CABA™ Continental Automated Buildings Association

Human Skin Cells: A Potential Source of Building Contaminants

A CABA WHITE PAPER

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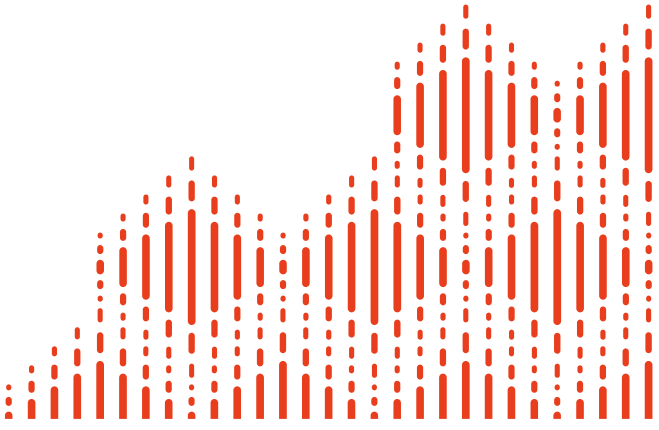

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Published: July 2018

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PUBLISHED

July 2018

Published: July 2018

TABLE OF CONTENTS

Published: July 2018

ABSTRACT

Human skin cells are a frequently reported biogenic particulate of indoor environments. They have been identified as odor producers, as well as fuel for microbial entities, beyond being a common contaminant of buildings. Over 99 percent of samples collected from both air and surfaces of indoor environments are reported positive for these entities by utilizing microscopic techniques. Non-culture based techniques reveal that it is one of the dominating bio-components in indoor environments, besides other abiogenic and biogenic particulates. Amelioration of these particles provides an enhanced experience of indoor air quality. Management of these building pollutants provides a significant improvement on health, energy and comfort.

INTRODUCTION

According to the United States Environmental Protection Agency (EPA), Americans spend up to 90 percent of their time indoors (EPA 1989), where contaminants in bioaerosols are generally at higher levels than those found in outdoor air (EPA 1987). Frequently, the duration of exposure to such contaminants is also greater indoors than out. It is estimated that more than 30 percent of buildings in the United States and Western Europe have moisture problems serious enough to promote microbial contamination of indoor air. Exposure to high levels of indoor moisture is associated with upper respiratory symptoms, including higher incidences of coughing, wheezing, and asthma in sensitized persons. Additional case studies, cluster investigations, and clinical experience associate other health complaints with living and working in damp buildings where mold and bacteria grow.

Healthcare professionals face a challenge due to symptoms being common and associated with many different disorders. Medical conditions associated with exposure to viruses, bacteria, or fungi include infectious diseases, respiratory disorders such as bronchitis and asthma, and other allergic, inflammatory, and toxic responses. In some cases, evidence links these disorders to exposure of bioaerosols. However, many times it is hard to link environmental risk factors in the absence of information on the causal elements. Skin cells are identified as one such particulate that may have adverse comfort and health implications on the occupants, which reduces productivity and quality of life.

Skin cells, or epithelial cells, are a frequently reported, airborne, biological component in indoor environments. Skin is the largest organ of the human body and it serves as a protective layer as well as a natural sensor. Cells grow and divide in the basement membrane causing newly developed cells to be pushed up into the epidermis. The supply of blood and other nutrients eventually stop reaching these cells and they slowly begin dying. The new skin

Published: July 2018

cells replace the sloughing ones. These cells consist of keratinocytes, melanocytes, Merkel cells and Langerhans' cells and they are macroscopic and microscopic in nature. The size range of microscopic particles may vary in size from 5 micrometers (commonly 10-100 micrometers) and above. Biochemically, they contain squalene and cholesterol in addition to water.

These cells are often reported as part of dust microflora in indoor environments, both in air as well as from surfaces. The skin cells are often overlooked in importance as a significant agent that may impact the quality of living space. Abiogenic or biogenic particulates such as bacteria, fiber, fiberglass, mold spores/fugal constituents, pollen grains, insect bio-detritus, inorganic particulates (that appear opaque under light microscopy), and others are some commonly encountered entities from closed environments that can be linked to health and hygiene related issues. However, it is estimated that 75-90 percent of household dust is made up of skin cells. A large portion of these bodies in indoor dust flora mainly depend on occupancy, humidity level and overall dermal health of occupants. It is estimated that humans shed 500 million cells a day, and drop off 30 to 90 mg of skin flakes every hour (Weschler *et al.* 2011). Subsequently, these particles of biological origin are mixed with dust and spread in and around indoor environments both on the surface as well as in the ambient air. These fragments also fuel and support the growth of many microorganisms including bacteria, fungi, mites, etc. Some common bacteria associated with human skin cells are Staphylococcus, Micrococcus, Corynebacterium, Propionibacterium, Brevibacterium, Acinetobacter, etc., whereas, Trichophyton, Candida and Malassezia are amongst some common fungal organisms. Also, Demodex mites such as Demodex folliculorum and Demodex brevis may feed on epithelial cells.

A new study, published in the American Chemical Society's journal, *Environmental Science & Technology*, concludes that oil in those skin cells makes a small contribution to reducing indoor air pollution. However, a number of other study suggests that house dust can trigger allergic reactions and harbor a number of microorganisms that can influence health and hygiene. A team of researchers led by Dr. Lai Kaman reveals that human skin flakes can lead to a bad smell in air-conditioning systems. They have reported that skin squalene shed from the human body can contribute to ammonia and volatile fatty acid production by bacteria colonizing air-cooling units. In evaluation of indoor environment quality, these components of nuisance dust are significant especially in cases where unexplained odors are causing potential issues leading to discomfort and low productivity.

Published: July 2018

MATERIALS AND METHODS

Utilizing an on-call basis for testing, 5,197 air samples were collected from approximately 2,359 buildings across 48 states in the US and territories along with one foreign country between the periods of April 2007 to December 2017. 14,056 Bio-Scan surface samples were collected from over 8,000 buildings located across 53 states in the US and its territories including one foreign nation during a period ranging from December 2003 to December 2017.

Surface samples were collected utilizing Bio-Scan 400 (a sticky tape imprint method), whereas, air samples were taken by drawing 15 liters of air for three minutes over a glass slip coated with an adhesive by spore trap method at 3' to 4' from the surface level. The spore trap method operates upon the principle of inertial impaction.

Samples collected using tape imprint methods are prepared for microscopic examination by transferring the entire Bio-Scan on top of a microscope glass slide (Premiere Premium Charged Fine Ground Edge 75 x 25 x 1mm) facing the specimen side toward the glass surface. Spore trap samples are processed by transferring the specimen collected on the microscope glass slide. One drop of lactophenol cotton blue stain is placed in the center of a clean, sterilized and labeled microscopic slide. The glass slip with the collected sample is removed carefully from the cassette and placed directly onto the drop of staining solution (the collection surface of the glass slip down, facing the stain) with the help of tweezers so that the stain disperses evenly. These slides were allowed to sit for about 5-10 minute prior to analysis. Qualitative identification of skin cells is based on reference slide comparisons.

A Bio-Scan has 400 squares that are 1 mm^2 in surface area each. Twenty-five randomly chosen squares representing all four zones and the center of the Bio-Scan are selected for microscopic evaluation. The primary microscopic evaluation of the collected samples is undertaken using 100x magnification (10x10), whereas, identification and quantification of skin cells is performed under 400x magnification (10x40).

Microscopic examination of the spore trap collected samples is initiated by scanning the entire trace for skin cells under 100x magnification (10x10). The counting and affirmation of skin cell particles in the specimen are completed by using 400x magnification (10x40).

Statistical analysis of all the above collected data is computed using a Computer Assisted Air Management Program (a proprietary Laboratory Information Management System, i.e., Paradox, for Pure Air Control Services, Inc.) and presented in Table-1 & 2.

Published: July 2018

RESULTS AND DISCUSSION

Table-1 lists the total number of air samples considered for the study. The table includes positive samples and negative samples as well as the mean, median, and mode values of skin cells trapped from the ambient air from specified indoor sites. Concentration of skin cells at the 67th percentile is also calculated and recorded into this table.

Table-2 includes the frequency and concentration of surface particulates from indoor environments. Data is recorded for low and high values along with middle, mean, and most commonly observed concentrations of skin cells in terms of counts/cm^2. Concentration of surface particulates from indoor environments at the 67th percentile is also included.

Figure-1 shows the frequency of skin cells identified both from air and surface samples in terms of total samples considered for this study.

Figure-2 illustrates the average concentration of skin cells and other particulates identified from air and surface samples collected from indoor environments using microscopic techniques.

Photograph-1 shows skin cell fragments in environmental samples.

Table-1: Frequency and concentration of airborne particulates from indoor environments

Particle Type	Total Samples	Positive Samples	Negative Samples	Concentration (Counts/m^3)					
				Low Value	High Value	Median Value	Mean Value	Mode Value	67th percentile
Skin Cells	5197	5156	41	22	171822	2800	4883	66	4940
Opaque Particles	5197	5186	11	22	2040000	14100	28069	1730	24000
Insect Biodetritus	5197	369	4828	22	1980	0	4	0	0
Fibers	5197	4720	477	22	66599	155	309	0	266
Pollen Grains	5197	1263	3934	22	46521	0	40	0	0

Published: July 2018

Fungal Spores	5197	4615	582	22	833000	198	3573	0	488
Others	5197	5163	34	22	2340000	2030	6654	622	3920

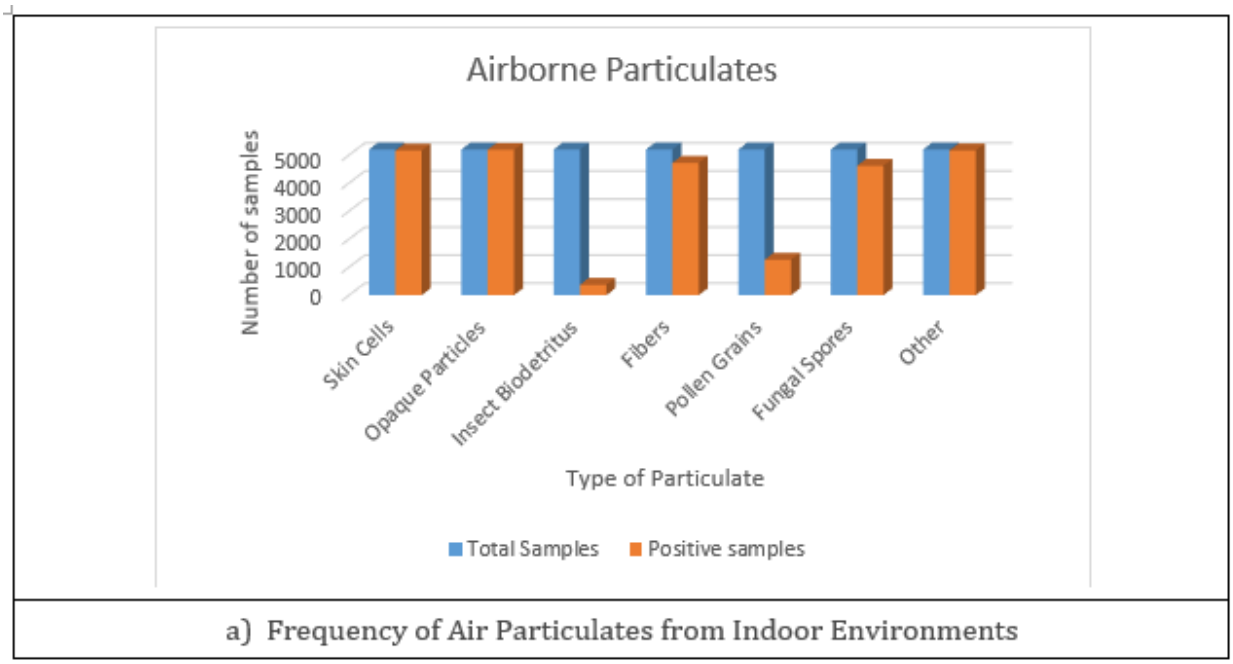
Table-2: Frequency and concentration of surface particulates from indoor environments

Particle Type	**Total Samples**	**Positive Samples**	**Negative Samples**	**Concentration (Counts/cm²)**					
				Low Value	**High Value**	**Median Value**	**Mean Value**	**Mode Value**	**67th percentile**
Skin Cells	14056	13073	983	4	102500	160	949	0	356
Opaque Particles	14056	13831	225	4	447500	1400	4727	0	2883
Insect Biodetritus	14056	2262	11794	4	4270	0	5	0	0
Fibers	14056	12840	1216	4	24400	52	192	0	112

Published: July 2018

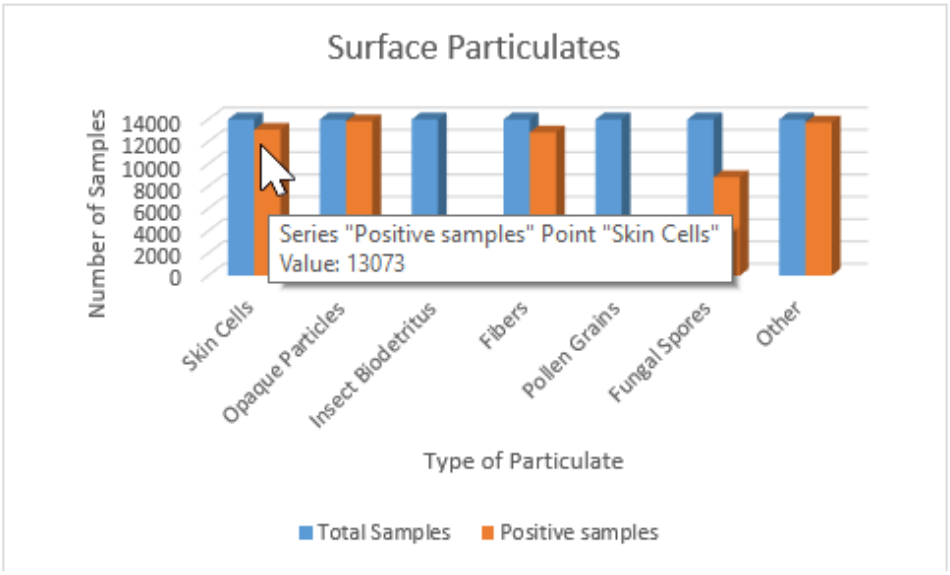
Pollen Grains	14056	3276	10780	4	11200	0	9	0	0
Fungal Spores	14056	8816	5240	4	9062500	8	6239	0	32
Others	14056	13719	337	4	752000	244	1452	0	500

Figure 1: Frequency of Particulates from Indoor Environments



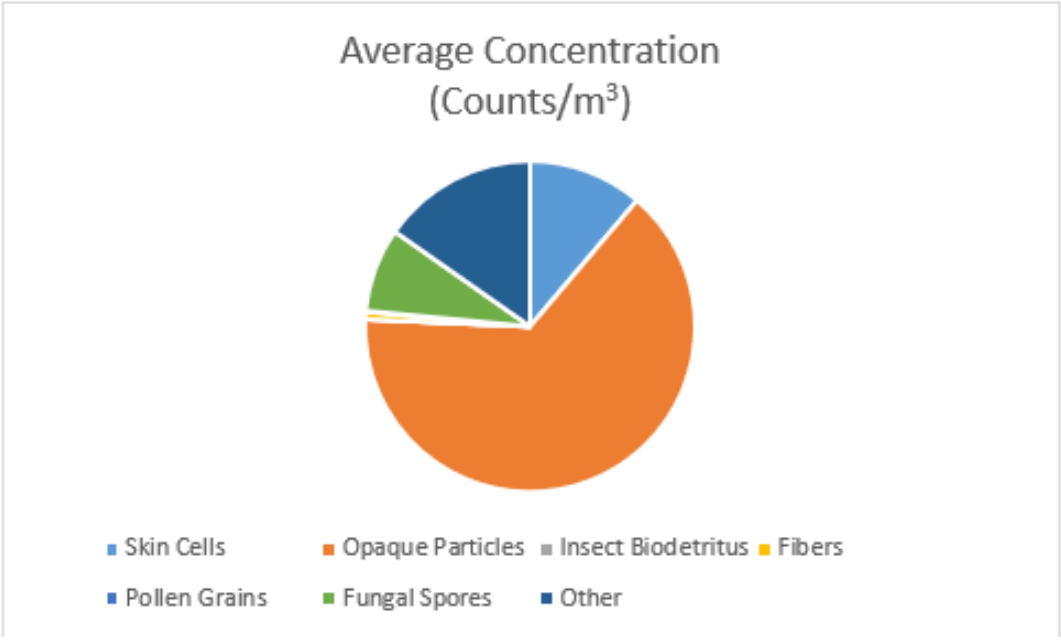
a) Frequency of Air Particulates from Indoor Environments

Published: July 2018



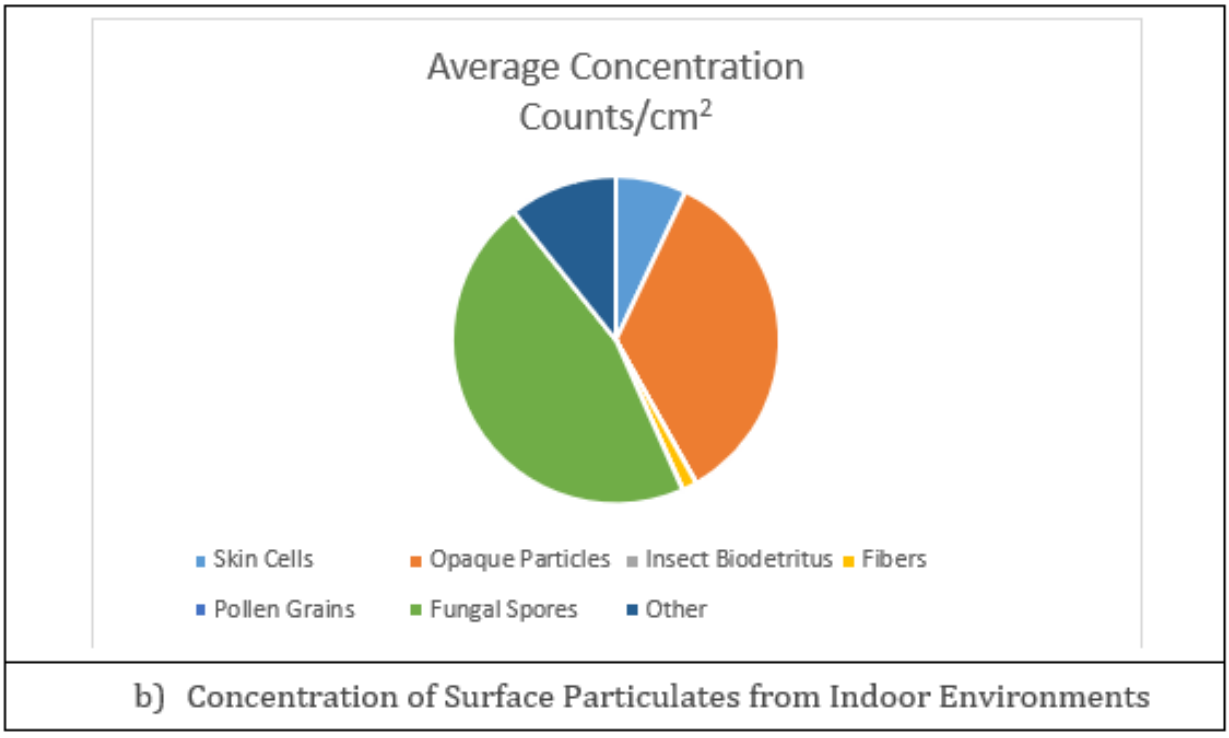
b) Frequency of Surface Particulates from Indoor Environments

Figure 2: Concentration of Particulates from Indoor Environments



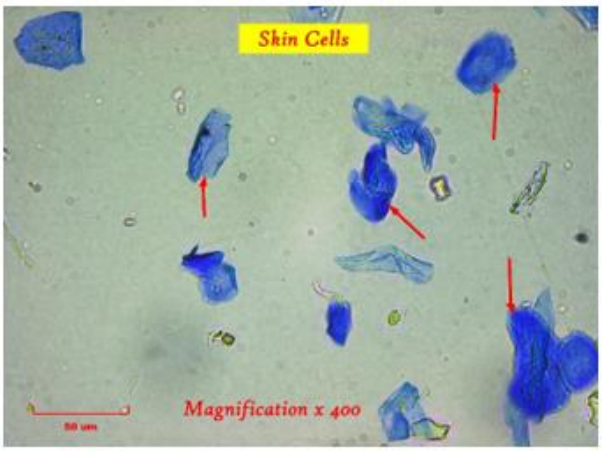
a) Concentration of Air Particulates from Indoor Environments

Published: July 2018

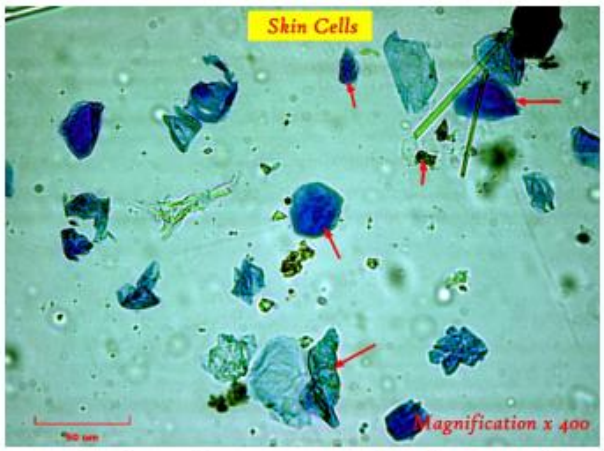


b) Concentration of Surface Particulates from Indoor Environments

Photograph 1: Showing human skin cell fragments in environmental samples



a. Skin Cells in Spore Trap (Air Sample)



b. Skin Cells in Bio-Scan (Surface Sample)

It is revealed that out of 5,197 air samples collected from indoor sites, including both residential as well as commercial buildings, approximately 99.21% (5,156) samples were examined as positive for skin cells (Photograph 1). Only about 0.79% (41) samples are negative and devoid of any such particles. The lowest concentration of skin cells found omitting negative samples is recorded as 22 counts/m^3 in comparison to a maximum value of 171,822 counts/m^3. Out

Published: July 2018

of seven identified categories of air particulates, skin cells are noticed as the third most prevalent airborne particle of indoor environments in regards to average concentration. Out of a total 5,197 air samples collected from indoor sites, Opaque Particles are reported as the most dominant (5,186), followed by Others (5,163), Skin Cells (5,156), Fibers (4,720), Fungal Spores (4,615), Pollen Grains (1,263) and Insect Biodetritus (369) (Figure-1a). Quantitatively, we have noticed that Opaque Particles dominated (28,069 counts/m^3) over the Others (6,654 counts/m^3) followed by Skin Cells (4,883 counts/m^3), Fungal Spores (3,573 counts/m^3), Fibers (309 counts/m^3), Pollen Grains (40 counts/m^3) and Insect Biodetritus (4 counts/m^3) (Figure-2a). At the 67th percentile of the collected samples, it is observed that Skin Cells counts (4,940 counts/m^3) are lower than Opaque Particles, but higher than the Other, Fungal Spores, Fibers, Pollen Grains, and Insect Biodetritus (Table-1).

In the case of surface samples collected from indoor sites, about 93% (13,073 samples) of samples were examined with skin cells; however, the number of negative samples (without skin cells) is close to 7% (983 samples). Data indicates that out of 14,056 surface samples, 13,831 samples are positive for Opaque Particles followed by Other (13,719), Skin Cells (13,073), Fibers (12,840), Pollen Grains (3,276) and Insect Biodetritus (2,262) (Figure-1b). When a comparison is made of the average counts, it stands out that Fungal Spores (6,239 counts/cm^2) dominates over Opaque Particles (4,727 counts/cm^2) followed by Others (1,452 counts/cm^2), Skin Cells (949 counts/cm^2), Fibers (192 counts/cm^2), Pollen Grains (9 counts/cm^2), and Insect Biodetritus (5 counts/cm^2) (Figure-2b). We have also observed that at the 67th percentile, the concentration of Skin Cells is 356 counts/cm^2 which is below the Opaque Particles and Other, whereas, it is higher than Fibers, Fungal Spores, Pollen Grains and Insect Biodetritus (Table-2).

The above observations reveal that Skin Cells are one of the major contributors of bio-components in indoor environments. While culture-based studies have focused on microbes, such as bacteria, fungi, etc., as ubiquitous in indoor environments, microscopic examinations divulge the presence of numerous, non-culturable particulates in the air and on surfaces. During this study, it is noticed that although the size range of these particles may vary from 5 µm to over 1000 µm, they are noticed to typically be within a size range of 10 µm to 15 µm.

A number of references (Gammage Richard B, 1996; Flannigan *et al.* 2001; Scott T. Kelley, *et al.* 2013) are available to correlate acute, chronic illness and other ailments which might affect human health in relation to spending time indoors and away from fresh air. Numerous indoor air pollutants such as dust mites, mold, pet dander, environmental tobacco smoke, cockroach allergens, particulate matter, and others, are "asthma triggers," meaning that some asthmatics might experience asthma attacks following exposure (Institute of

Published: July 2018

Medicine 2000). Productivity, comfort and the well-being of occupants are also compromised due to the diverse nature of indoor contaminants. It is primarily believed that microbes of indoor biota may influence healthy living; however, unpleasant odors originating from other abiogenic and biogenic substances of indoor sites can distress the comfort and well-being of occupants.

We have observed that these small skin cells may become airborne and enter into air conveyance systems through return ductwork or open plenum areas. Once they are airborne, they may start disseminating through air systems into an entire building. These particles can also deposit/enter into a buildings air handling units (AHU), blower cage assembly, porous fiberglass insulation liner, and subsequently become lodged deep within evaporator coil fins, also commonly called fouling.

Depending on moisture availability and other environmental parameters, these tiny particles of indoor environments start decomposing in that ecological niche, releasing organic matters and other byproducts. Bacteria and other microbial agents play a pivotal role in such biodegradation.

A study reveals that human skin flakes lead to "bad smells" in air-conditioning systems (Lai K.M. *et al.* 2018). As per the study, bacteria harbor in air-conditioning systems and utilize human skin cells as a food source. Ammonia and other volatile fatty acid is produced due to bacterial enzymatic action, even in a dust free environment. These compounds release body odors and a urine-like smell. Odors emitted in air conditioning systems can be easily distributed within occupiable/air-conditioned areas within the building, disturb comfort, and raise complaints regarding the overall indoor air quality.

Contrary to the information above, the presence of human skin cells can also be helpful in reducing indoor pollution. It is reported that cholesterol and squalene in house dust helps in removing ozone (2 to 15%) in an indoor environment (Weschler Charles J. *et al.* 2011).

As discussed above, dead human skin cells in indoor environments have both negative and positive impacts. The dead cells are capable of removing ozone (one of the significant indoor pollutants in and around buildings). Ozone is listed as an indoor pollutant that is capable of reducing lung function and inflaming the linings of the lungs. Repeated exposure may lead to permanently scarred lung tissue according to the EPA. As a matter of fact, oil associated with dead skin cells removes ozone by depleting the three-oxygen molecule in this molecule. However; the excessive amount of these entities in indoor environments may influence the building occupancy by nurturing several other existing bio pollutants of indoor environments. We have noticed an average concentration of these particles does not typically exceed 15,000

Published: July 2018

counts/m^3 in air samples; whereas, not more than 1,200 counts/cm^2 in the surface samples. Ameliorating these indoor pollutants not only helps in improving air quality, but also provides enhanced productivity and comfort experience of building occupancy. Air filtration and other therapeutic means, such as steam cleaning and others, are in practice to reduce the population of these particulates. Application of HEPA equipped, negative air machines in indoor environments for 24 to 48 hours significantly controlled these particles by removing them from air. In modern buildings, they are transported through the air conveyance system and deposited on coils (heat exchanger of air conditioning unit) and thus transform into a reservoir for microbial proliferation and further distribution in the facility. This activity also interferes in airflow and restrictive distribution has a direct impact on energy and contributes to poor indoor quality. Professional steam treatment (PURE-Steam Coil Cleaning method) is noticed to be 99.99% effective in removing deposited debris, lint, microbial entities, skin cells and several other biological as well as a-biological pollutants to enhance the airflow and optimal health, energy and comfort quality in building occupancy. The EPA has completed extensive modeling to assess the compatibilities and tradeoffs between energy, indoor air quality and thermal comfort that provides an overall superior performance for building automation.

At this time, limited data is available to correlate direct health implications due to skin cells within an indoor environment. However, skin cell concentrations reported from indoor environments may be used in combination with other indoor air quality investigation parameters to determine ventilation adequacy, occupant density, microbial growth probability, humidity level, and housekeeping consistency.

CONCLUSION

The accumulation of skin cells and bacterial degradation of skin squalene in AHU and associated ductwork can cause a urine-like smell in air-conditioned systems and is identified as a potential source of building contaminants.

Odor control in indoor environments is not an easy task. In day-to-day practice, it is believed that the accretion of dust, debris, microbes, moisture and other contaminants within air-conditioning systems is a main source of odor emission; however, a pronounced “dirty sock” smell is experienced even though the air-conditioning unit is otherwise free from visible dust accumulation.

This study reveals that the presence of skin cells in air-conditioning and other indoor sites is common. Mitigation of odor control in visibly cleaner environments may be tricky and requires an adequate building diagnosis,

Published: July 2018

inspections, and source determinations through the engineering and nature of buildings along with the occupant's behavior.

In order to minimize skin cells and associated building pollutants in an indoor environment, ecofriendly, green technology such as high MERV (minimum efficiency reporting value) filtration, air purification units fitted with HEPA (high efficiency particulate air) filters (rated at 99.9% efficiency), steam cleaning of evaporator coils, blower case assemblies and drain pans as well as topical cleaning practices may be useful techniques in neutralizing these bio contaminants.

ACKNOWLEDGMENT

The authors would like to acknowledge all of the past and present analysts who contributed to the examination of the samples referred to in this report. Our thanks are also extended to all of our data entry persons who assisted in insuring that the data was reported and entered in the most accurate way possible. We would also like to acknowledge Building Sciences for providing us with numerous samples from many different locations. We would also like to thank Pure Air Control Services, Inc., for providing us with the support and abilities to receive and compile this data in order for us to create this important document. We would also like to thank CABA and the Intelligent Buildings Council (IBC) White Paper Sub-committee. Thank Special thanks to Mrs. Cynthia Bailey, Data Administrator, for the upkeep and technical changes to Paradox. A final thanks to anyone else who has helped in one way or another that lead to us reaching this spectacular achievement.

Published: July 2018

REFERENCES

1. U.S. Environmental Protection Agency. 1987. The total exposure assessment methodology (TEAM) study: Summary and analysis. EPA/600/6-87/002a. Washington, DC.
2. U.S. Environmental Protection Agency. (1989): Report to Congress on indoor air quality: Volume 2. EPA/400/1-89/001C. Washington, DC.
3. U. S. Environmental Protection Agency (2000): Indoor Environments Division (6609J) Office of Air and Radiation EPA-4-2-S-01-001.
4. Gammage Richard B. and Berven Barry A. (1996): Indoor Air and Human Health. CRC Press Taylor and Francis ISBN 9781566701440 Pp. 384.
5. Institute of Medicine (2000): Clearing the air: Asthma and indoor air exposures. Washington, DC: National Academies Press.
6. Flannigan Brian, Samson Robert A., and Miller J. David (2001): Microorganisms in Home and Indoor Work Environments. CRC Press Boca Raton, London, New York, Washington, D.C. ISBN 0-415-26800-1 Pp. 490.
7. Charles J. Weschler, Sarka Langer, Andreas Fischer, Gabriel Beko, Jørn Toftum, and Geo Clausen (2011): Squalene and Cholesterol in Dust from Danish Homes and Daycare Centers. *Environ. Sci. Technol*. 2011, 45, 3872–3879.
8. Elizabeth A. Grice and Julia A. Segre (2013): The skin microbiome. Nat. Rev. Microbiol. 2011 Apr; 9(4): 244–253.
9. Scott T. Kelley and Jack A. Gilbert (2013): Studying the microbiology of the indoor environment. *Genome Biol*. 2013; 14(2): 202.
10. Ng T. W., Chan P.Y., Chan T.T., Wu H. and Lai K.M. (2018): Skin squames contribute to ammonia and volatile fatty acid production from bacteria colonizing in air-cooling units with odor complaints. *INDOOR AIR*, Vol. 28, issue 2, pages 258-265.

Published: July 2018

GLOSSARY

A-biogenic
Not originating from a biological origin of source

Aerosol
Suspension of fine solid or liquid droplets in air or other gaseous medium

Bioaerosol
Aerosols of biological origin

Biogenic
Having a biological origin of source

HVAC
Heating Ventilation and Air Conditioning

Indoor Air
Ambient air within a closed environment

Indoor Biota
Materials of biological origin perpetuating within a closed environment

Lactophenol
Stain/dye contains phenol, lactic acid, glycerol, water and cotton blue

Squalene
An organic compound

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