

Advances in Materials Science for Environmental and Energy Technologies V

Edited by

Tatsuki Ohji

Raghunath Kanakala

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Gary Pickrell

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Ceramic
Transactions
Volume 260



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Contents

Preface	ix
GREEN AND SUSTAINABLE TECHNOLOGIES FOR MATERIALS MANUFACTURING AND PROCESSING	
“Commonization” of Materials: Guilty by Association Marsha S. Bischel, Amy A. Costello, and Tawnya R. Hultgren	3
Experimental Research and Application of Copper Oxide Flotation using the Combined Collectors of Benzohydroxamic Acid and Butyl Xanthate Daixiong Chen, Jun Xiao, Chunming He, and Xiaodong Li	13
Investigation of the Microstructural Evolution between Pellet and Sinter under the Conditions of an Oxygen Blast Furnace Wentao Guo, Qingguo Xue, Long Chen, Yingli Liu, Xuefeng She, and Jingsong Wang	27
Novel Engineered Cementitious Materials by using Class C Fly Ash as a Cementitious Phase M. F. Riyad, M. Fuka, R. Lofthus, Q. Li, N. M. Patel, and S. Gupta	35
Effects of Composition Changes on the Sintering Properties of Novel Steel Slag Ceramics Lihua Zhao, Yu Li, Feng Jiang, and Daqiang Cang	45
Efficiency Gains in Powertrain Components by Molybdenum- Alloyed Special Steels Hardy Mohrbacher	53

Niobium Carbide—An Innovative and Sustainable High-Performance Material for Tooling, Friction and Wear Applications Hardy Mohrbacher, Mathias Woydt, Jef Vleugels, and Shuigen Huang	67
---	----

MATERIALS FOR NUCLEAR APPLICATIONS AND EXTREME ENVIRONMENTS

Microstructure of Yttria Doped Ceria as a Function of Oxalate Co-Precipitation Synthesis Conditions Laurent Brissonneau, Aurore Mathieu, Brigitte Tormos, and Anna Martin-Garin	83
--	----

High Temperature Corrosion of Structural Alloys in Molten Li_2BeF_4 (FLiBe) Salt Guiqui Zheng, David Carpenter, Lin-Wen Hu, and Kumar Sridharan	93
--	----

Crack Initiation due to Liquid Metal Embrittlement for the Steel T91 and Two ODS Steels in Liquid Lead L. Rozumová, F. Di Gabriele, A. Hojná, and H. Hadraba	103
---	-----

NANOTECHNOLOGY FOR ENERGY, ENVIRONMENT, ELECTRONICS, AND INDUSTRY

Stabilization of Nano-Scale Nickel Electro-Catalysts at High Temperature David R. Driscoll and Stephen W. Sofie	115
--	-----

Nanotechnology Advancements and Applications Stephen Miranda	125
---	-----

The Sensing Properties of Fuzzy Carbon Nanotube Based Silica Fibers M. Radetić, P. Cortes, G. Kubas, Jim Cook, Ravi Chandra Reddy Gade, and T. Oder	139
--	-----

Nanomodified Low-Cost Biological Material for the Removal of Heavy Metal Ions L. Rozumová, J. Seidlerova, and I. Safarik	147
---	-----

MATERIALS ISSUES IN NUCLEAR WASTE MANAGEMENT IN THE 21ST CENTURY

Effects of Al_2O_3 , B_2O_3 , Li_2O , Na_2O , and SiO_2 on Nepheline Crystallization in Hanford High Level Waste Glasses Jared O. Kroll, John D. Vienna, and Michael J. Schweiger	161
---	-----

Evolution of Repository, Container, Waste Form Characterization and Design at the Proposed US Disposal System in Volcanic Tuff Rob P. Rechard	171
Effect of Hydration Heat on Iodine Distribution in Gypsum-Additive Calcium Aluminate Cement Tomofumi Sakuragi, Yu Yamashita, and Shigeto Kikuchi	185
MATERIALS AND PROCESSES FOR CO₂ CAPTURE, CONVERSION, AND SEQUESTRATION	
Porphyrin-Based Chemistry for Carbon Capture and Sequestration Lawrence P. Cook, Winnie Wong-Ng, and Greg Brewer	201
Thermal Stability of Novel Multilayer Lanthanum Zirconate Based Thermal Barrier Coatings Xingye Guo, Zhe Lu, Yeon-Gil Jung, Li Li, James Knapp, and Jing Zhang	223
HYBRID ORGANIC-INORGANIC MATERIALS FOR ALTERNATIVE ENERGY	
Electrochemical Properties of Melting Gel Coatings L. C. Klein, A. Degnah, K. Al-Marzoki, G. Rodriguez, A. Jitianu, J. Mosa, and M. Aparicio	235
Author Index	243

Preface

The Materials Science and Technology 2015 Conference and Exhibition (MS&T'15) was held October 4–8, 2015 at the Columbus Convention Center, Columbus, Ohio. One of the major themes of the conference was Environmental and Energy Issues. Twenty papers from six symposia are included in this volume. These symposia include:

- 7th International Symposium on Green and Sustainable Technologies for Materials Manufacturing and Processing
- Materials Issues in Nuclear Waste Management in the 21st Century
- Nanotechnology for Energy, Healthcare and Industry
- Materials and Processes for CO₂ Capture, Conversion, and Sequestration
- Materials Development for Nuclear Applications and Extreme Environments
- Hybrid Organic-Inorganic Materials for Alternative Energy

The success of these symposia and the publication of the proceedings could not have been possible without the support of The American Ceramic Society and other organizers of the program. The program organizers for the above symposia are appreciated. Their assistance, along with that of the session chairs, was invaluable in ensuring the creation of this volume.

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Green and Sustainable Technologies for Materials Manufacturing and Processing

“COMMONIZATION” OF MATERIALS: GUILTY BY ASSOCIATION

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ABSTRACT

As transparency efforts driven by green building requirements move the evaluation of “green” materials and chemicals into the offices of architects and designers and away from scientists, it is important to understand that common, generic terms may not necessarily represent the hazards and risks associated with specific chemicals or materials. Such terms, and the perceptions they create, may negatively exaggerate the actual health-based risks associated with the exposure to a specific product, often via a “guilty by association” mindset. This paper will review requirements that encourage material selection based on chemical content, and will provide examples of common building materials and how generic chemical terms influence market-place decisions.

INTRODUCTION

In 2014, the construction industry accounted for 4% of US GDP;¹ according to a recent report by McGraw Hill Construction, nearly 50% of all buildings in the US are being built to be “green.”² Therefore, trends in this industry segment will have a large impact on the materials science community, which ultimately provides the materials and finishes used in buildings.

In the green building community, there is a growing belief that sustainable buildings should enhance the health and well-being of occupants, resulting in a desire to construct them using “non-toxic” materials.² These factors have driven a movement to have manufacturers publically share the content of construction materials and finishes to levels as low as 1000 or even 100 ppm, with the presumption that such transparency will eliminate all harmful chemicals from the building. For example, Version 4 of the United States Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) Building Rating System, which is arguably the most influential green building rating system in the world, offers credit for selecting products that identify material ingredients to 1000 ppm.³ Common sense and science dictate that the mere presence of a chemical in a product does not necessarily make that product a health risk. Even the most regulated drinking water will contain trace amounts of lead and other heavy metals.

Credits such as the LEED v4 Material Ingredient Credit can inadvertently create fear in the marketplace. The intent of this LEED credit is “to encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts.”³ Yet, most people in the building industry are not scientists and likely do not understand that the mere presence of a chemical in a product does equate to a product health risk. Before jumping on this bandwagon, it is important to remember that chemical risk is a function toxicity, exposure, hazard, dose and time, and is specific to each compound. Toxicity indicates what health problems are associated with various doses or concentrations, and is estimated using two sources of information: 1) any available data on effects on humans, and 2) bioassay experiments. Exposure is an estimate of how much of the chemical a person is likely to eat, drink, or absorb from water, air, or other sources.

Many decisions made to comply with the green ratings systems and requirements are based solely on the potential hazard a chemical poses rather than the actual risk a chemical poses or the risk that is created if the chemical is not utilized. OSHA has stated that hazard determination does not involve an estimation of risk and that the difference between the terms hazard and risk is often poorly understood. OSHA goes on to say that considerable differences may exist in the risk posed by a substance depending on conditions that result in or limit exposure.⁴

An easily grasped example of hazard versus risk involves the hand-held hair dryer. If “hazard” is broadly assumed to be anything that can cause harm, then these devices clearly have inherent hazards associated with their use. If “risk” is considered to be the chance that someone will actually suffer harm, then an example of risk associated with a hand-held dryer would be the risk of being electrocuted if one uses it in standing water, such as a bath tub.

In an effort to simplify the identification of potentially “harmful” chemicals for non-technical specifiers, so-called listings of “chemicals of concerns” (COC’s) have been developed by a wide variety of groups. Such lists are commonly being used by the promoters of healthy buildings. Unfortunately, many of these groups have overly simplified risk and hazard and rely instead on simple lists of broad groups of chemicals that should be avoided. Generally, the worst-case hazard, or “hazard endpoint,” such as “reproductive toxin” or “potential carcinogen” is given, without including information about exposure, dose or toxicity levels. In addition, these COC groupings often link materials together based on a “worst player,” and ultimately target not only problematic chemicals, but ones that are perfectly safe. This “commonization” of materials through the use of generic terms and broad classes can create negative perceptions of whole groups of materials that are not based on sound science, and can ultimately create fear and frustration on the part of end-users and manufacturers.

Generic terms for chemical compounds can be extremely misleading. It is not uncommon for non-scientists to refer to an entire class of related, or even non-related, compounds using a common name. Examples of these include “chlorine,” “antimicrobials,” and “phthalates.” To a scientist, such terms are vague, and often refer to a part of a compound or even a material’s function. However, by using such common, non-exact terms, whole classes of materials are being lumped together and are presumed to be equally dangerous to human health; this phenomenon unfairly targets many safe materials. For instance sodium chloride (table salt) and chlorine gas are two extremely different compounds, but both could be listed as chlorine-containing substances; only the latter is generally considered to be dangerous.

In 2008, the United States passed legislation prohibiting the manufacture, sale, distribution, or import of any children’s toy or child care article that contains concentrations of more than 0.1 percent of three (3) specific phthalate-based plasticizers due to concerns about their toxicity and ability to bioaccumulate. Although parts of the ban apply only to items that can be placed in the mouth and be sucked or chewed^{5,6} the details are often overlooked. This lack of addressing the specific risk associated with exposure via oral ingestion, combined with the use of the generic term “phthalate” has penalized other products which contain other phthalate-based chemicals, since opponents assume that all phthalates are harmful via any route of exposure or contact. Although the use of these chemicals in building materials does not pose a health risk since there is no route for ingestion-based exposure, by using the common term “phthalate,” all chemicals in the family become suspect.

By focusing too narrowly on a presumed health risk and a specific product function, it is possible that other benefits to building occupants or consumers are not being considered. For example, some green building schemes, including LEED V4, frown upon the addition of all antimicrobial compounds out of fears that we are unnecessarily using chemicals that will result in

microbes that are resistant to modern medicines. While specific antimicrobial agents have been linked to such resistance, the use of a common term based on a material’s function has created the perception that all antimicrobial substances are problematic and should be avoided. However, when these compounds are eliminated, the risks of mold and bacteria growing on materials greatly increases, the material life span can be reduced, and germs and harmful bacteria may be more easily spread. In general, the effort to eliminate a few “dangerous” compounds is not accounting for such holistic trade-offs.

Finally, titanium dioxide is an example of a commonly used material that is simultaneously considered “dangerous” by some and beneficial by others. The fine dust forms of titanium dioxide have been listed as possible carcinogens by IARC, yet other forms are approved for use in cosmetics, food and other products due to its low risk to human health. It is a well-known UV-blocking substance widely used in sunscreens, and has documented antimicrobial properties, both of which enhance human health. It has other beneficial uses in sustainable buildings as well, but none of these can be realized if the material is avoided due to a specific, narrowly defined health risk associated with only one form.

Although these trends towards transparency and simplifying chemical risks are global, the examples discussed here will pertain to the US market. The impacts of commonization by chemical family, function and form will be addressed.

GUILTY BY CHEMICAL FAMILY: “PHTHALATES”

One example where an entire family of chemicals is now perceived by some to be unsafe based on the issues of a few specific chemicals is the case of phthalate esters or “phthalates.” “Phthalates” are a class of synthetic chemicals with a broad spectrum of uses including softeners in plastics, solvents in perfumes, and additives to nail polish, as well as in lubricants and insect repellents. Polyethylene terephthalate (PET) is one of the most commonly used polymers in the world, used to make polyester fibers and clear plastic bottles, among other things. However, when people use the generic term “phthalate,” they not generally referring to terephthalates but to dialkyl ortho-phthalates, which are a class of about 30 commercial chemicals; these ortho-phthalates are used primarily as plasticizers for polyvinyl chloride (PVC) and as solvents.

In February 2009, three types of ortho-phthalates were permanently banned from use in children’s toys and child care articles in the US: di (2-ethylhexyl) phthalate (DEHP); dibutyl phthalate (DBP); and butyl benzyl phthalate (BBP). The US Consumer Product Safety Improvement Act (“CPSIA”) of 2008 prohibits the manufacture, sale, distributions, or import into the United States any children’s toy or child care article used for feeding or teething that contains concentrations of more than 0.1 percent of DEHP, DBP, or BBP. Three additional phthalates were “interim banned:” diisononyl phthalate (DINP); diisodecyl phthalate (DIDP); and di-n-octylphthalate (DnOP).^{5,6} The permanent CPSIA ban applies to children’s toys and to child care items that can be brought to the mouth by a child so that it can be sucked and chewed. The interim ban applies only if the toy or toy part can be placed in the mouth; if it can only be licked, then it is not considered as being able to be “placed in mouth.”⁶ Yet, the later part of this requirement – must be able to be sucked and chewed – is usually not mentioned.

Furthermore, to assume that because these chemicals are harmful in children’s toys they must be harmful in all products is not accurate. For example, for a child to be exposed to DEHP in a toy they must chew or suck on it for lengthy periods of time. In fact, the CSPC specifically states that the ban does not apply to components of children’s toys that are inaccessible, nor to children’s socks, shoes, and packaging for toys or feeding items.⁶ These same chemicals used in building materials, such as carpets or floors, do not pose a risk, because there is no route for oral exposure. However, many manufacturers have moved away from the use of ortho-phthalates due

to market demand. Other chemically different members of the phthalate family, such as PET, have been widely tested and are generally considered to be safe for human use.

But, for many people, the fact that a few specific phthalates have been banned from being used in a limited number of specific types of products has translated into a belief that all phthalates should be universally banned. As a result, products which contain other chemicals in this family are penalized because of the negative association with the term “phthalate,” even though they are not part of the ban. The CPSC even states that children’s items may contain other non-banned phthalates, which should suggest that other phthalates are safe to use.⁶ Thus, by using a generic chemical term, an entire family of chemicals has been given a “bad reputation,” even though the hazards are associated with a limited number of specific compounds.

GUILTY BY FUNCTION: “ANTIMICROBIAL” COMPOUNDS

So-called “antimicrobial” compounds are another example whereby a large number of materials have been lumped together as being dangerous. In this case, the determination has been made based on the function of the material, i.e., the ability to inhibit the growth of microbes, rather than by chemical classification. Indeed, antimicrobial products make use of a wide variety of organic and inorganic compounds, some of which are man-made, and some of which are naturally occurring. Discouraging, or even banning, the use of all “antimicrobials” without consideration of their actual chemistry in an effort to reduce the potential for drug-resistant microbes is reactionary and is frequently not based on good science.

Many of the concerns and issues surrounding antimicrobials may again be attributed to not understanding the complete risk assessment of specific chemicals. Antimicrobial use has increased dramatically, with at least 275 chemicals now registered with the US EPA.⁷ As an example, Triclosan is a synthetic broad-spectrum antimicrobial that was first registered with the EPA as a pesticide in 1969.⁸ In recent years, evidence of Triclosan (and other antimicrobials) has been found throughout our environment including in water, soil, breast milk, and urine. Due to the amount of Triclosan in the environment and its ability to bioaccumulate, there have been many questions raised regarding the impacts Triclosan and other antimicrobials may have on the environment and human health. These questions have resulted in the discouragement or even banning of numerous antimicrobials in green buildings without an understanding the risk or benefit of the specific chemicals, presuming that all are “guilty” simply based on their ability to kill microbes.

In many cases there is no proven benefit to adding antimicrobials to consumer goods or building products. However, for many years this was deemed to be a best practice for controlling microbial growth, and was an attribute requested by customers; as a result, in many cases antimicrobials were overused. Now the pendulum is beginning to swing the other way, and there is a movement to ban all use of antimicrobials, even though there is currently no true scientific understanding of the actual environmental and health impacts of many members of this broad group of unrelated materials.

However, there are cases in which there truly is a need for antimicrobials, such as in healthcare facilities treating individuals with compromised immune systems. And although many consumer products lack clear evidence that antimicrobial addition is beneficial, in 1997 the FDA studied Triclosan in toothpaste and found that it was effective in preventing gingivitis.⁹ This is an example of an instance where we may cause more harm by NOT using antimicrobials.

Perhaps the most glaring example of harm that could occur by not using antimicrobials is in hospital settings. A report based on hospital infections in Pennsylvania estimates that in the US in 2006 there were approximately 720,000 hospital acquired infections, resulting in 74,000

deaths, and \$125 billion in additional health care costs.^{10,11} And yet, motivated by legitimate fears of creating anti-bacterial resistant microbes, some hospitals and the USGBC are now encouraging the elimination of antimicrobials from buildings. However, the use of antimicrobial compounds in materials that are frequently touched and that are difficult to clear is known to be an effective means of reducing the transmission of infectious disease.

In addition to organic substances, including Triclosan, inorganic materials have also been shown to have antimicrobial properties. These include copper and silver, both of which have been used for over a century to control microbial growth. Copper alloys, such as brass and bronze, have also been shown to prevent the spread of microbes in healthcare facilities.

Initial research indicates that clean, uncoated copper surfaces are perpetually able to kill certain microbes that come in contact with the metal surface; thus, copper appears to be a “self-sanitizing” compound. For example, the use of copper in hospitals on specific surfaces such as toilet seats, faucet handles and door plates has been shown to reduce the amount of three specific types of microbes by 90 -100% as compared to the control fixtures, made of plastic, chrome-plated metals, or aluminum.¹⁰ In another study, a consulting room was retrofitted with copper in areas of high patient contact. Over six months, 71% of the bacterial load was reduced. A study from 1983 showed that the use of copper and bronze doorknobs prevented the spread of microbes in hospitals.¹² However, the use of copper fixtures is banned from LEED V4.³ This is despite any firm evidence showing that copper leads to the development of drug-resistant microbes.

Silver has also been shown to be highly effective at killing microbes. There is a long history of applying silver compounds directly to wounds; this practice is being resurrected to avoid the use of antibiotics, which have clearly been linked to the rise of so-called “super bugs.”¹³ Other recent research suggests that the addition of small amounts of silver to other drugs can greatly enhance the efficacy of those drugs in killing microbes, increasing the number of bacteria killed by 10 to 1000 times.¹⁴ Silver does have some documented toxicity issues: there have been documented cases of silver-resistant bacteria,¹³ and silver coatings were shown to be toxic to heart tissue when used in heart valves. It can also cause the skin to permanently turn blue-gray.¹⁴ However, outright bans of antimicrobials do not address the potential benefits in reducing the number of fatal infections in healthcare facilities.

Beyond the control of infectious disease, there are reasons to use materials containing antimicrobials in healthcare settings, specifically in porous substances used for sound control. Numerous studies have shown that modern hospitals are extremely noisy, and that this noise has a negative impact on patients, as well as staff. For example, studies have shown that the addition of sound absorbing materials to healthcare spaces can dramatically improve the acoustical quality of the space, directly resulting in reduced patient pain and stress, improved sleep, and reduced medical errors. Ultimately, all of these contribute to improved patient recovery rates.^{15,16}

However, many of the best materials for correcting ambient noise issues are open, porous materials.¹⁶ Because mold and bacteria can grow in these materials, due to their inability to be easily cleaned, they cannot be considered for use in healthcare settings unless they are treated. But guidelines put out by several healthcare organizations limit the use of antimicrobials in building products. By limiting the ability of manufacturers to add antimicrobial agents to porous products, it becomes even more difficult to justify the use of these acoustical absorbers in healthcare settings, potentially causing documented, negative impacts on patients due to increased noise.

Moving beyond applications in healthcare, there are valid uses for antimicrobial substances in other arenas that may not be immediately obvious to non-technical end users. For example, manufacturers may add these substances to enhance processability, for example

extending the time during which a paint or binder is able to be used before it is attacked by microbes (i.e., spoils) and needs to be disposed of. Thus the use of small amounts of specific antimicrobials can avoid the generation of unnecessary waste, and the associated environmental impacts.

Manufacturers may also add specific antimicrobials to give final products particular functions. Again, the addition of small amounts to paints helps to ensure the long-term stability and durability of the paint and the surfaces below.¹⁷ However, adding these substances to items that are cleaned regularly, such as clothing or flooring, is not functionally necessary, and could cause more harm than good. In such cases, responsible manufacturers should be assessing all the potential risks associated with the use of antimicrobial agents and using them only when the benefits outweigh the risks.

Research is also being conducted into ways of incorporating antimicrobials into coatings in such a way that they continue to inhibit the growth of microbes, but remain safe for humans. Examples include the addition of silver to zeolites, glass, epoxies and other materials.¹⁷

Understanding all of the risks should naturally lead to a discussion of the potential trade-offs involved with using or avoiding specific antimicrobials. However, banning entire classes of materials solely due to function is not a holistic perspective, and can result in harm being done, or benefits not being realized. It also avoids addressing the risks associated with specific chemicals, instead broadly implying that all members of the category are problematic simply based on one of the functions.

GUILTY BY FORM: TITANIUM DIOXIDE

A specific example of the importance of understanding the entire risk equation is titanium dioxide. Titanium dioxide is used to whiten many products, from food to building materials. The US Centers for Disease Control lists respirable titanium dioxide particles, i.e. dust, as an occupational carcinogen and IARC lists the powdered form as possibly carcinogenic to humans. Yet at the same time, the US FDA allows the use of titanium dioxide in cosmetics and in food products, in quantities up to 1% by weight of the food.¹⁸ The EPA Safer Choices (formerly Design for the Environment) program considers titanium dioxide to be a “material of verified low concern.”¹⁹ So without an understanding of the entire risk equation, including the chemical form, it is easy to understand the confusion that arises when one is told in one instance that the substance is a carcinogen and in another, it is safe.

To clarify the carcinogen classification, it is important to understand that the IARC listing is related specifically to findings that fine and ultrafine powders were found to cause respiratory cancers in rats. This led to concern that workers exposed to high levels of dust could be at risk, and the subsequent listing as a possible carcinogen.²⁰ When used in foods, cosmetics and other products, in the appropriate amounts, the dose and routes of exposure are not ones by which humans can be harmed. Thus the form of this chemical is key to its safety or risks.

In addition, any assumptions that all forms of titanium dioxide are dangerous fail to acknowledge many known benefits for this common material. Beyond its ability to whiten cosmetics, titanium dioxide is a well-known, effective UV-blocking additive used in many sunscreens²¹ and other sun-blocking cosmetics. Thus, while the loose particulate form of TiO₂ is considered a carcinogen, it is also a key ingredient in a product known to reduce the instances of skin cancers.

Within the building products industry, titanium dioxide has traditionally been used as a filler in many architectural materials due to its very high light refractive index (2.7 for the rutile form); the addition of titanium dioxide can consequently increase the light reflectance of the finish. This in turn has been shown to increase the effectiveness of natural light within a space,

lowering the need for lighting, thereby reducing energy usage.^{22,23,24} Many of the sustainable building schemes recognize the use of highly reflective surfaces as a strategy for enhancing daylighting and lowering energy costs and the associated environmental impacts. Increased regulation of green house gasses emitted from power plants will likely increase the desire for products that contribute to reductions in energy usage, making the use of highly reflective surfaces that incorporate TiO₂ even more desirable.

Newer uses for titanium dioxide in construction products include self-cleaning surfaces, which take advantage of the super-hydrophilic properties of the material;²⁵ the use of these in architectural finishes would lower or negate the use of cleaners, potentially reducing exposure of occupants to these chemicals. In exterior applications, it could be used to help keep daylight harvesting surfaces, such as solar cells and windows, clean.

In addition, titanium dioxide has beneficial photo-catalytic properties that are being exploited in a number of ways to improve the built environment.²⁵ ALCOA and others have developed architectural coatings which oxidize harmful nitrous oxide (NO_x) fumes and turn them into nitrides;^{26,27} others have used the same principles to create “smog-eating” roof tiles and other surfaces.^{28,29} These products have the potential to use existing surfaces to reduce the generation of harmful smog in the environment.

Finally, the anatase form of titanium dioxide has been shown to be an anti-bacterial substance that is activated by UV light, creating the potential for surfaces that can sterilize themselves in the presence of light.^{25,30} The use of this property in medical facilities and other areas is being investigated.

Thus, while titanium dioxide can be a potential carcinogen in certain situations related primarily to the generation of dust during manufacturing, it can also be used with minimal risk to humans, as evidenced by its approval for use in food and cosmetics. Furthermore, it can actually be used to improve the indoor environmental quality of buildings and the health of humans. It can also reduce the environmental impacts of buildings through various mechanisms, including energy reduction. Thus, although different forms of this material have different hazards, there are some who are assuming that all forms are problematic based on the listing of the dust. Indeed in many of the new transparency requirements and lists of chemicals of concern, only the hazard end-point of “potential carcinogen” would be listed, despite the fact that this classification, in this case, is for a narrowly defined form of titanium dioxide. Again such broad groupings, in this case ignoring form, can ignore the potential benefits associated with other, non-hazardous forms.

TRADE-OFFS

Trade-offs such as those associated with antimicrobials and titanium dioxide are frequently not being addressed by those advocating the elimination of chemicals to improve the health of building occupants. Instead, it is likely that a non-scientist would see that LEED credits that encourage the avoidance of antimicrobials are “proof” that any material that can kill microbes should be avoided. Similarly, they might see that TiO₂ is a possible carcinogen and leap to the conclusion that it should be avoided as a “toxic” chemical. Indeed, the internet is full of articles and blogs asking such questions as whether one’s lipstick, hand wash, toothpaste or sunscreen is causing health issues due to the presence of titanium dioxide or antimicrobial chemicals.

In addition to balancing the trade-offs between a material’s beneficial properties and potential hazards and risks, manufacturers face other trade-offs. These include costs, both in using alternate materials, including things such as capital investment and availability of materials, and productivity losses, due for example to spoiled paint. There can also be a lack of

“Commonization” of Materials: Guilty by Association

non-toxic alternatives; even the US EPA’s Safer Choice program recognizes that in some cases there may be hazards associated with some of the chemicals that are currently “best options.”

However, by referring to generic lists of potentially problematic materials, commonization is resulting in a situation whereby these trade-offs are generally not considered. As a consequence, some beneficial and safe products can be overlooked or omitted from use in buildings and other products.

MARKETPLACE FRUSTRATIONS

Today’s climate for increasing transparency, while well intended, is creating frustration for manufactures and consumers alike. For manufacturers, much of this frustration can be linked to the difficulty in obtaining and then conveying highly technical information around chemical content and risk to their customers and stakeholders. For consumers, much of the frustration can be linked to a lack of easy-to-understand information, resulting in difficulties in assessing risks and comparing products.

Efforts to simplify such information for non-technical audiences have been made. In some cases, the use of generic terms, such as “antimicrobial” or “phthalate” have helped lead to these cases of “commonization” and have allowed perfectly safe chemicals to be assumed to be health hazards. Indeed, several of the earliest influential “red lists” of so-called toxic chemicals were primarily lists of generic families or functions, helping to propagate the issues associated with commonization. Updated programs tend to have summary lists which contain generic terms, but these are generally now expandable into more detailed lists that include specific CAS numbers, etc. However, if someone merely scans the summary lists, the commonization effect is still applicable. Additionally, the ability to thoroughly comprehend the chemical and toxicity information associated with each chemical requires a reasonably scientific background, and most consumers do not have this skill set.

While manufacturers and consumers would both like easy-to-understand ways to assess the true risks associated with products, there is currently no easy solution. And the current trend of requiring chemical transparency to lower and lower trace levels is likely to only add to the confusion and resulting frustration.

CONCLUSIONS:

As transparency requirements in building products becomes more widespread and stringent, manufacturers and consumers alike will continue to face issues related to the evaluation and understanding of a material’s true risk. Efforts to simplify the transparency process have resulted in the misuse of generic terms for chemicals and materials. This commonization often oversimplifies or takes the place of a complete and thorough chemical evaluation and may misrepresent a chemical.

True risk assessments for chemicals should be based on the end-use and include consideration of exposure route, duration of exposure, and dose. Exposure is rarely being considered by the current schemes for evaluating chemicals, but it plays a vital role in understanding risk. These assessments should also compare costs, benefits and hazards of using the material. For building materials, such cost-value assessments should include the impact on the total indoor environmental quality and health of the occupants, the impact on the building’s environmental profile, and other pertinent factors, such as manufacturability and availability of alternatives.

This commonization of materials based on chemical family, function or form has resulted in many safe materials being perceived by the public as potentially toxic. In some instances, this

misconception has resulted in the green building schemes avoiding or banning whole groups of materials. These decisions tend not to have addressed a holistic, scientific assessment of the benefits and risks associated with specific materials and finished goods.

Attempts to simplify transparency have led to many misinformed decisions regarding the appropriate use of a specific chemical or products containing these chemicals. Just as the industry has adopted comprehensive life cycle analyses, ultimately allowing for the creation of environmental product declarations that attempt to address all of the environmental impacts and phases of a product, there needs to be a clear way to perform a similar assessment of a product's true impact on human health and well-being. Such systems need to be chemical and product specific, and consider the holistic impacts rather than use common terms for chemical family, function or form. They need to be based on internationally recognized, consensus-based standards that give guidance on how to evaluate the hazards, risks and benefits of specific materials, similar to the ISO suite of standards that were developed to for creating life cycle assessments.

In short, scientists need to actively steer the industry away from a system that utilizes over-simplified lists to one that assesses the true, holistic risk associated with the use of a specific chemical in a specific product. Only then will we move away from a market in which products can be guilty merely by association to one in which well-informed, science-based decisions can be made.

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EXPERIMENTAL RESEARCH AND APPLICATION OF COPPER OXIDE FLOTATION USING THE COMBINED COLLECTORS OF BENZOHYDROXAMIC ACID AND BUTYL XANTHATE

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ABSTRACT

Benzohydroxamic acid with double dentate can combine with copper and form cyclic hydroxyl oxime acid copper chelate, so it has good recovering capability and selectivity for copper oxide minerals, especially for malachite. The flotation results of the pure mineral malachite show that the strongest synergistic collecting effect between hydroxamic acid and xanthate can be generated with the highest malachite recovery of 95.5% when certain sodium sulphide is used as vulcanizing agent in the optimal pH range and the best ratio of hydroxamic acid to xanthate is 3.5:1. In the refractory real ore flotation experiments, due to the synergistic collecting effect, the flotation recovery of malachite can reach to over 92% under the condition of optimum proportion, increasing 12% compared with the conventional collectors. In industrial production, the flotation indexes of the copper grade are high, and the copper oxide resource is utilized with high efficiency.

INTRODUCTION

Beneficiation of copper oxide ore is one of the recognized puzzles in mineral processing industry, and it is also the important research field for dressing workers. Copper oxide ore is the vital component of copper resource in the world, which has abundant reserves. Majority of sulphide deposits have oxidized zone on the top, and some oxidation deposits are oxidized to become the large and medium-sized oxidation deposits [1]. However, most copper oxide ores have the problems such as high slime, poor floatability, complex ore property and low flotation recovery, so it is of great significance in beneficiation of copper oxide ore to develop an efficient collector for copper oxide ore especially for malachite[2~4]. At present, sulfuration-xanthate

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