry LE BLAN
Technical Manager
thierry.leblan@ceti.com

IFTH
Arnaud VATINEL
Olfactive analysis laboratory Manager
avatinel@ifth.org

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Origin of odours from Textiles

Vapour Pressure

Emitted compounds function of the product

Individual compound Complex mixture

Substances Adsorbed on the product surface

Emission of impurities and contaminants from the transport, storage and handling of the products (new material) OR after contact with the skin (using conditions)

Substances contained in the product

Emission of auxiliary compounds impurities and contaminants from the process
Textile and skin interactions

- **SKIN = not sterile surface**: Ecosystem which plays an important role in the body balance

- Resident micro-organisms: various bacteria adapted to the physiological skin conditions: surface temperature between 30°C and 35°C, pH from 5 to 6.5, various nutritive substances (perspiration, sebum from the sebaceous glands, cellular fragments)

- Major skin microflora strains: Staphylococcus (*Staphylococcus aureus* and *epidermidis* – Gram-positive), micrococcus, aerobic and anaerobic corynebacteria, propionobacteria and, in case of lack of hygiene: Gram-negative bacteria

- Transient micro-organisms (Temporary colonization): constituted of many micro-organisms from endogenous (from the body) or exogenous (environnement) sources.
Textile and Bacteria interactions

- **Role of the textile in odour generation**: Act as a barrier which block the water evaporation and increase its condensation. The consequent moisture combined with the presence of nutrients at the interface between the skin and the textile induce the growth of micro-organisms and the potential to generate malodour.

- Reinforced by the high specific surface of the textile products

- After 8H of «normal» wearing, the bacteria population reach $10^4$ / cm²

- The body odour intensity is considered as a malodour from $10^7$ germs/cm². As the number of bacteria can double about every 30 minutes, a malodour can be perceptible after 12 hours of a «normal» wearing.
Interaction Textile / Odorous substances

- Relation between malodour and number of total specific bacteria Coryneforms (James et al. 2004)
- Other bacteria participate to the global sweat odour: Staphylococci and Micrococi

- Odorous compounds issued from the bacteria degradations:
  - 3-Methyl-2-hexenoic acid (axillary)
  - Isovaleric acid (feet)
  - 3-hydroxy-3-methylhexanoic acid
  - Thioalcohol
  - Androstenone
  - …
Textile – Bacteria interactions in the odour release

• First Observations:
  ✓ Higher adhesion of bacteria on hydrophobic, non polar surfaces: Polyester vs. Cotton ([Fletcher, M., 1996. Bacterial adhesion](#))
  ✓ Lower growth of *Staphylococcus* on hydrophilic compared to hydrophobic fibers ([Teufel and Redl, 2006](#))

• Complementary Studies:
  ✓ Comparable microbial numbers on wool, cotton and polyester after 1 day use ([Teufel and Redl, 2006](#))
  ✓ Higher survival rate of bacteria on wool than on polyester or cotton
  ✓ BUT: odour intensity is lower on wool

Odour retention on fabrics – Axillary odours

- The odour intensity is higher for hydrophobic fibers regardless of sweat composition (Polyester >> Cotton and Wool).

- Significant results were obtained in particular for Wool fabrics which are less odorous after wear than polyester (panel of 13 assessors).

- Short-chain carboxylic acids were detected as responsible of the polyester odour after wear (Otago University).

- An other study (New Zealand) found that wool fabrics retained about 66% less body odour intensity than polyester fabrics and 28% less than cotton fabrics (olfactory measurement).
Odour retention on fabrics – Feet odours

- Sensory Study on odour emissions from socks made with different fabrics
- From The Wool Research Organisation New Zealand Inc. (WRONZ), become Canesis Network Ltd and then AgResearch Ltd.

- Confirm previous studies (Wool, far less odours compared to Polyester or Acrylic)
# Synthesis: Influence of the type of fiber on bacteria and odour

<table>
<thead>
<tr>
<th></th>
<th>Polyester</th>
<th>Cotton</th>
<th>Viscose</th>
<th>Acrylic</th>
<th>Polyamide</th>
<th>Wool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Odour</strong></td>
<td>+++ (fatty acids, Ketones and aromatic comp.)</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>- / + (Aldehydes / Ketones)</td>
</tr>
<tr>
<td><strong>Bacteria initial development</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Bacteria persistancy</strong></td>
<td>++</td>
<td>+</td>
<td>- -</td>
<td>-</td>
<td>+ / -</td>
<td>+ +</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>Develop. of specific odour releasing strains</td>
<td>1 – Staphylococcus epidermidis / 2 – Propionobacterium / 3 – Corynebacterium / 4 – Micrococcus / 5 - Enhydrobacter strains</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Impact of washing on textile odours

- Fabric softeners seems to enhance the bad odour on Polyester (Laitala et al. 2012)
- Lipase in detergents may have an impact on odour formation (Munk et al. 2000)
- Volatile substances like carboxylic acids are faster removed in a washing process than micro-organisms (Chung and Seok, 2012)
- Volatils substances are easier removed on Cotton than on Polyester (McQueen et al., 2013)
- Volatiles from washing machine contribute to laundry malodour (Stapleton et al., 2013)

Potentially odorant substances at the interface of human skin and textile

Odour

S
H₂S Mercaptans*
Sulfides*
Thiazoles
Thiophenes

N
Amines*
Pyrazines*
Pyrridines
Nitriles
Pyrroles
Indole

O
Alcohols*
Aldehydes*
Ketones / Esters*
Acids*
Furanes
Acetals

Hydrocarbons
Alkenes
Terpenes
Some Alkanes

Aromatics
BTEXS / BHT

* Typical Sweat Odours
**Testing**

**Olfactory Evaluation:**
- External parameters control (French norms (sensory analysis) AFNOR V09 105, SSHA).
- Samples management
- Measurement of Detection, Intensity, type of Odours (+ deodorization efficiency, following ISO 17 299)
- Repeatability and reproducibility of the measurement

**Microbiological testing:**
- ISO 20743, ASTM2149, JIS L 1902 & AATCC100

**Other Tests:**
- Durability (Wash, Abrasion)
- VOC (GC/MS and HPLC/MS)
- Air or water permeability
Odour elimination in textiles

- Sensory deodorization
- Chemical deodorization
- Entrapment deodorization
- Biochemical deodorization
Odour elimination in textiles

- Sensory deodorization:
  *Textile*: controlled release (microcapsules, resines)

  - Masking Agents (biology / biochemistry): Hiding bad odours (essential oil): Competitive chemical bonding with the olfactory receptor (« fragrance finishing »): masquodor® (Protex)
  - Neutralizing Agents (chemistry): Based on a chemical reaction directly with the malodourous substance (air or liquid phase): Decrease of the « bad » odour intensity or modification of the chemical structure (odour modification)

- Processes: Impregnation (crosslinking agent), Spraying, Coating, Incorporation in the fibre.
- Stage: Impregnation: thermal fixation (=at 130 to 170°C (drying and curing step))
- Release: Physical (dialytic: wall insoluble and product soluble in water and body fluids) / Biochemical (enzymatic degradation) / Chemical (dissolution by specific reactions)

- Advantages: many manufacturing processes / Several types of textiles
- Disadvantages: Curing temperature decreased aroma retained inside the microcapsule / washing durability (< 25 home launderings) / Biocidal products regulation (BPR) 528/2012
Odour elimination in textiles

- Chemical deodorization:

  Textile: Addition of chemically active products to degrade odorous substances (ex: TiO2 for photocatalysis)

  - Chemical reaction to transform substances with a bad odour in other substances without odour or with a better odour
    - Redox reactions (organic compounds),
    - Acido-basic (nitrogenous compounds with acidic reagent or sulfur compounds with basic reagent)
    - Ionic exchange (ammoniac or sulfure compounds neutralization by ferric salts or acétaldéhyde, H2S and amines by polyoxometalates)
    - Photocatalysis (Reaction between radical species from O2 and H2O and organic compounds)
Odour elimination in textiles

- **Biochemical deodorization:**
  **Textile:** biocides

  - **Bactériostatic:** Hinder proliferation of bacteria (without changing bacteria’s skin flora).
  - **Bactericide:** Eliminate micro-organisms (lethal action)
Odour elimination in textiles

- Biochemical deodorization:

  * Textile: biocides

  o Regulations (biocide directive N°98/8/CE : Biocide market regulation)
  o Selection of the technology depending on the objective (fabric protection or deodorization) and
    on the manufacturing process (melting process: dissolution in the melting polymer (PES, PA
    et PP), Dry or Solvent process: dissolution in the solvent (cellulosic acetate, acrylic and
    chlorofibers) or wet process: dissolution in water (viscose)

<table>
<thead>
<tr>
<th>Biocide</th>
<th>Ratio (%)</th>
<th>Price ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>32,5</td>
<td>70* - 130</td>
</tr>
<tr>
<td>Silane Quats</td>
<td>13</td>
<td>30 - 50</td>
</tr>
<tr>
<td>Quats</td>
<td>4,5</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: Report Biocides in Textiles, 2017

And... Triclosan, Zinc Pyrithione, Izothiazolinones (BIT, MIT, CMIT), formaldehyde
releasers, phenolic derivates, paraben, copper, organic acids, alcohols
Odour elimination in textiles

- **Biochemical deodorization**: formulation and application processes

  o Biocide coated finishes (90% production in volume of pure product)
    - Aegis, Aglon, Purista (Lonza), Irguard (BASF), Foamfresh (Piedmont), Sanitized, Ultrafresh (Thomson), Silvadur (Dow), Pure TF (HeiQ)
    - Processes: Exhaustion, Padding, Spraying
    - Stage: Pre-spinning (on thread), Finishing (on raw textile), Spraying

  o Biocide Inherent fibres (10% production)
    - Allerban (Advansa), Coolmax (Asota), Saniguard (Miroglio), Rhovyl, Bactershield (Sinterama), Mushon (Toray), Bioactive (Trevira), Radilon (Radici), XT2 and X-static Fibers (Silverescent products, Noble), Newlife (Polygiene / Sinterama)
    - Processes: Synthetic fibre production
    - Stage: Spinning solution, mixed at the melt polymer

**Limits**:

- Some studies did not prove the efficiency of antibacterial treatments on odour reduction (*Mc Queen et al. (2013), Journal of the textile institute, 104 (1), p. 106*) and the durability is still called into question (Swedish Chemicals Agency, KEMI, PM 8/15, 2015)
- High cost of treatment

Source: Report Biocides in Textiles, 2017
Odour elimination in textiles

- **Entrapment deodorization**:
  
  **Textile**: Trapping charges (physical and chemical interactions: cyclodextrines, **activated carbons**, silica gel, argiles, zeolites)

**Activated Carbon**

- Odorous substances are chemically or physically fixed on active sites at the surface of the material. Hydrogen, Van der Waals or ionic bonds (+ chemical functionalisation to increase reactivity).
- Chemical selectivity depending on:
  - The pore size (macropores: from 50 to 2000 nm, mesopores: from 2 to 50 nm, micropores: < 2 nm)
  - The polarity (hydrophilic characteristics)

**NEW DEVELOPMENTS**

- Activated carbon fibers (in comparison with standard activated carbon functionalisation: larger specific surface, better adsorption capacity, better accessibility to micropores, faster adsorption kinetics)
- Porous polymers: Control of the specific surface and hydrophilic parameters, purity

Products: HeiQ Fresh NKU (zeolithes), Scentry (Microban, activated carbons),
Odour elimination in textiles

- Entrapment deodorization - CYCLODEXTRINES

Torus-shaped molecules with hydrophobic cavities between 0.5 and 0.85 nm (trapping of organic molecules)

Advantage:

- Do not interact with dying products (colour and odour efficiency)

Table 1. Feasible interactions between β-CD and some textile fibres [14].

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cotton</th>
<th>Wool</th>
<th>PES</th>
<th>PA</th>
<th>PAN</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic interactions</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Covalent bonds</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Van der Waal forces</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Crosslinking agents</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Graft polymerisation</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

+=possible, -=not possible, PES-polyester, PA-polyamide, PAN-polyacrylonitrile, PP-polypropylene.

AOBCI. AUTEX Research Journal, vol.11, N° 4; Dec 2011
Anti-odour fabrics – Market Study

**Entrapment technology**

- Carbon based (Activated carbon, activated carbon fibers...)
  - Zorflex (Calgon)
  - Cocona (replaced by 37,5)
  - Scafé
  - Bamboo charcoal (Acelon Chemical)
  - Saratech (Blücher)

- Minerals (zeolites, clays, nanomaterials...)
  - LAVA XL (Sciessent)

- Polyméric (Synthetics polymers...)

- Molecular (Cyclodextrines)
Anti-odour fabrics

- Activated Carbon Fibers

<table>
<thead>
<tr>
<th>Blücher</th>
<th>Chemviron</th>
<th>Kureha</th>
</tr>
</thead>
</table>

Standard Claims

- Ammonia, Trimethylamine
- Methylmercaptan, Hydrogensulfide, Methyldisulfide
- Carboxylic acids (C2 to C4), Aromatic compounds, Acetic ether, Methyl isobutyl Ketone, i-butanol
- Aldehydes (C3 to C5)
Anti-odour fabrics

- Cyclodextrine solutions

- Pulcra Chemicals GmbH: Anti-odour treatment Cyclofresh® (+ silver: cyclofresh plus®)
  - Liquid application
  - Body odours absorption + Fragrance release
  - Suit with many types of fabrics
  - Regenerated by washing or spraying

- Sanitized AG: Traitement ACTIFRESH®
  - Liquid / Solid applications (liquid, paste, masterbatch, powder), for extrusion, padding, extraction, spray, coatings
Anti-odour fabrics

- Photocatalytic Fibers

SELFCLEAR is a self-cleaning fiber that uses light as a catalyst

Exlan, Japan
Anti-odour fabrics

- Antibacterial agent
  ✓ Liquid-based coating, applied after dying (during finishing process)

Thank you!