POST-PANDEMIC EMPHASIS ON HYGIENE – CERAMIC TILE AND TEST METHODS

Dr. Jyothi Rangineni

Organization: Tile Council of North America (TCNA)

ABSTRACT

The most disruptive event of a generation, the COVID-19 pandemic will have serious implications for many areas of the built environment, forcing people to adapt, without notice or exception. Spaces that promote personal safety and wellbeing and that prevent transmission and spread of disease are becoming a priority.

Architects and designers are already inquiring about building materials that are better suited for built environments in the post-pandemic era. Understandably, surfaces that are naturally resistant to microorganisms and easy to clean and sanitize, while at the same time aesthetically pleasing, are preferred. As such, the addition of antimicrobial coatings—coatings that kill, resist, and inhibit the growth of microorganisms (i.e., coatings with antimicrobial efficacy)—to already popular materials is receiving a lot of attention.

How can surfacing materials be appropriately selected in a post-pandemic world? It is becoming increasingly important that products be tested for resistance to microorganism growth and that the efficacy of antimicrobial coatings be evaluated. In the world of standardization, this is a huge challenge. Different kinds of building materials cannot be evaluated by a single method, and each individual microorganism has its own unique testing requirements. For example, the COVID-19 causing SARS-CoV-2 virus is extremely pathogenic and cannot be used in normal laboratory settings because of exposure risk.

In such cases, appropriate surrogates must be identified. Furthermore, different materials being evaluated may require differing conditions that do not unrealistically and unintentionally stress the test microorganisms. Such stress can lead to incorrect and misleading results that may indicate efficacy, but under conditions that do not simulate real world effects. External factors such as temperature, humidity, and light can play a major frole in the outcome of the testing.

While many existing microbiological test methods can be applied to various materials, very few specifically apply to ceramic tile including test methods intended for plastics and fabrics.

TCNA is heavily involved in the development of standards and test methods for evaluating the microbiological properties of ceramic tile surfaces and has conducted research on a variety of bacteria and viruses as a result of the COVID-19 pandemic. This paper details challenges with applying existing microbiological test methods to ceramic tile. It also explains ongoing research and efforts into methods better suited for ceramic tile, specifically toward standardized testing protocols for determining surface antimicrobial properties and assessing the survivability of microorganisms.

1. INTRODUCTION:

Many examples exist in history where the built environment has been shaped by diseases, their spread and effect. In the 14th century, bubonic plague motivated the fundamental urban improvements of the Renaissance. Cities cleared overcrowded living quarters, developed early quarantine facilities, and opened large public spaces (Chang, 2020; Lubell, 2020). During the industrial era, cholera and typhoid influenced the sanitary reform movement. These epidemics contributed to developing water and sewage systems to fight pathogens, leading to sanitary innovations, and the third plague pandemic in 1855 changed the design of everything from drainpipes to door thresholds and building foundations (Budds, 2020; Klaus, 2020; Wainwright, 2020). More recently, the wipe-clean aesthetic of modernism can be partially attributed to tuberculosis: buildings began including large windows, balconies, and flat surfaces that could be easily cleaned, and white paint, which emphasized the appearance of cleanliness grew in popularity (Budds, 2020; Chang, 2020).

Against this background, the current health crisis should lead to the development of built environments with measures that will help to prevent the spread of infections and diseases.

When the World Health Organization (WHO) declared COVID-19 as a pandemic, citizens around the globe hastened to go home. In addition to significantly influencing personal and professional lives, the global pandemic had a direct bearing upon the very foundations of urban planning and the theory and practice of architecture (Allam & Jones, 2020; Haleem et al, 2020; Saadat et al., 2020).

Architects and designers are now facing many challenges and questions when designing interiors that not only limit transmission and spread, but also aid in reducing transmission and provide an additional layer of disease prevention to make interior spaces as risk free and safe as possible. The solutions to these challenges will guide post-pandemic architecture into the future.

From the perspective of material utilization, the questions and challenges that architects and designers face can be broadly categorized as follows:

- Post-pandemic public spaces - There is no doubt that COVID-19 will impact future public buildings and spaces. However, how long will this impact last? What about furniture materials, shared facilities, and services? Broadly stated, what is the future of commercial building?

- Post-pandemic housing - What is the future of residential building? Should residences be adapted to better accommodate workspaces? Should they be self-sufficient? More specifically, could COVID-19 be a catalyst for healthy housing and sustainable buildings?

- Post-pandemic office space - What is the future of co-working spaces and open-plan offices? Will they need new design criteria? What is the future for high-rise building? What happens when nobody wants to use elevators?

The ongoing pandemic has already taught us several crucial lessons, which we should consider when designing future antiviral and antimicrobial materials. Perhaps the most relevant lesson is the outsized role everyday material surfaces have in virus transmission [Sun, 2020]. Droplets and aerosols released during coughing or sneezing are deposited on material surfaces, where the Coronavirus can survive for substantially longer periods than other viruses [Van Doremalen, 2020]. Touching virus-contaminated surfaces and then mouth or eyes has now been widely accepted as one of the more probable mechanisms for viral infection.

There will be a special effort to consider every possible place within the built environment touched by people and the possibility of virus transmission. Contemporary designers are likely to use hygienic materials that can be easily sanitized, and post-pandemic architecture will likely include cleaning strategies based on new technologies, such as antimicrobial materials that are self-cleaning and exhibit residual antimicrobial activity.

1. AMBIGUITY IN THE TERM "ANTIMICROBIAL"

Basically, anything that can cause a negative impact on microorganisms can be called "antimicrobial". As such, the spectrum of products labeled antimicrobial exhibit a range of activity, as shown in the figure below:

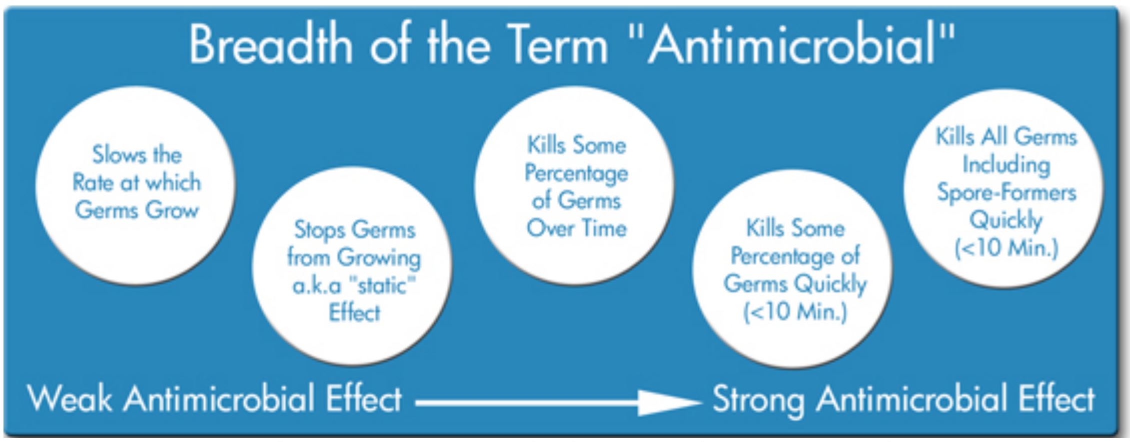

***Figure 1**: Antimicrobial activity (Tanner, 2014)*

So, for products labeled as antimicrobial, what kind of antimicrobial properties do such products possess? How to determine the efficacy of such products? What are the testing criteria that need to be established and which microorganisms to choose? These are only a few of the many questions that arise when considering methodologies for testing the efficacy of antimicrobial building materials.

2. ANTIMICROBIAL TEST METHODS

Many antimicrobial test methods are currently available for the assessment of antimicrobial activity. However, there is a lack of methods that have been specifically developed for building materials.

When it comes to antimicrobial efficacy, "one method for all" cannot be the approach for testing building materials likely to be in contact with building occupants. There are many criteria that have to be considered, discussed below are some of the most relevant.

3. MATERIAL POROSITY:

Commonly microorganisms being tested are applied in a liquid medium. In the case of porous materials like carpet or cork, the liquid containing the microbes will be absorbed into the material. In such a case, the method of recovery should include robust retrieval such as sonication to make sure all the surviving microbes are recovered. On non-porous surfaces, especially those that are hydrophobic (such as most ceramic tiles), their inherently dry nature can lead to sample dehydration, which can result in the death of the microbes invalidating any measure of a potentially antimicrobial surface.

4. ANTIMICROBIAL AGENT:

The nature of the antimicrobial agent will determine the methodology for its testing. For example, some antimicrobial surfaces require activation by ultraviolet irradiation, while others need to be "charged" by a frictional force. For antimicrobials that have long lasting or residual antimicrobial activity, the surface may need to be reloaded with microorganisms at regular intervals. In every testing scenario, the nature of the antimicrobial agent needs to be closely evaluated, sometimes through trial and error, to arrive at a testing protocol that effectively evaluates its efficacy.

5. ENVIRONMENTAL CONDITIONS:

The testing conditions should reflect the real-life application of the product being tested. Issues of humidity, film thickness, lighting, and temperature all must be considered and certainly they will differ between interior and exterior applications.

6. CONTACT TIME:

How long should the microbe be allowed to be in contact with the surface? This depends upon the product and its antimicrobial agent. One specific time point cannot be used for all materials. Rather, samples should be taken across broad spectrum of contact times considering whether the agent is intended to be fast-acting or efficacious over a longer time.

7. WHICH MICROORGANISM TO CHOOSE?

This is an important criterion that requires a good understanding of the diseases under consideration and whether such are caused by viruses, bacteria or fungi.

Most viruses are exceedingly small (20 – 200 nanometers in diameter) and consist of little more than a small piece of genetic material surrounded by a thin protein coating. Some viruses are also surrounded by a thin, fatty envelope. Viruses are different from all other infectious microorganisms because they are the only group of microorganisms that cannot replicate outside of a host cell but can survive outside of a host cell.

Bacteria are ten to 100 times larger than viruses. Most bacteria consist of a ring of DNA surrounded by cellular machinery, all contained within a fatty membrane. They acquire energy from the same essential sources as humans, including sugars, proteins, and fats. Some bacteria live and multiply in the environment while others are adapted to life within human or animal hosts. Some bacteria can double in number every fifteen minutes, while others take weeks or months to multiply. Bacteria cause many types of diseases, ranging from mild skin irritation to lethal pneumonia.

Fungi are diverse in terms of their shape, size and means of infecting humans. Fungi are eukaryotes, meaning their cells have a true nucleus and complex internal structures. They are most commonly found as environmentally resistant spores and molds.

As these three types of microorganisms are very different, structurally, and physiologically, antimicrobial test methods should also be different for viruses, bacteria and fungi. One cannot be substituted for the other; for example, a bacterial technique cannot be applied for fungi or vice versa.

Additionally, even within the three broad categories described above, microorganisms differ from one another. A test conducted using one specific microorganism cannot be correlated to another microorganism within the same category. For example, a test result using a flu virus does not necessarily predict a result using the COVID-19 causing coronavirus. While indicator organisms exist that can give a general efficacy expectation, evaluating activity against an individual microorganism is the most accurate way of making an antimicrobial assessment for that microorganism. However, not all disease-causing microorganisms can be practically used for testing due to risks to users and technicians handling them. In such cases, surrogates or those microorganisms that are very similar to the pathogens, but do not pose the same risk, should be identified.

From all the above, it becomes evident that method selection and/or development for ceramic tile surfaces is a complex process and requires high expertise. In this context, all testing results need to be considered specifically in the context of a clearly delineated testing protocol.[1]

8. EXISTING METHODS FOR ASSESSMENT OF CERAMIC TILE SURFACES

While many methods exist for assessment of antimicrobial surfaces, there are a very limited number of methods available specific for ceramic surfaces. Below is the list of methods that are currently available for ceramic surfaces:

- ISO 17721-1:2021 Quantitative determination of antibacterial activity of ceramic tile surfaces — Test methods — Part 1: Ceramic tile surfaces with incorporated antibacterial agents.
- ISO 17721-2:2021 Quantitative determination of antibacterial activity of ceramic tile surfaces — Test methods — Part 2: Ceramic tile surfaces with incorporated photocatalytic antibacterial agents
- ASTM E3031 Standard Practice for Determination of Antibacterial Activity on Ceramic Surfaces

[1] TCNA leads several efforts by the International Standards Organization (ISO) and American Society for Testing and Materials (ASTM) for the development of standards and test methods for evaluating the microbiological properties of ceramic tile surfaces and has conducted research on a variety of bacteria and viruses as a result of the COVID-19 pandemic.

ISO 17721, parts 1 and 2 are recently published standards that were developed by ISO TC 189, the technical committee for ceramic tiles. The standards are for the assessment of antibacterial activity using gram-positive and gram-negative indicator bacteria. The methods allow for other bacteria to be chosen for testing and also allow for different contact/exposure times to be assessed. ASTM E3031 tests the efficacy of antimicrobial ceramic surfaces using a single indicator bacterium and a single contact time of 24 hours.

9. OTHER EXISTING METHODS

Due to the lack of methods specific to ceramic tile, methods that were developed for other materials are being widely used for testing the antimicrobial efficacy of ceramic surfaces, although with limitations. Listed below are the more common of such methods.

10. ANTIVIRAL:

- ISO 21702:2019 Measurement of antiviral activity on plastics and other non-porous surfaces.
- ISO 18071:2016 Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of antiviral activity of semiconducting photocatalytic materials under indoor lighting environment — Test method using bacteriophage Q-beta.
- ISO 18184 :2019 Textiles — Determination of antiviral activity of textile products.

11. ANTIBACTERIAL:

- ISO 22196:2011 Measurement of antibacterial activity on plastics and other non-porous surfaces.
- ISO 27447: 2019 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for antibacterial activity of semiconducting photocatalytic materials.
- ISO 20743:2013 Textiles — Determination of antibacterial activity of textile products.
- JIS Z 2801 Test for Antimicrobial Activity of Plastics.
- ASTM E2149 Standard Test Method for Determining the Antimicrobial Activity of Immobilized Antimicrobial Agents Under Dynamic Contact Conditions.
- ASTM E2180 Standard test Method for Determining the Activity of Incorporated Antimicrobial Agents in Polymeric or Hydrophobic Materials.

12. ANTIFUNGAL:

- ISO 13125:2013 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for antifungal activity of semiconducting photocatalytic materials.
- ASTM G21 - 15(2021) e1 Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.

13. STANDARDS BODIES DEVELOPING NEW TEST METHODS:

Listed below are the standards bodies currently active in developing test methods to assess antimicrobial activity using ceramic tile surfaces:

- ISO TC 189, Ceramic Tiles: New work proposals being submitted for the development of antiviral and antifungal test methods for ceramic tile surfaces.
- ISO TC 330, Surfaces with biocidal and antimicrobial properties: New technical committee whose scope covers the standardization of test methods used to assess the biocidal performance and efficacy of any surfaces with antimicrobial activities, including their compatibility with different families of disinfectants and cleaning agents.
- ASTM: Development of antiviral test methods for porous and non-porous surfaces. Additional test methods to determine the survivability of viruses on interior furnishings and finishes.

14. SUMMARY

From the review detailed above, it is clear that methods that address the antimicrobial properties of ceramic tile surfaces are few, and many other methods that are being used are not well-adapted to ceramic tile testing. Though some methods for ceramic tile surfaces have now been developed, many other methods are needed. For example, test methods for a variety of microorganisms are yet to be developed, as well as methods to evaluate different antimicrobial agents, or methods that consider a variety of means to activate antimicrobial properties (UV light, visible light, etc.). As the world adapts to a new emphasis on health and safety, these methods and those already developed for ceramic surfaces will help architects and designers in identifying appropriate hard surface materials.

15. BIBLIOGRAPHY

[1] Allam, Zaheer, and David S. Jones. "Pandemic stricken cities on lockdown. Where are our planning and design professionals [now, then and into the future]?." Land Use Policy 97 (2020): 104805.

[2] Budds, D. "Design in the age of pandemics." Curbed 2 (2020): 233-240.

[3] Chang, Vanessa. "The post-pandemic style." Slate. https://slate.com/business/2020/04/coronavirus-architecture-1918-flu-cholera-modernism. html (2020).

[4] Dawson, P., Inyee Han, M. Cox, C. Black, and L. Simmons. "Residence time and food contact time effects on transfer of Salmonella Typhimurium from tile, wood and carpet: testing the five-second rule." Journal of applied microbiology 102, no. 4 (2007): 945-953.

[5] Haleem, Abid, Mohd Javaid, Raju Vaishya, and S. G. Deshmukh. "Areas of academic research with the impact of COVID-19." The American journal of emergency medicine 38, no. 7 (2020): 1524-1526.

[6] Klaus, Ian. "The post-pandemic urban future is already here." CityLab. Available online: https://www. bloomberg. com/news/articles/2020-04-06/how-will-the-pandemic-transform-urban-space (accessed on 25 April 2020) (2020).

[7] Lubell, Sam. "Commentary: Past pandemics changed the design of cities. Six ways covid-19 could do the same." Los Angeles Times 22 (2020).

[8] Saadat, Saeida, Deepak Rawtani, and Chaudhery Mustansar Hussain. "Environmental perspective of COVID-19." Science of the Total environment 728 (2020): 138870.

[9] Sun, Ziqi, and Kostya Ostrikov. "Future antiviral surfaces: Lessons from COVID-19 pandemic." Sustainable materials and technologies (2020): e00203.

[10] Tanner, B "Introduction to Antimicrobial Products or "Treated Articles"". http://www.housekeepingchannel.com/a_733-Introduction_to_Antimicrobial_Products_or_Treated_Articles

[11] Van Doremalen, Neeltje, Trenton Bushmaker, Dylan H. Morris, Myndi G. Holbrook, Amandine Gamble, Brandi N. Williamson, Azaibi Tamin et al. "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1." New England journal of medicine 382, no. 16 (2020): 1564-1567.

[12] Wainwright, Oliver. "Smart lifts, lonely workers, no towers or tourists: Architecture after coronavirus." The Guardian 13 (2020).