Material Solutions for Indoor Air Quality:
walls, floors, and ceilings improve health

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Research conducted at: CASE | RPI

EXISTING IAQ MAINTENENCE IS ENERGY INEFFICIENT

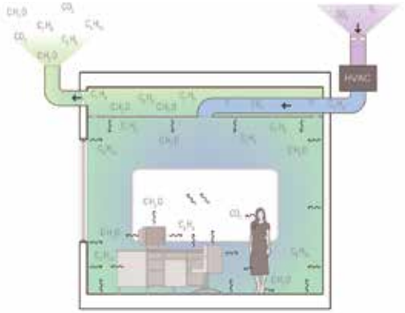
Indoor air quality (IAQ) is currently maintained by heating, ventilating, and air conditioning (HVAC) equipment accounting for 30% to 40% of a building's total energy consumption. It is necessary to continuously replace interior air with exterior air to prevent the accumulation of harmful toxins inside buildings. True energy sustainability is not possible as long as we rely predominantly on outdoor air to maintain healthy indoor environments. Virtually all polymers: plastics, composite building materials with polymer binders, and coatings and finishes release volatile organic compounds (VOCs) such as formaldehyde and toluene. Many VOCs have been linked to respiratory ailments, nervous-system degradation, and even cancer. Responsible architects will specify non-toxic materials and products when possible, but the architect has limited ability to control the indoor environment post-occupancy. Even if all buildings and products were made harmless, biological pathogens carried by humans and present indoors would still pose an indoor air threat.

Furnishings, office equipment, and even many office supplies such as dry-erase markers will be present in indoors for the foreseeable future. As long as product designers continue to use materials that off-gas potentially harmful toxins, and as long as we use combustion equipment indoors, there will be a persistent indoor air quality problem. Even if all buildings and products were made harmless, biological pathogens carried by humans and present indoors would still pose an indoor air threat. Therefore, it is not enough for designers to simply limit the introduction of harmful materials to a space, but they should also be providing materials that remediate toxins indefinitely.

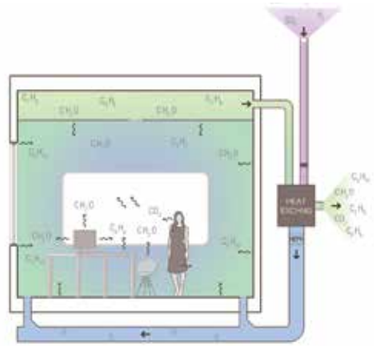
MATERIAL REMEDIATION POTENTIAL

Since this is a material-based problem, the question is what is the material-based solution. This research presents a scalar spectrum of materials with inherent antibacterial, antifungal, and decay resistant properties. This research investigates enzyme impregnated paint, cedar, black walnut, eucalyptus, activated carbon, and zeolite for greater understanding of their natural behavior. Knowledge of intrinsic material intelligence can be leveraged for an architectural benefit.

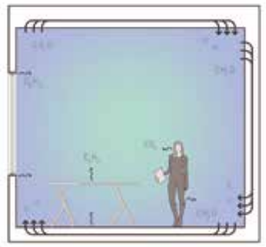
In the case of the woods, there have been a number of identified compounds that are thought to cause anti-decay behavior, such as cedrines. In the case of the adsorption materials, their ability to sequester even very small toxins can be attributed to their fundamental structure. This research asks: can these properties be harnessed or mimicked in architecturally viable materials to actually improve indoor air quality?



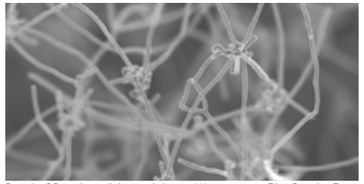
EXISTING THERMAL CONDITIONING & AIR CONTENT MANAGEMENT
Indoor spaces are constantly flushed with outdoor air to prevent the accumulation of harmful levels of toxins. This outdoor air is conditioned to meet thermal comfort needs at great energy cost. The general assumption is that outdoor air quality is adequate for this purpose. HEPA filters are used to remove outdoor contaminants, again at a high energy cost.



ENERGY EFFICIENT THERMAL CONDITIONING & AIR CONTENT MANAGEMENT
The use of high-efficiency heat exchangers allow heat or coolth to be transferred from indoor air to outdoor air, thereby reducing the total amount of energy needed to meet both health and comfort standards. This method still relies on dilution of indoor toxins with outdoor air.



PROJECTED FUTURE CLOSED CONDITIONING & CONTENT MANAGEMENT
With the right combination of material science, biological technology, and real-time sensing and actuation, it may be possible to create indoor environments that are self-cleaning without dependence on outdoor air. Outdoor air quality is not adequate to promote health in many locations.

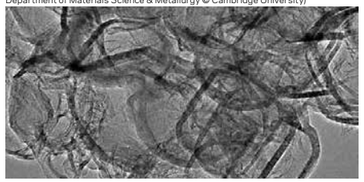


Ravindra C Pangule, et all. Antistaphylococcal Nanocomposite Films Based on Enzyme-Nanotube Conjugates. ACS Nano, Vol. 4, No. 7, 2010 IMAGE: http://www.nanotech-now.com/nanotechnology-glossary-N.htm (Charanjeet Singh, Polymer Research Group, Department of Materials Science & Metallurgy © Cambridge University)

Researchers at RPI have successfully suspended bacteria-destroying enzymes in paint. Carbon nanotubes are used to securely anchor the enzymes within the solvent. Enzyme filled paints have shown 99% effectiveness at killing bacteria, and are envisioned for hospital use.

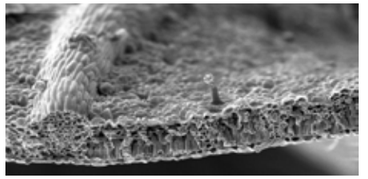
Wolverton, B C. How to Grow Fresh Air: 50 Houseplants that Purify Your Home or Office, Penguin, 1996. IMAGE: Bruce G. Marcot, photographer. www.taos-telecommunity.org

A variety of plants, including ivy, golden pathos, and snake plant are potent toxin remediators. The symbiotic relationship between the plants and root bound microorganism community, coupled with an adsorptive growing medium, such as activated carbon, is effective at removing VOCs from indoor air.



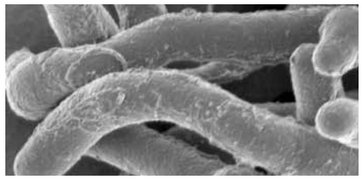
http://grapheneindustries.com/What+is+graphene3F IMAGE: http://www.scientificamerican.com/article.cfm?id=graphene-electronics-mass-production

Graphene is a one-atom thick planar sheet of carbon atoms arranged in hexagons. One of the many future applications for graphene is the development of super sensitive gas sensors. These sensor could be portable allowing for real-time identification of diverse aerosols possible. Currently aerosols are identified in laboratories, or single gasses may be deteced with handheld devices.



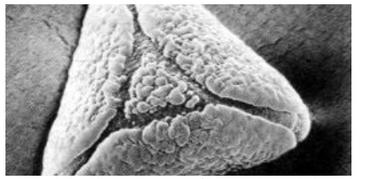
Omar, Antimicrobial activity extracts of eastern North American hardwood trees and relation to traditional medicine, Journal of Ethnopharmacology, Vol. 73, 2000. IMAGE: http://remf.dartmouth.edu/images/botanicalLeafSEM/source/3.html

Several wood species have adapted to resist decay from moisture and biological parasites. Black Walnut wood, nuts, and essential oils all exhibit natural antimicrobial, antifungal, and antiparasitic characteristics. The effective inherent structures that lead to this behaviour are still be identified.



http://www.solutionsiec.com/Microbes.html IMAGE :http://connect.in.com/bioremediation/photos-bolin-bioremediation-jpeg-c01e194df5c64b84.html

Phytoremediation systems leverage the biological processes present in plant-based ecologies to sequester and degrade toxins in soil, water, or air. Communities of microbes located in the plant's root rhizosphere are capable of digesting some toxins and converting them to an energy source for the plant.

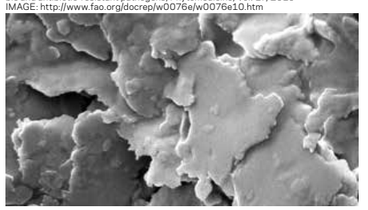


Mulyaningsih, S et all, Synergistic properties of the terpenoids aromadendrene and 1,8-cineole from the essential oil of Eucalyptus golbulus against antibiotic-susceptible and antibiotic-resistant pathogens, Phytomedicine, Vol. 17, 2010 IMAGE: http://www.fao.org/docrep/w0076e/w0076e10.htm

Eucalyptus leaves and oil have long been used for medicinal purposes. Eucalyptus has strong antibacterial and antifungal effectiveness. Eucalyptus is used to treat acne and other skin ailments due to its' antibacterial nature.

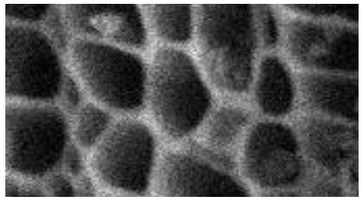
Johnston, W.H. et all, Antimicrobial activity of some Pacific Northwest woods against anaerobic bacteria and yeast, Phytotherapy Research, Vol. 15/7, 2001, IMAGE: http://weblogs.marylandweather.com/2007/10/1000yearold_cedar_topples.html

Cedar is commonly used in steam showers, saunas, and as an exterior building cladding due to it's extreme durability in the presence of moisture. Cedar wood and molecular components (cedrines & nootkanin) are naturally decay resistant and antibacterial.



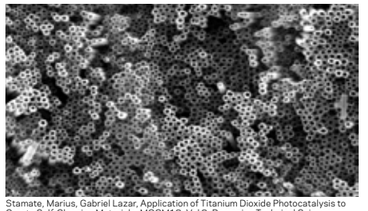
Thomas, Frank, Convincing Clay (Part 1), http://www.strawtec.com.au/page.php?id=39, date accessed: February 16, 2013 IMAGE: http://www.claylab.de/

Bentonite clays are capable of absorbing radiation and are used by scientists as a barrier when working with nuclear materials. Bentonite also has the ability to regulate humidity indoors by absorbing and desorbing moisture within a comfort range of 40 to 70 % RH.



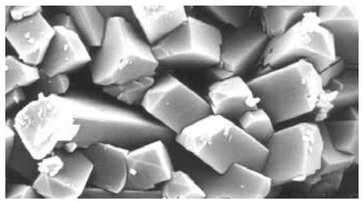
www.calgoncarbon.com/carbon_products/faqs.html
IMAGE: http://www.air-purifier-home.com/aboutCarbon/

Activated carbon is a widely used filtratioin medium from acquarioum filters to respirators. Activated carbon is also used in large-scale toxin clean-up efforts. Activated carbon utilizes its' massive surface area and internal transport and adsorption pores to trap pollutants where they are sequesterd by Van der Waals forces.



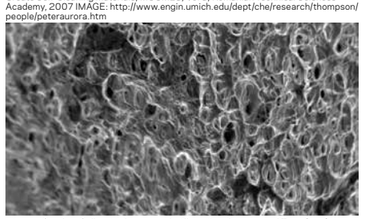
Stamate, Marius, Gabriel Lazar, Application of Titanium Dioxide Photocatalysis to Create Self-Cleaning Materials, MOCM13, Vol 3, Romanian Technical Sciences Academy, 2007 IMAGE: http://www.engin.umich.edu/dept/che/research/thompson/people/peteraurora.htm

The photocatalyst Titanium Dioxide (TiO2) can be used to create superhydro-philic glass, ceramic, or other building surfaces. In the presence of sunlight, TiO2 decomposes organic compounds such as dirt and grease. The by-products are easily removed from the surface with water, and in many applications with rain.



www.molecularsieve.org/Zeolite_Molecular_Sieve.html
IMAGE: http://www.drydenaqua.com/afm/applications/afm_swimming/reports/afm_crushed_glass_sand/biological_aspects/afm_sand_or_zeolites.htm

Zeolites are both natural and synthetic minerals that are commonly used to adsorb unwanted toxins from air, water, and soil. Zeolite's crystalline structure results in subnanometer three-dimensional pores with high adsorption capacity .



Warnes, Sarah L, Callum Highmore, and William Keevil, Horizontal Transfer of Antibiotic Resistance Genes on Abiotic Touch Sufaces: Implications for Public Health, mBio Vol 3, No 6, American Society for Microbiology, November 27 2012. IMAGE: http://www.trincoll.edu/~alehman/photoengr232_06sem.html

Brass, an alloy of copper, naturally destroys infection causing bacteria, leading hospitals to return to the material for door knobs and other hardware in lieu of plastic or stainless steel. Copper and its' alloys prevent disease transmission by both killing the bacteria and preventing their DNA from passing-on drug-resistant mutations.