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Potential Beneficial Effects of Volatile Organic Compounds from Wood on Human Well-Being and Health

Jure Pohleven

InnoRenew CoE – Human Health in the Built Environment

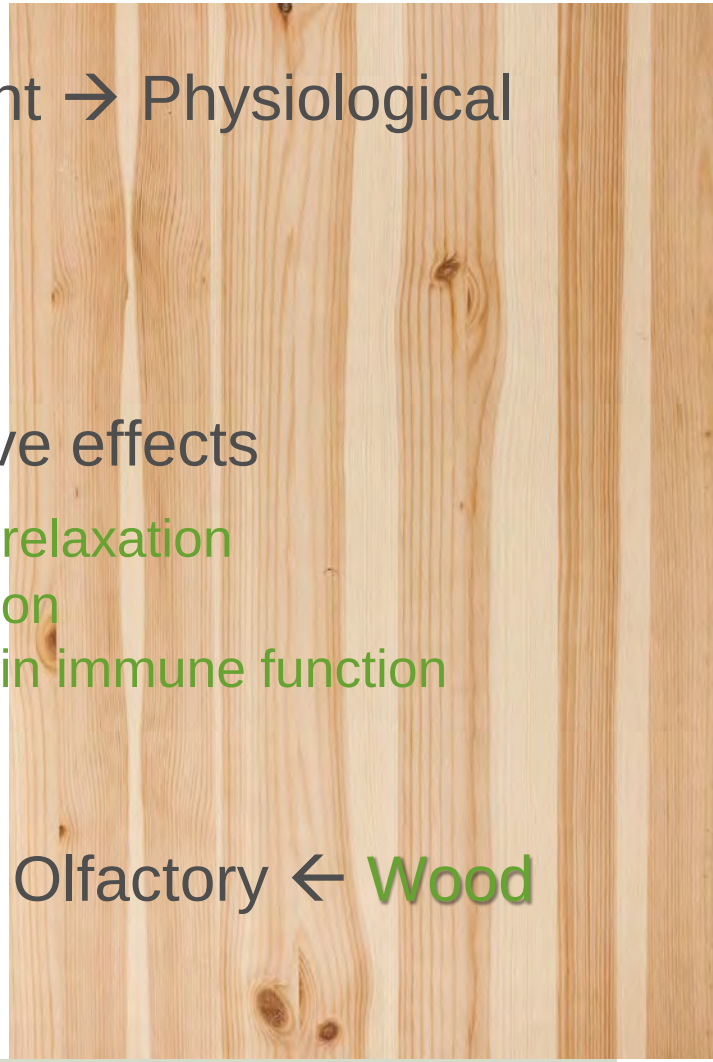
Timber – A healthy future for sustainable buildings
Koper, 7 March 2019

Horizon 2020 Framework Programme of the European Union; H2020 WIDESPREAD-2-Teaming: #739574

Presentation outline

1. Restorative Properties of Wood
2. Volatile Organic Compounds (VOCs)
3. Wood VOCs
4. Beneficial Effects of Wood VOCs
5. Conclusion

1. Restorative Properties of Wood



Modern humans in artificial environment → Physiological stress

vs.

Natural materials = Wood → Restorative effects

Physiological relaxation
Stress reduction
Improvement in immune function

Wood stimuli: Visual, Tactile, Auditory, Olfactory ← Wood

VOCs

Horizon 2020 Framework Programme of the European Union; H2020 WIDESPREAD-2-Teaming: #739574

2. Volatile Organic Compounds (VOCs)

Indoor activities and sources – building materials and products

↓ Emission

Volatile organic compounds (VOCs)

Anthropogenic VOCs

Biogenic VOCs

↓ Inhalation, absorption

Human body →
Effects
↓

Human well-being and health

Indoor Air Quality (65 – 90% time)

https://yellowbluetech.com/category/products/betterair/

2. Volatile Organic Compounds (VOCs)

Anthropogenic VOCs

Benzene, toluene, (formaldehyde)…

Released from artificial materials, chemical agents, activities…

Negative effects on human health - respiratory and eye irritation
- allergies and asthma
- headache
- sick building syndrome
- cancer

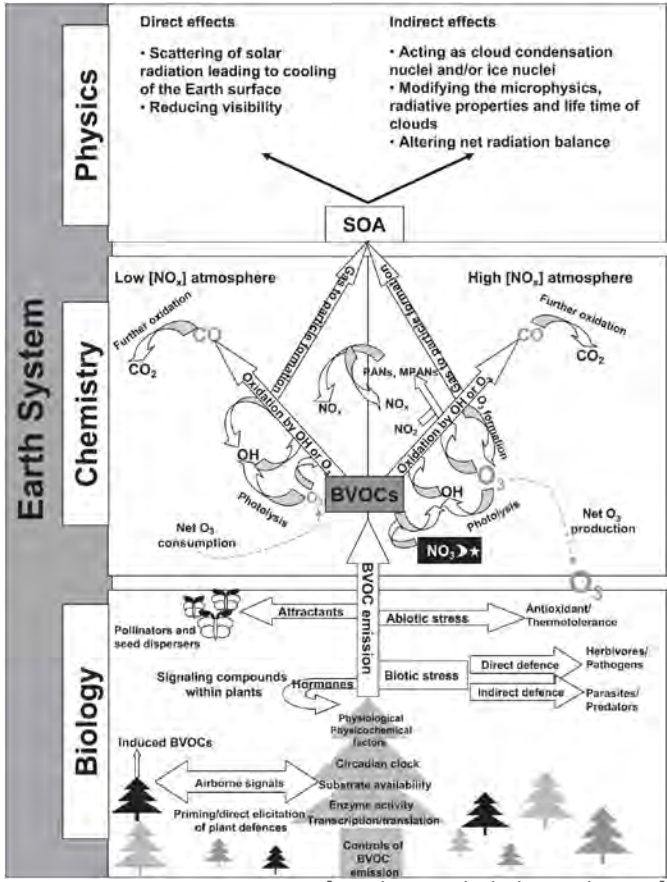
2. Volatile Organic Compounds (VOCs)

Biogenic VOCs

Released by plants (wood), etc
(Plant volatiles, Phytoncides)

Isoprene (C_5), Monoterpenes (C_{10}), Sesquiterpenes (C_{15}), Ethylene, Oxygenated hydrocarbons

Vast quantities released from vegetation (forests) to the atmosphere (½ Isoprene, ⅓ Monoterpenes)



[Laothawornkitkul in sod. 2009]

2. Volatile Organic Compounds (VOCs)

Biogenic VOCs

Biological function in plants → Signalling, communication, defence:

- Repel herbivores (direct defence)
+ Attract predators (vertebrates, mammals) and parasites of herbivores (indirect defence)

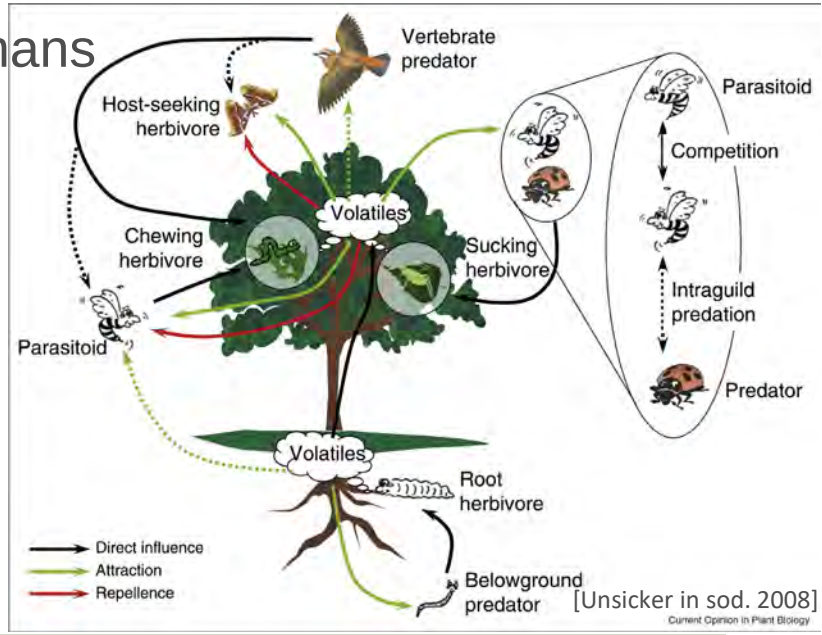
→ Beneficial effects on higher animals/humans

↓

Various physiological responses in different organisms

↓

Positive or negative effects



[Unsicker in sod. 2008]

3. Wood VOCs

PRIMARY WOOD VOC EMISSIONS

- Free (non-bound) plant volatiles with biological function
- In storage compartments – resin canals/ducts → emitted
- Softwoods
- Volatile terpenes – monoterpenes (α-pinene, 3-carene, β-pinene, limonene…)
  – sesquiterpenes (β-caryophyllene, humulene, γ-cadinene…)

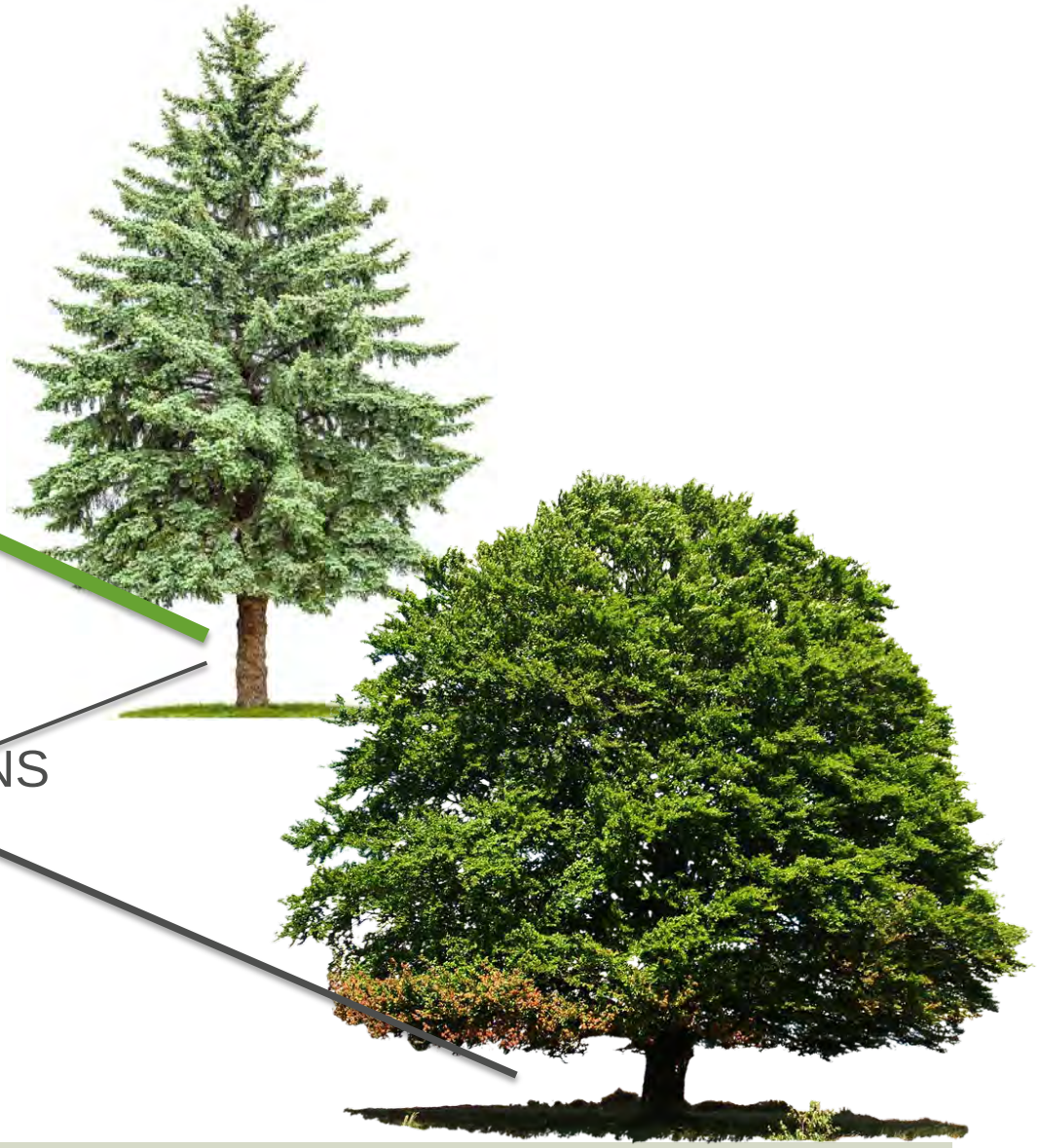
SECONDARY WOOD VOC EMISSIONS

- Products of wood degradation (↑ temperature, oxidising agents) → liberated → emitted
- Hardwoods and softwoods
- Hexanal and other aldehydes, acetic acid

3. Wood VOCs

PRIMARY VOC EMISSIONS

SECONDARY VOC EMISSIONS



4. Beneficial Effects of Wood VOCs

- Softwoods, Wood Essential Oils, isolated Wood VOCs:

  Monoterpenes and sesquiterpenes: α-pinene, β-pinene, limonene, cedrol, β-thujaplicin (hinokitiol)

- Softwood species: *Pinus*, *Chamaecyparis*, *Cryptomeria*, *Thujopsis*,…

- Biological systems: Cell lines (*in vitro*), Mammalian model organisms (mice, rats), Humans

4. Beneficial Effects of Wood VOCs

Two pathways involved in mediating the effects of inhaled VOCs:

- the neurological pathway
  via olfactory nerve → central nervous system

- the pharmacological pathway (main route, long-term action)
  inhaled → absorbed through the respiratory tract → bloodstream
  → distributed throughout the body → delivered to the target site = tissue or cells → effects

4. Beneficial Effects of Wood VOCs

- Relaxation and stress reduction
- Improvement in immune function
- Anti-inflammatory activity
- Antioxidant activity
- Anticancer activity
- Neuro-, cardiovascular-, liver-, kidney-, gastroprotective activity
- Antimicrobial activity (antibacterial, antifungal)

4. Beneficial Effects of Wood VOCs

- Relaxation and stress reduction

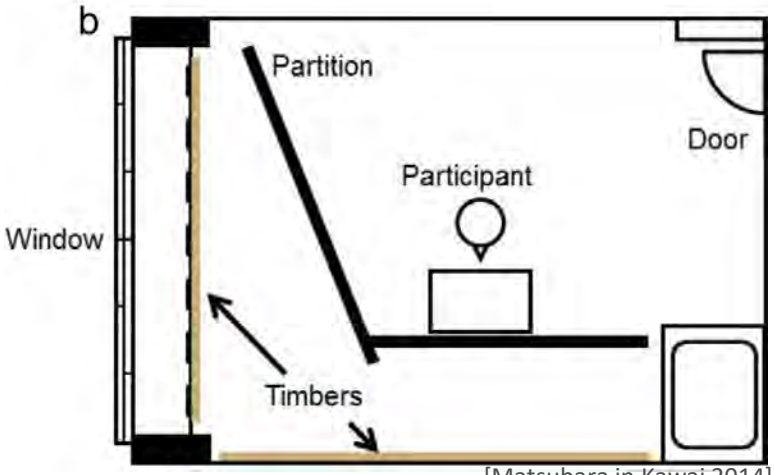
Olfactory stimulation → Decreases the levels of physiological arousal:

↓ Blood pressure and heart rate

↓ Stress hormones/markers (adrenaline, noradrenaline, chromogranin A, α-amylase)

↑ Parasympathetic nervous system activity → Body at rest → Relaxation

		Increase in PSNS activity
Inhalation of wood VOC	α-pinene (90 sec)	46.8 %
	D-limonene (90 sec)	26.4 %
	cedrol (10 min)	36.0 %
Forest therapy	walking in forest (16 min)	102.7 %
	viewing scenery (14 min)	55.0 %



[Matsubara in Kawai 2014]

4. Beneficial Effects of Wood VOCs

- Improvement in immune function

α-pinene and 1,8-cineole enhance immune responses:

→ Activation of natural killer (NK) immune cells → Provide defence against tumours and viruses

↑ Cytolytic activity of NK cells → ↑ Expression of cytolytic proteins →

Induce death (apoptosis) in cancerous cells or cells infected with viruses

4. Beneficial Effects of Wood VOCs

- Anti-inflammatory activity

Modulation of immune-inflammatory responses by volatile terpenes:

↓ expression of proinflammatory cytokines (immune signalling molecules; IL-1β, IL-6, TNF-α)

→ Suppress inflammation

Positive effects against arthritis, dermatitis, and other inflammatory diseases

4. Beneficial Effects of Wood VOCs

- Antioxidant activity

→ Volatile terpenes can prevent diseases associated with oxidative stress

→ Prevent oxidative reactions → Cell damage → Diseases

↓ Reactive oxygen species (ROS) via:

- free radical scavenging
- inducing the expression of antioxidant enzymes

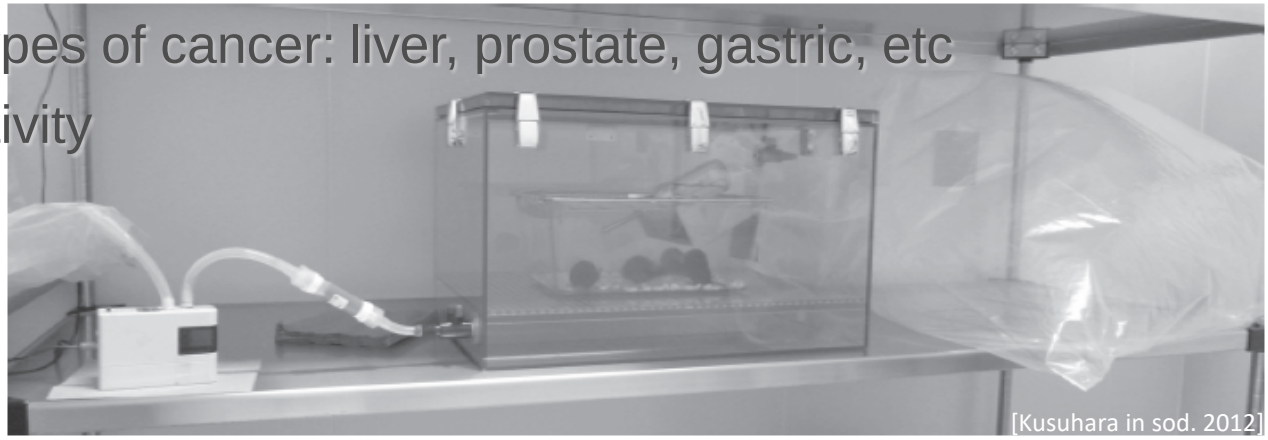
4. Beneficial Effects of Wood VOCs

- Anticancer activity

→ Potential use as chemotherapeutic agents in cancer treatment

→ Volatile terpenes (α-pinene, limonene, etc) in *in vitro* and *in vivo* studies:

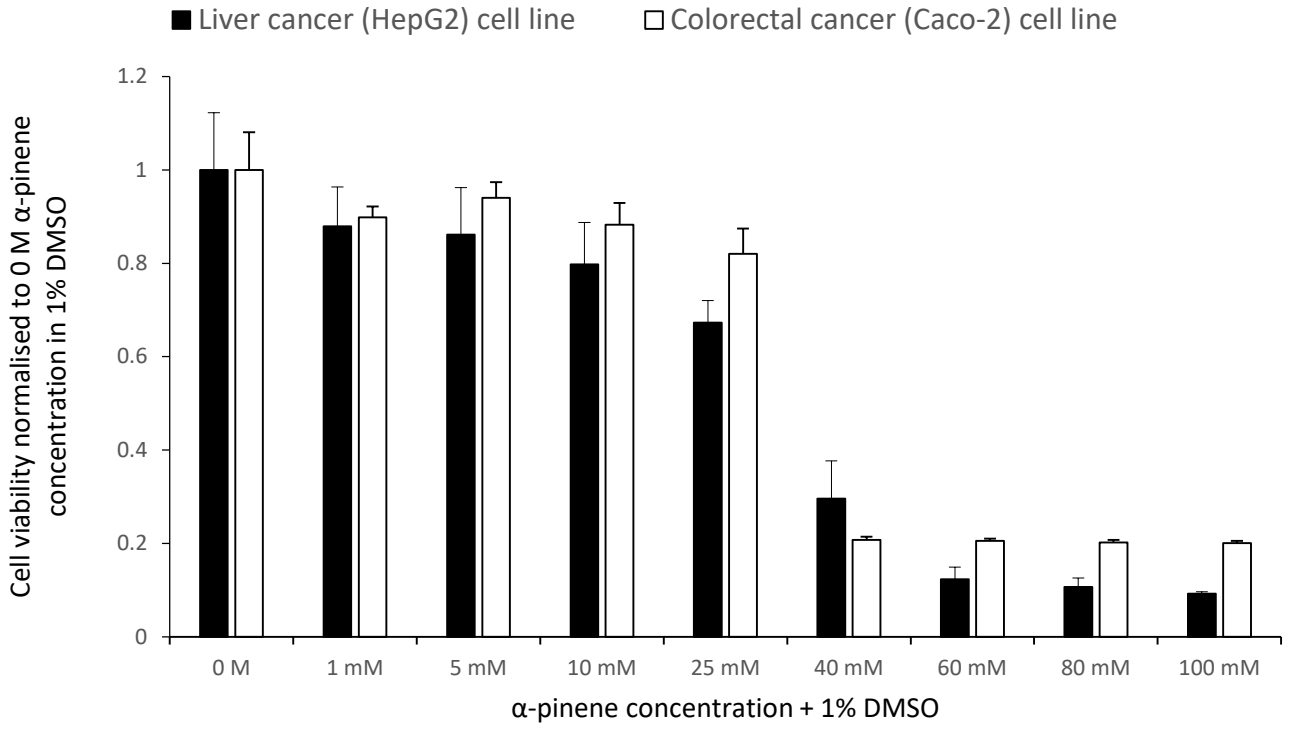
- 40 % ↓ melanoma tumour (skin cancer) in mice in α-pinene environment
- Against various types of cancer: liver, prostate, gastric, etc
- Antimetastatic activity



[Kusuhara in sod. 2012]

4. Beneficial Effects of Wood VOCs

- Anticancer activity – α-pinene on liver and colorectal cancer cells



4. Beneficial Effects of Wood VOCs

- Neuroprotective (antioxidant, anti-inflammatory activity → against neurodegenerative diseases – animal models of Alzheimer‘s and Parkinson‘s)
- Cardiovascular protective (↓ blood pressure, heart rate, glucose levels, cholesterol)
- Liver protective
- Kidney protective
- Gastroprotective activity

4. Beneficial Effects of Wood VOCs

- Antimicrobial activity (against pathogenic bacteria and fungi)

Antibacterial activity:

- MRSA (methicillin-resistant *Staphylococcus aureus*)
- *Bacillus*, *Streptococcus*, *Staphylococcus*, *Salmonella*, *Pseudomonas*, etc

Antifungal activity:

- *Candida albicans* (yeast), *Aspergillus* sp. (mould)
- wood-decay fungi – *Trametes versicolor*, *Laetiporus sulphurous*,…

5. Conclusion

- Restorative properties of Wood
- Wood VOCs (defence: – herbivores or + higher predator animals)
- Emitted to indoor environment → inhaled, absorbed
- Positive or negative effects in humans → Impact on IAQ
- Beneficial properties of WVOCs

relaxation/anti-stress, immunostimulation, anti-inflammatory, antioxidant, anticancer, antimicrobial, etc

Thank you!

Faculty of Health Sciences (University of Primorska)

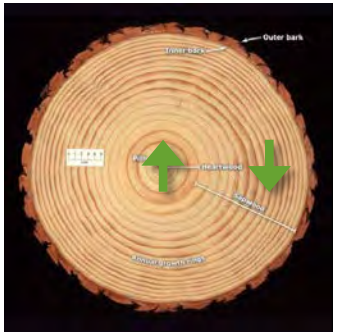
doc. dr. Saša Kenig
doc. dr. Zala Jenko Pražnikar
doc. dr. Ana Petelin
dr. Katja Bezek
Katja Kramberger

3. HOS iz lesa

Hlapni terpeni (monoterpeni, seskviterpeni), ocetna kislina, metanojska kislina, metanol, aldehidi (heksanal, acetaldehid, formaldehid), ketoni (aceton),…

Primarne HOS

Sekundarne HOS



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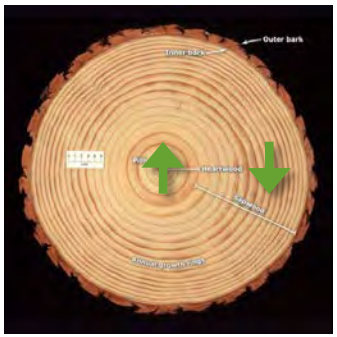
Primarne HOS

Sekundarne HOS



2. Hlapne organske spojine (HOS, VOC)

Biogene HOS in podnebje

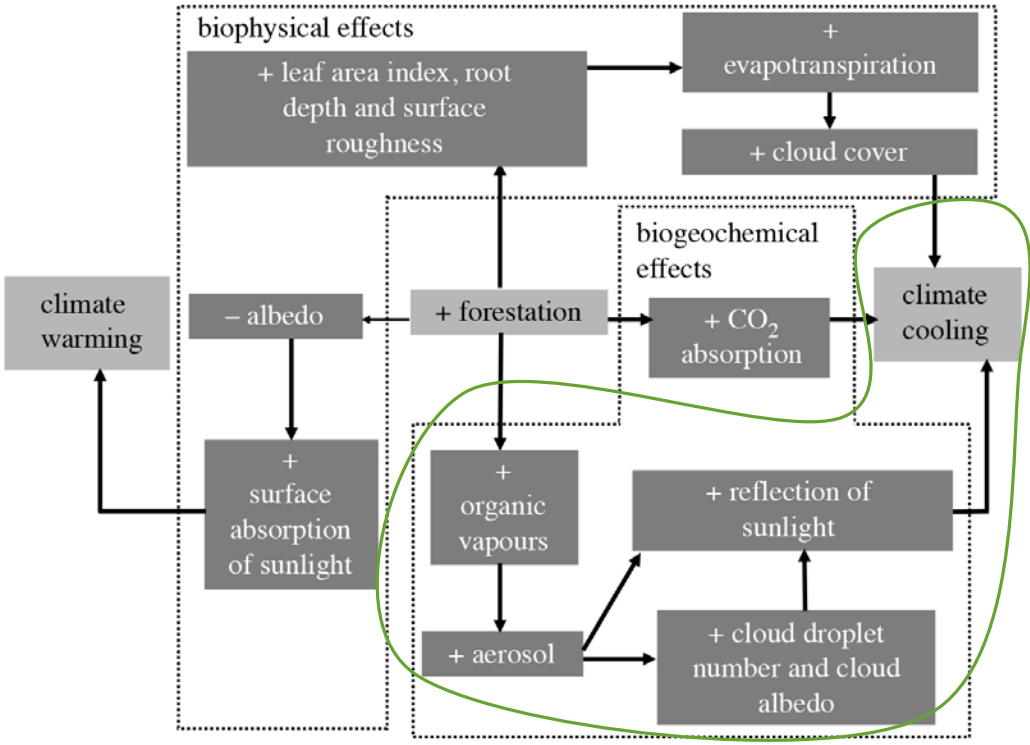
Kemično reaktivni v atmosferi

↓

Vpliv na atmosfero

↓

Vpliv na globalno podnebje



[Spracklen in sod. 2008]

4. Blagodejni učinki HOS iz lesa

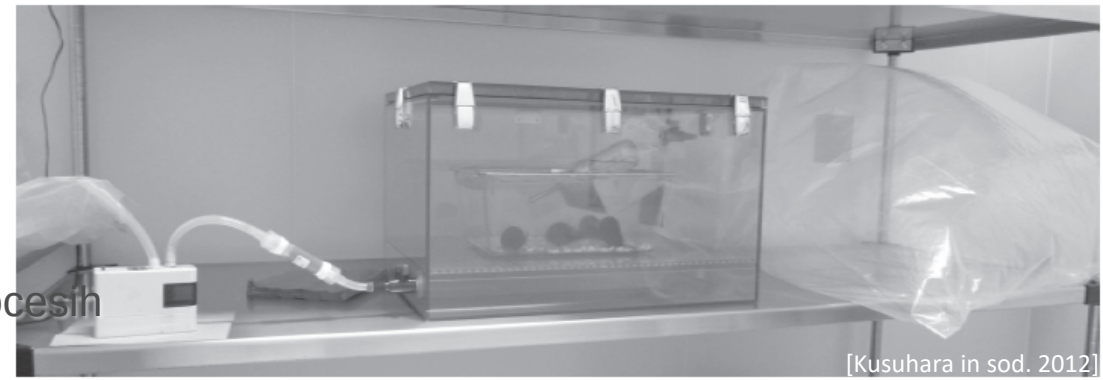
• Protirakavo delovanje

α-pinen:

- 40 % ↓ melanoma (kožni rak) pri miših + α-pinen
- Protimetastatsko delovanje pri melanomu
- ↓ hepatoma (rak jeter) in ↓ rast tumorja raka prostate
- ↓ celice nevroblastoma (rak živčnega sistema)

Mehanizem delovanja prek:

- Ustavitve celičnega cikla
- Indukcije programirane celične smrti
- Antioksidativnih lastnosti
- ↓ vnetja
- Regulacije ekspresije proteinov v procesih



[Kusuhara in sod. 2012]

3. ForestValue project

Beneficial Effects of Volatile Organic Compounds from Wood on Human Well-Being

Scope:

Biological activity of WVOCs (focus on positive effects)

→ Impact of wood on indoor air quality → human well-being or health

6 WPs involving 4 partners:

WP1 – Project Management and Dissemination (InnoRenew)

WP2 – Selection and preparation of samples (InnoRenew, Göttingen University)

Samples: Softwood + Hardwood + Modified Wood

- Thermal modification at elevated pressure within closed reactor system
- VOCs retained
- Additional modified VOCs?

3. ForestValue project

WP3 – Identification and Emission Studies of WVOCs (WKI, Aalto University)

WVOC identification

Emission test chambers
Sampling by adsorption on Tenax
Identification + quantification by GC-MS

Emission studies

Analysis of VOC products

3. ForestValue project

WP4 – Biological Activity Studies of Identified WVOCs (InnoRenew)

Tests on different biological systems

- Human (tumour / immune) cells → viability →
  inhibition of t. c. / activation of i. c. (cell surface markers, cytokine production)
- Bacteria
- Fungi

  } influence on growth
- Animal model organisms – mammalian (mice, rats)
- Humans – psychophysiological responses
  (salivary cortisol levels, skin conductance, heart rate variability, blood pressure)

Biological activity studied on molecular level → Mode of action

3. ForestValue project

WP5 – Analysis and Math. Modelling of VOC Emissions and Biol. Activity

Develop mathematical models for the prediction of

VOC emissions (predictors: temperature, relative humidity)
Biological activity of VOCs (predictor: VOC concentration)

WP6 – Exploitation of the Results

4. Germany Visit

- Göttingen University (Göttingen)

  Faculty of Forest Sciences and Forest Ecology

  Institute of Wood Biology and Wood Technology

Prof. Holger Militz, Prof. Carsten Mai, Sascha Brinker, Yagmur Bütün

- Fraunhofer WKI (Braunschweig/Brunswick)

  Department of Material Analysis and Indoor Chemistry

Prof. Tunga Salthammer, Dr. Jan Gunschera, Dr. Alexandra Schieweck

Prof. Bohumil Kasal

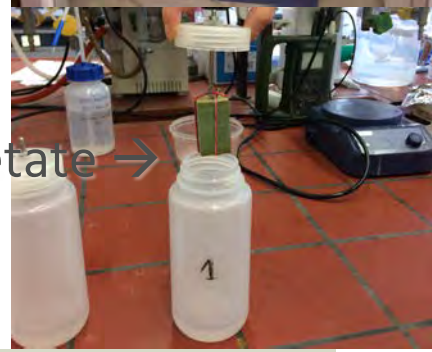
4. Germany Visit

- Göttingen University (Göttingen)

Determination of formaldehyde content in wood samples:

- ❖ Formaldehyde Emissions Testing (standardized):
  - Gas analysis method (60°C, air pump rate of 60 L/h, 1+1h)
  - Perforator method (boiling, 2h)
  - Flask method (40°C, 24h)
- ❖ Formaldehyde concentration determination:

  Acetylacetone colorimetric method + Ammonium acetate → Spectrophotometer (412 nm)



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Prof. Bohumil Kasal

1. My background

- Biologist
- PhD in Biotechnology
- Biochemistry, Molecular Biology & Cell Biology

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Medicinal properties of fungal proteins
(immunomodulatory, anticancer properties)

Neurodegenerative diseases
(ALS, FTLD)