ODOURS IN BIOLOGICAL WASTE MANAGEMENT WORKSHOP

Composting Council of Canada
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OBJECTIVE

• By the end of this morning you should have a better understanding of

  – The properties and nature of odours
  – The sampling and testing of odours
  – The generation of odours in composting
  – The management of odour under normal operations
  – The management of odours during a major odour event
All smells are small volatile organic molecules (less than 300 molecular mass)
ODOUR

• PROPERTY OF A SUBSTANCE THAT AFFECTS OR STIMULATES THE SENSE OF SMELL

• MOST FREquent SOURCE OF ENVIRONMENTAL COMPLAINTS

• HIGHLY SUBJECTIVE
ODOUR ATTRIBUTES

1. Perceived intensity (just-detectable to overpowering) – measurable

2. Character (permits identification of source) - e.g. smell of lemon

3. Acceptability (pleasant to offensive) – highly subjective and independent of the odour’s character [hedonic tone - HT ]
ODOUR INTENSITY

1. Measure of the strength of the subjective response to an odour – it is a sensation.

2. Odour intensity is determined by referencing the odour sensation (strength) to an equivalent sensation (strength) from a reference compound at a known concentration (expressed in ppmv or ppbv for gaseous samples).

3. Intensity varies greatly for different compounds.
e.g. 30 ppbv allylmercaptan and 10 ppbv allylsulfide produce the same faint perception but the corresponding concentrations are 10 and 5000 ou, respectively.
4. Hypoadditivity - the perceived intensity of two chemicals, at a certain concentration in a mixture, is lower than each chemical alone at the same concentration.

5. The Common Chemical Sense responses, such as pungency, of the two chemicals in a mixture are mainly additive.
ODOUR CONCENTRATION THRESHOLDS

*Detection Threshold*: concentration at which the odour is just-detectable (weak signal) by a person but not identifiable.

- Threshold Odour Concentration (TOC): minimum concentration in ppbv resulting in a sensation.
- \( \text{TOC}_{50} \) concentration at which 50% of panel detected the odour. (other values \( \text{TOC}_{100} \) and \( \text{TOC}_{10} \))
- Dilution techniques are used to determine the threshold.
- Common unit used to express the number of dilution to threshold is the Odour Unit (ou)
Steven's Psychophysical Law: $I = K(C)^n$
ODOUR CHARACTERIZATION

The character or quality of an odour determines what the sample smells like.

The character of an odour is often associated with a particular industry of process: e.g. sewage treatment

Various classification systems are available to describe an odour.
ODOUR CHARACTERIZATION

Example Odor Descriptor Graph

Example Odor Descriptor Histogram

Garlic
Onion
Apple
Herbal
Almond
Disinfectant
Ammonia
Chlorinous
Oil
Sulfur
Amine
Sewer
Burnt
Manure
Rotten eggs
Putrid
Stale
Chalk-like
Smoky
HEDONIC TONE

Judgment of the relative pleasantness or unpleasantness.

An approximate indicator of the acceptability of an odour.

Comparison of the hedonic tone to a standard (e.g. vanillin is consider very pleasant but isovaleric acid is very unpleasant).
ODOUR ‘NOISE’

1. Probabilistic nature - Perception of weak odoriferous signals is stochastic (comes and goes randomly).
   – Number of odour molecules striking receptors varies with time.
   – Person’s state of readiness, fatigue, health.

2. Odour background level
   – High odour ‘noise’ results in greater tolerance when a ‘negative’ odour occurs (e.g. a pig farmer is used to a high odour ‘noise’ level and is not likely to be offended by composting odours)

3. May result in an odour signal when there is no odour –“false positive”
DETECTION OF ODORANTS

- Human nose does not have a specific receptor for a specific odorant; such as the smell of roses.
- Instead the nose detects a particular mixture of sweet, sour and floral sensation … which the brain recognizes as the smell of a rose.
- Odour detection and recognition is a learned response.
HUMAN NOSE

• Thus if we come across a new odour for which we have no memory, we would say: “It smells like ….”

• Taste is about 75% smell.
Bloodhounds can pick up a 24 hour old trail and identify the person. If a bloodhound comes across a 20 minute-old trail at right angles, sniffing for 2-5 steps will give the direction of the trail.
NOT BAD EITHER

"sniffer rats" have been used to detect explosives
OLFACTORY

Olfactory is one of two sensory channels responsible for human detection of inhaled substances in the environment.

Chemosenses of animals not only outperform humans, they also outperform current instrumentation in their sensitivity and specificity in detecting specific odorants.

• DOGS TRAINED TO DETECT BLADDER CANCER ODORS
• BEES AND WASPS HAVE BEEN TRAINED TO DETECT EXPLOSIVE RESIDUES
HUMAN OLFACTORY SYSTEM

Section through nose
OLFACTORY RECEPTOR NEURON

Nasal epithelium
CENTRAL OLFACTORY PATHWAYS

Each receptor sends a nerve fiber into the olfactory bulb of the brain from where information is passed onto different parts of the brain, including *the seats of emotion and memory.*
ODOURS CAN MAKE PEOPLE PHYSICALLY ILL

• Present at concentrations that produce sensory irritation (runny nose; red eyes) and/or other symptoms (sore throat; rash)

• Change in breathing patterns (nausea; palpitations).

• Association with negative experiences causing learned or conditioned response
  (e.g. response to hospital odours - nausea; headache).

• Perception (fear) that foul-smelling air is also unhealthy (nausea; headache; loss of appetite) [“environmental worry”]
FACTORS IN DETERMINING SENSITIVITY

• Sensitization - enhanced reaction or response to repeated exposure to an odor; increase in complaints

• Tolerance – diminishing reaction or response

• Short-term quickly repetitive or continuous-pungency stimulation causes an increased response.

• Repeated exposure normally results in a desensitization to a particular odorant.
FACTORS IN DETERMINING SENSITIVITY

• Diseases

• Drugs (e.g. estrogen, alcohol, tobacco smoke)

• Hormones often mediate emotional states.
  – olfactory sensitivity in women varies during the menstrual period (peaking just before and after ovulation)
  – women are generally more sensitive than men after reaching sexual maturity
ODOROUS BIODEGRADATION PROCESSES

• FOOD PROCESSING WASTE
  • RENDERING

• ORGANIC SOLID WASTE MANAGEMENT
  • COMPOSTING
  • ANAEROBIC DIGESTION

• AGRICULTURE WASTE
  • ANIMAL PRODUCTION
BIOCHEMISTRY OF COMPOSTING

Chemical changes during the composting cycle.
BREAKDOWN OF CARBOHYDRATES AND PROTEINS

• carbohydrates → simple sugars → organic acids → CO₂, H₂O and bacterial protoplasm

• proteins → peptides → amino acids → ammonium compounds → bacterial protoplasm and atmospheric nitrogen or ammonia
INHERENT ODOUR PROBLEMS

1. Biological treatment starts with odorous feedstocks.

2. Biological decomposition of organic waste produces intermediate compounds that are odorous.

4. Release of odorous compounds at some time is inevitable regardless of design and operation.
ODOROUS COMPOUNDS ASSOCIATED WITH THE COMPOSTING PROCESS

The three major groups of odorous compounds identified in composting systems are:

1. Sulphur containing compounds: sulphides & thiols
2. Nitrogen containing compounds: ammonia and amines
3. Volatile Fatty Acids (VFAs)

Other compounds found:
- ketones, terpenes, alcohols
## DETECTION LIMITS OF COMMON ODOROUS COMPOUNDS

<table>
<thead>
<tr>
<th>Compound</th>
<th>Odour Characteristic</th>
<th>Odour Threshold Concentration (ppmv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sulphur Compounds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hydrogen sulphide</td>
<td>rotten egg</td>
<td>0.7</td>
</tr>
<tr>
<td>dimethyl sulphide</td>
<td>rotten cabbage</td>
<td>2.5</td>
</tr>
<tr>
<td>dimethyl disulphide</td>
<td>sulfide</td>
<td>0.1</td>
</tr>
<tr>
<td>methamethiol</td>
<td>pungent</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Nitrogen Compounds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ammonia</td>
<td>pungent, sharp</td>
<td>26.6</td>
</tr>
<tr>
<td>aminomethane</td>
<td>fishy, pungent</td>
<td>25.2</td>
</tr>
<tr>
<td>dimethylamine</td>
<td>fishy, amine</td>
<td>84.6</td>
</tr>
<tr>
<td>trimethyl amine</td>
<td>fishy, pungent</td>
<td>0.8</td>
</tr>
<tr>
<td>3-methylindol (skatole)</td>
<td>feces, chocolate</td>
<td>4.0x10^{-5}</td>
</tr>
</tbody>
</table>

Low | High
---|---
14 | 50.8
346 | 82
39,600 | 12,000
84.6 | 0.8
268 |
## DETECTION LIMITS OF COMMON ODOROUS COMPOUNDS

<table>
<thead>
<tr>
<th>Compound</th>
<th>Odour Characteristic</th>
<th>Odour Threshold Concentration (ppmv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volatile Fatty Acids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>methanoic (formic)</td>
<td>biting; ants</td>
<td>45.0</td>
</tr>
<tr>
<td>acetic</td>
<td>vinegar</td>
<td>2,500</td>
</tr>
<tr>
<td>propanoic</td>
<td>rancid, pungent</td>
<td>84.0</td>
</tr>
<tr>
<td>butyric</td>
<td>rancid</td>
<td>1.0</td>
</tr>
<tr>
<td>valeric</td>
<td>unpleasant</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Ketones</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>acetone</td>
<td>sweet, minty</td>
<td>47,500</td>
</tr>
<tr>
<td>methylethyl ketone (MEK)</td>
<td>sweet</td>
<td>737</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>benzothiozole</td>
<td>penetrating</td>
<td>442</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile Fatty Acids</td>
<td>45.0</td>
<td>37,800</td>
</tr>
<tr>
<td>methanoic (formic)</td>
<td>2,500</td>
<td>250,000</td>
</tr>
<tr>
<td>acetic</td>
<td>84.0</td>
<td>60,000</td>
</tr>
<tr>
<td>propanoic</td>
<td>1.0</td>
<td>9,000</td>
</tr>
<tr>
<td>butyric</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>valeric</td>
<td>47,500</td>
<td>1,610,000</td>
</tr>
<tr>
<td>acetone</td>
<td>737</td>
<td>147,000</td>
</tr>
<tr>
<td>benzothiozole</td>
<td>442</td>
<td>2210</td>
</tr>
</tbody>
</table>
ODOUR COMPLAINTS

• A complaint results from the detection of an odorant that is different from the norm and intense enough to be annoying.

• Once a composting facility is perceived to have odour problems, it has one regardless of what the data shows (self-reinforcing) and must be addressed.

• Resolution of the problem requires addressing the real odour problem and the perceived one. Obviously the latter is the most difficult.

• Association of odours with unhealthiness or environmental hazard is a major cause for concern and complaints.
ENVIRONMENTAL ODOUR COMPLAINT PROCESS

• Odour complaint registered with regulatory agency
• Certified technicians take air samples at the reported location
• Air samples are analyzed chemically
• Air samples are evaluated by a certified ‘odour panel’
TYPICAL ODOUR SAMPLING TRAIN
ODOUR SAMPLING OF CURING PILE

Flux chamber.

Tedlar® bags filled with air sample.
OLFACTOMETER SCHEMATIC
ODOUR PANEL

Group of trained odour assessors waiting for their turn to analyze the odor samples using olfactometry.

The assessors function as the actual analytical ‘instrument’.
OLFACTOMETER
Panelist sniffs sample starting at highest dilution.
Simultaneous analysis.
MATCHING FUNCTIONS BETWEEN ODORANTS AND n-BUTANOL
PROBLEMS WITH ODOUR PANEL DATA

• SAMPLING EVENT RARELY CAPTURES ODOUR EVENT THAT CAUSED COMLAINT UNLESS OCOGRS ARE A CONTINUOUS PROBLEM.

• LIMITED NUMBER OF SAMPLES OBTAINED TO REPRESENT A LARGE VOLUME OF SUBSTRATE.

• CANNOT USE PANEL RESULTS FOR REAL-TIME PROCESS CONTROL.

• RESULTS ARE USED WITHOUT REGARD FOR THE INHERENT VARIABILITY AND STATISTICAL UNCERTAINTY OF THE UNDERLYING DATA.
INAPPROPRIATE USE OF RESULTS

CASE STUDY:

- CoA requires 1 OU at nearest receptor

- Odour sampling, panel analysis and dispersion modeling resulted in 3 OU

- Conclusion: site is not in compliance.

- The site has operated with only one (invalid?) odour complaint for a year!
EXAMPLE OF DESCRIPTOR HISTOGRAM PREPARED FROM THE PANEL’S ANALYSIS OF ONE SAMPLE
### SUMMARY OF DESCRIPTORS SUBMITTED BY PANEL

<table>
<thead>
<tr>
<th>DESCRIPTORS</th>
<th>PANEL MEMBERS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SP 1 (343 OU)</td>
</tr>
<tr>
<td>WOODY</td>
<td>38</td>
</tr>
<tr>
<td>SWAMPY</td>
<td>38</td>
</tr>
<tr>
<td>EARTHY</td>
<td>38</td>
</tr>
<tr>
<td>GRASSY</td>
<td>38</td>
</tr>
<tr>
<td>GARBAGE</td>
<td></td>
</tr>
<tr>
<td>OFFENSIVE</td>
<td>38</td>
</tr>
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</table>
# VARIABILITY OF DATA

<table>
<thead>
<tr>
<th>WEEK</th>
<th>LOCATION</th>
<th>AVE OU</th>
<th>STD OU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tunnel</td>
<td>3084</td>
<td>823</td>
</tr>
<tr>
<td>2</td>
<td>Covered windrow</td>
<td>2231</td>
<td>604</td>
</tr>
<tr>
<td>3</td>
<td>Covered windrow</td>
<td>1557</td>
<td>306</td>
</tr>
<tr>
<td>4</td>
<td>Covered windrow</td>
<td>555</td>
<td>199</td>
</tr>
<tr>
<td>5</td>
<td>Covered windrow</td>
<td>371</td>
<td>189</td>
</tr>
<tr>
<td>6</td>
<td>Covered windrow</td>
<td>357</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>Covered windrow</td>
<td>371</td>
<td>189</td>
</tr>
</tbody>
</table>
OBSERVATION

1. There is no justification for using 1 OU to determine an odour problem (by def’n: 1 OU on the butanol intensity scale represents the intensity when 50% of the population will detect an odour different from the background)

2. For a 1-butanol scale of
   - 1 (15 ppmv) to 3 ou (60 ppmv) – too weak for odour complaints
   - 4 (120 ppmv) to 6 ou (500 ppmv) – complaints are possible to probable
   - 7 (1000 ppmv) to 8 (2000 ppmv) ou – nuisance level
RESEARCH CHALLENGE

DEVELOP A MULTI-SENSOR SYSTEM (ELECTRONIC NOSE) THAT ACCURATELY MIMICS THE HUMAN OLFATORY RESPONSE TO ODORANTS TO DETECT REAL-TIME EMISSIONS TO ELIMINATE THE VARIABILITY OF UNCERTAINTY OF ODOUR PANELS AND TO PROVIDE OPERATIONAL INFORMATION.
COMMERCIALY AVAILABLE ELECTRONIC NOSE.
SOURCES AND EMISSION OF ODORANTS IN COMPOSTING PLANTS

Generic composting facility consists of the following unit operations:

1. receiving: inbound waste, tipping floor
2. pre-processing: mixing and shredding
3. primary reactor
4. windrow phase
5. post-processing: screening
6. curing/maturing
7. storage
8. biofiltration
Bagged kitchen waste: anaerobic and high moisture content.

Yard waste and grass are also significant sources of anaerobic material.
Leachate (slop) full of dissolved nutrient and anaerobes is tracked by the loader on the tipping floor. Need to clean the floor when done.

SSO and yard waste mixed on tipping floor, ready for shredding.
Shredding is required to reduce the particle size and to open bags.

It also provides good mixing of the SSO and amendment.

The operation allows emission of volatile odorants as bags are opened and waste is shredded.
Enclosed reactors, such as tunnels and large boxes, are in themselves not emitters of odorants because the processing air is readily captured and treated (point source).

Loading and unloading of enclosed reactors do contribute to the odour levels in the building.

Since many tunnels are used a primary composting phase, the substrate is an important source of odorants and must not be stockpiled.
CHANNEL, WIDE-BED AND INDOOR WINDROWS SYSTEMS

All have large surface emissions to the building environment, especially with updraft (positive) aeration.

Large volumes of process air and building air has to be treated which at Times may over load the odour treatment process.

High corrosion potential.
CHANNEL, WIDE-BED AND INDOOR WINDROWS SYSTEMS

Ammonia levels tend to be unbearably high because the process is often run with low C/N ratios in order to maximize capacity.

Leakage of odorants from the building is found to be problematic, especially when older buildings are used or doors are not kept closed.
OPEN WINDROW COMPOSTING/CURING

• Most of the plants closed due to odour complaints involved windrow operations (many US plants composted biosolids).
• Weather, especially prolonged periods of rain, often has an adverse effect on the process (leachate production, oxygen supply).
OPEN WINDROW COMPOSTING/CURING

Building and managing MSW windrows are subject to considerable odour potential.

Truck unloads substrate from tunnel directly into windrow to minimize handling.
OPEN WINDROW COMPOSTING/CURING

- Large surface area for emissions.
- Turning event cause significant, short-term emissions of odorants.

Windrow turners reduce the duration of the turning process and reducing total emissions. Turning with frontend loader prolongs emissions.
MANAGING WINDROW TURNING

• Turn during unstable meteorological conditions (usually 9:00 am – 7:00 pm) rather than stable conditions (early morning – 6:00 to 8 am and evening - after 8 pm). Odorants are more easily diluted and dispersed during unstable conditions.

• Reduce substrate/compost handling during periods of stagnant, humid summer conditions – pervasive odours will ‘hang around’.

• Avoid turning windrows/piles when the wind is blowing towards the receptors sites (need wind direction /speed indicator on site).

• Cool grounds will ‘trap’ odours and release them as the ground warms up – may result in a sudden release of odours from the site, depending on the topography.
SCREENING OF IMMATURE COMPOST

- Screening of immature compost prior to curing allows the escape of odorants in much the same way as turning.

- But screening is a continuous operation.

- In addition to the compost fraction, screening produces one or more fractions.

- Piles of overs contain partly decomposed material, such as wood, and can be a major source of odours.
MATURING/CURING OF COMPOST

• Usually done in large static piles or windrows with or without aeration or mixing.

• Material is still active and odorant production occurs, albeit at a slower rate.

• Surface areas are large and process period is up to several months.

• Given inherent difficulties in controlling moisture and airflow distribution in windrows, portions of the compost are less degraded than expected and may be anaerobic, transferring the problem to the curing process.
LEACHATE AS A SOURCE OF ODORANTS

Leachate is the result of drainage of free water from the substrate or run off from watering operations or weather effect.

Leachate in tunnel is tracked by frontend loader onto the floor. Windrow leachate caused by rain – must provide drainage.
MAJOR LEACHATE AND ODOUR PROBLEM
Leachate collection and treatment ponds are a potential source of odorants.

Large quantities of available dissolved nutrients.

Pond operation requires careful attention to prevent Odour complaints.
ODOUR CONTROL

1. Plant siting
2. Plant and process design
3. Proper plant operation
4. Treatment of off-gases
PLANT SITING

• Attention to establishing a large buffer zone between the plant and current/potential receptors is the single most effective way to prevent odour complaints.

• Even the best designed and operated plant will sooner or later experience a serious odour event.

• Once a site has been found it is imperative that the neighbours understand the process and that composting odorants may be an annoyance but are not hazardous to their health.
PLANT DESIGN

1. Enclosed tipping floor
2. Negative pressure in receiving/plant areas
3. Airlock for entering vehicles
4. Leachate control and management
5. Yard waste storage (if any)
6. Rapid processing of inbound waste and removal of screened-out materials (before or after high-rate composting)
ODOUR MANAGEMENT

1. Process optimization to ensure aerobic composting, minimizing production of odours.

2. Minimize the release of fugitive odours.

3. Treat off-gases to prevent escape of odours from the plant.
COMPOSTING OF SSO

<table>
<thead>
<tr>
<th>OPERATIONAL PARAMETERS</th>
<th>RANGE</th>
<th>TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/N ratio</td>
<td>25-35/1</td>
<td>30/1</td>
</tr>
<tr>
<td>Moisture content (% w.b)</td>
<td>45-60</td>
<td>55</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>40-60</td>
<td>45 or 55</td>
</tr>
<tr>
<td>Oxygen (interstitial) (vol %)</td>
<td>10-21</td>
<td>16</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>45-60</td>
<td>50</td>
</tr>
<tr>
<td>Particle size (mm)</td>
<td>50-75</td>
<td>60</td>
</tr>
</tbody>
</table>

PROCESS CONTROL: temperature, oxygen and moisture

MIXING: to breakup anaerobic pockets and clumped substrate; reestablish porosity

WASTE HANDLING: keep the waste moving; prevent storage

HOUSEKEEPING: keep the place clean
CORRECT MOISTURE CONTENT <60%

Tom Richard, Cornell
Moisture (blue) and near surface pores are aerobic while deeper into particle pores, environment is anaerobic.
MOISTURE CONTENT TOO HIGH >65%

Tom Richard, Cornell
SUBSTRATE WITH EXCESSIVE MOISTURE
CRITICAL MOISTURE CONTENT

![Graph showing temperature changes over time with annotations:]

- **60% MOISTURE**
- **REMOVED - DRY MATERIAL ADDED**
- **61% MOISTURE**
- **LOADED AT 66% MOISTURE**

**TEMP. °F**
- 190
- 180
- 170
- 160
- 150
- 140
- 130

**TEMP. °C**
- 80
- 70
- 60

**TIME (DAYS)**
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
TREATMENT OF ODOUR EMISSIONS

Treatment of odorants generated during the process should be regarded as a fail-safe system rather than the primary mechanism to prevent emissions.

Well-established air emissions control processes have been developed by the chemical industry. Most of them are applicable to composting BUT the designer must understand the composting process.
Air pollution control processes are often categorized as follows:

1. **Physical processes**
   - dispersion (high stack), dilution, adsorption

2. **Chemical processes**
   - wet scrubbing (NH$_3$ removal), chemical oxidation, thermal oxidation

3. **Biological process**
   - biofiltration (absorption and biological oxidation)
BIOFILTRATION

• Provides effective removal of a wide spectrum of odorous compounds from composting gases.

• Maintaining proper moisture content in the media is crucial to achieving and maintaining maximum removal efficiencies.

• Microbial population in a biofilter is diverse and stratified resulting in removal of different compounds at different levels.

• Acclimation of a new biofilter requires about one week with maximum removal after one month.
Gases from the composting facility are filtered through the biofilter to reduce odour.
# BIOFILTER DESIGN PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of material (m)</td>
<td>0.6 – 1.0</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>40 – 60</td>
</tr>
<tr>
<td>Air residence time (s)</td>
<td>30 – 60</td>
</tr>
<tr>
<td>Loading rate (m³/h.m²)</td>
<td>30 – 50</td>
</tr>
<tr>
<td>Specific weight of bed (kg/m³)</td>
<td>400 – 800</td>
</tr>
<tr>
<td>pH</td>
<td>6.0 – 8.5</td>
</tr>
<tr>
<td>Bed temperature (°C)</td>
<td>15 – 45</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>40 – 60</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>25 – 35</td>
</tr>
</tbody>
</table>
BIOFILTER MATERIAL

Mixture of materials must provide high adsorption capacity, low pressure drop, uniform porosity and enough organic matter to support the microbial population during periods of low odour emissions or shut down:

– mixture of mature compost, bark and soil works well.
– manufactured biofilter media are also available but is usually more costly.
– several researchers, including myself, have found little difference in performance between natural and manufactured biofilter material
– Manufactured filters are designed as enclosed units and usually include a stack to provide better dispersion
## BIOFILTER ODOUR REMOVAL EFFICIENCIES

<table>
<thead>
<tr>
<th>Compound</th>
<th>Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrogen sulphide</td>
<td>&gt;99</td>
</tr>
<tr>
<td>dimethyl disulphide</td>
<td>&gt;91</td>
</tr>
<tr>
<td>terpene</td>
<td>&gt;98</td>
</tr>
<tr>
<td>organo-sulfur gases</td>
<td>&gt;95</td>
</tr>
<tr>
<td>ethylbenzene</td>
<td>&gt;92</td>
</tr>
<tr>
<td>tetrachlorethylene</td>
<td>&gt;86</td>
</tr>
<tr>
<td>chlorobenzene</td>
<td>&gt;69</td>
</tr>
</tbody>
</table>
WHAT IF THERE IS AN UNUSUAL ODOUR EVENT?

Every plant must have a written contingency plan to deal with unusual odour events because they will occur at some time either due to equipment failure or operational errors.

Staff must be trained to deal with such events and be prepared to take immediate action.

Must inform the neighbours to assure them that everything is being done to rectify the problem and that the odours are not an health concern.
ACTION IN AN UNUSUAL ODOUR EVENT

• In an extreme case remove the offending material from the site to a landfill or for reprocessing.

• Go Back to Basics:
  – check the process parameters (especially moisture and oxygen levels but also pH).
  – check the temperature history of the substrate
  – C/N ratio information is also important but will take too long before action is required.
ACTION IN AN UNUSUAL ODOUR EVENT

- Get the system back to the proper conditions.
  - may need to turn the substrate to enhance airflow and oxygen distribution
  - turning will release additional odorants which can be mitigated by spraying an odorant suppressing chemical.
ACTION IN AN UNUSUAL ODOUR EVENT

• For windrows or piles, cover the substrate with a 0.3 m or more layer of stable, moist compost to form a temporary biofilter. If there is no change in operating parameters (temperature and oxygen content) additional action is needed.

• If the pH is lowered due to excess formation of volatile fatty acids, mix 15 to 20% lime on a dry basis with the substrate. Adding lime to the surface only has no effect.
• Understand the composting process with respect to odorant generation and emissions.

• Operate the plant with the objective of minimizing generation of odorants.

• Maintain odour treatment process.

• Get ready for the inevitable odour event.