

PDH Academy

Designing Healthy and Productive Workspaces and Buildings

3.0 PDH/ 3.0 CE hours/ 3.0 AIA LU/HSW

AIAPDH200

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Final Exam Designing Healthy and Productive Workspaces and Buildings

1. What are some of the primary factors associated with healthy and productive workplaces and Buildings presented in this course?
 - a. Air Quality, Water Quality and Tobacco smoke
 - b. Biophilic environment, Covid 19 transmission factors and EMF exposure.
 - c. Noise levels, Views and Nutrition.
 - d. Dust, Noise levels and exercise

2. We spend up to _____ % of our time indoors as in the statement presented in the course?
 - a. 95
 - b. 90
 - c. 85
 - d. 80

3. ERV as presented in the course stands for _____ system and reduced energy costs?
 - a. Energy Resource Vector
 - b. Environment Resource Value
 - c. Energy Resource Value
 - d. Energy Recovery

4. Even low levels of lead in the drinking water are associated with cognitive impairment in children and _____ levels in adults are associated with Hypertension, lowered kidney function, nerve disorders, reproductive problems, risk factors for heart disease, reduced fetal growth in pregnant women.
 - a. low
 - b. high
 - c. very low
 - d. extremely low

5. The 2011–2012 U.S. National Health and Nutrition Examination Survey reported detectable serum PFAS concentrations in virtually all individuals - _____.
 - a. 30%
 - b. 50%
 - c. 70%
 - d. 97%

6. Select all that apply to the course statement: One study found 45 chemicals in multiple classes (_____.) from the consumer and building materials in dust are associated with endocrine/hormone disruption, Cancer and reproductive toxicity.
 - a. Phthalates and Phenols
 - b. Flame Retardants and Fluorinated Chemicals
 - c. Fragrances
 - d. All of the above

7. It is estimated that an adult can ingest _____ dust in a day.
 - a. 1000mg
 - b. 500mg
 - c. 200mg
 - d. 100mg

8. In a study, office workers' exposure to blue-enriched fluorescent light (17,000 K) vs. white light (_____ K) reported greater alertness, better mood, concentration and sleep quality compared to working in standard office lighting _____ K.
 - a. 5000
 - b. 4500
 - c. 4000
 - d. 3500

9. In a study - the 2016 Digital Eye Strain report - of 10,000 US adults they found _____ overall self-reported prevalence of digital eye strain symptoms.
 - a. 24%
 - b. 35%
 - c. 50%
 - d. 65%

10. Participants finished tasks in the green offices faster than the lean offices with an increase of productivity of _____ in the green offices vs. the lean offices.
 - a. 5%
 - b. 8%
 - c. 15%
 - d. 30%

11. _____ studies found that exposure to natural scenes rather than urban scenes decreased the tendency to discount the future or value the future less thus reducing behavior to make changes.
 - a. One
 - b. Two
 - c. Three
 - d. Four

12. It is estimated that _____ people in the US have been exposed to noise levels between 55-60 dBA which increases the risk of heart disease and hypertension.
 - a. 90 million
 - b. 100 million

- c. 120 million
 - d. 145 million
13. The exposure of children to environmental noise is associated with:
- a. Behavioral problems
 - b. Irritability
 - c. Fatigue, increased hyperactivity and emotional symptoms
 - d. All of the above.
14. Office workers are exposed to more noise and the resulting work interference because about _____% of offices in the United States now have open workspaces.
- a. 25
 - b. 50
 - c. 70
 - d. 90
15. Select the design factor (including coefficient) from the course to help reduce noise in an office: Sound reduction surfaces: Noise Reduction Coefficient (A **Noise Reduction Coefficient** is an average rating of how much **sound** an acoustic product can absorb.NRC):
- a. Ceilings: Open workspaces NRC .9
 - b. Ceilings: Conference and teleconference rooms 50% at NRC .5
 - c. Walls: Open workspaces 25% at NRC .5
 - d. Walls: Closed workspaces, conference and teleconference spaces 25% at NRC .5
16. Fill the blank with all that apply per summary: ...Biophilic indoor environment includes natural elements such as: _____...
- a. Plants, water, airflow, sunlight, natural materials
 - b. Biomorphic patterns
 - c. long-distance natural view
 - d. All of the above.
17. _____studies in a meta-analysis, including 1492 samples indicate exposure to mobile phones was associated with reduced sperm motility and viability.
- a. 1
 - b. 2
 - c. 5
 - d. 10
18. Select all that apply to approaches to mitigate EMF exposure in workspaces and buildings presented in the course:
- a. Use hard wired routers instead of WiFi or keep WiFi routers at least 20' from people
 - b. Wiring inside buildings should be EMF shielded. Devices plugged in to outlets should be 3 prong/grounded
 - c. Don't use cell phones in crowded areas. Shield cell phones from EMF. Don't carry phones in pockets
 - d. All of the above

19. When the relative humidity is between _____% more of the virus is in the bigger droplet form which is heavy and falls to the ground after traveling a few feet.

- a. 20-50
- b. 30-50
- c. 30-60
- d. 40-60

20. The Covid 19 virus is viable on stainless steel surfaces for about _____ hours.

- a. 72
- b. 80
- c. 96
- d. 100

Designing Healthy and Productive Workspaces and Buildings

By Chris Hubbard, AIA, LEED-AP, CNU-A, CAM

COURSE DESCRIPTION:

This course will look at physical factors in a workspace or building which when optimized – per research - are associated with a healthier and productive workspace or building. Some optimized factors are associated with increases in cognition, productivity, improved health and mood and decreased sick days and associated costs. The factors include Air Quality, Water Quality, Thermal Conditions, Dust, Lighting quality, Views, Noise levels, Biophilic Environment, EMF Exposure and Covid 19 transmission factors. This course includes a sample audit of a workspace including: Air Quality: Formaldehyde in air, Total Volatile Organic Compounds (TVOCs) in air, Particulate Matter (PM) 2.5 and 10 micron in the air. Carbon Dioxide (CO₂) in the air, Daylight level and Melanopic Lux, Identification of Electromagnetic field Hot Spots, Sound level and Covid 19 transmission factors.

LEARNING OBJECTIVES:

1. The student will learn to identify some of the factors associated with a healthy workspace and building.
2. The student will learn ways to optimize these factors to design healthier and more productive workspaces and buildings.
3. The student will learn about current research related to designing for healthier and more productive workspaces and buildings.
4. The student will learn about some of the Covid 19 transmission factors in a workspace.
5. The student will learn about some of the Electromagnetic Field factors associated with health.

COURSE OUTLINE:

- 1.0 Introduction
- 2.0 Factors associated with healthy and productive workspaces and buildings and ways to optimize them.
 - 2.1 Air Quality
 - 2.2 Water Quality
 - 2.3 Thermal Conditions

- 2.4 Dust
- 2.5 Lighting Quality
- 2.6 Views
- 2.7 Noise Levels
- 2.8 Biophilic Environment
- 2.9 EMF Exposure
- 3.0 Covid 19 Transmission Factors
- 4.0 Sample Workspace Audit
- 4.1 Discussion
- 5.0 Conclusion
- 6.0 References

2.0 Factors associated with healthy and productive workspaces and buildings and ways to optimize them.

2.1 Air Quality:

Indoor air can have up to 2 times the concentration of outdoor pollutants as outdoor air, per the US Environmental Protection Agency, and we spend up to 90% of our time indoors. In addition, in the pursuit of energy conservation we have made building envelopes tighter to reduce air infiltration but have increased the concentration of pollutants from interior elements below. These pollutants include: Odors, Particulate Matter (PM), Volatile Organic Compounds (VOCs), carbon dioxide (CO₂), Ozone and Carbon Monoxide. In offices these pollutants may come from cleaning products, paint, carpet, printers, office furniture, pollen, dust, fungal spores and pesticides. These pollutants can cause symptoms including: headaches, congestion, cough, sneezing, nausea, dizziness, fatigue, shortness of breath and eye, throat and skin irritations.^{1,2} The pollutants have also been associated with asthma, bronchitis, allergies and pulmonary problems.^{3,4,2} VOC's have been associated with some types of cancer and Ozone is associated with heart arrhythmias. VOCs have been found to harm children's lungs in school classrooms.^{5,6} Particulate Matter (PM) exposure (2.5 micron diameter) has been associated with Heart Disease, Respiratory Disease, Asthma and Diabetes.⁷ A group of symptoms like these have been called the sick building syndrome (SBS) by the World Health Organization (WHO). These pollutants can decrease productivity, reduce cognitive function and increase sick days.^{8,9,2} There is a link between building related symptoms which include headaches, nausea, fatigue, etc., and the loss of productivity and increase in sick days.¹⁰

So how can we reduce these pollutants to increase productivity and the healthiness of the workspace? The first way is to increase outside air to dilute the pollutants. Operable windows allow for this. In buildings without operable windows, this can be achieved by opening the outside air intake louver(s) - this will affect humidity, temperature and air pressure and increase costs for the short term but

decrease costs overall considering sick days and loss of productivity. Avoid locating outside air intake louvers at street level and near sources of pollution and monitor air quality for mitigation of air quality problems.

There is research which associates increased outside air with decreased sick days, decreased respiratory infections and decreased costs.^{11,12} There is research at Harvard University School of Public Health which associates an increase in cognitive function with an increase in outside air per person from 20 Cubic feet per Minute (CFM) to 40 CFM. The increase in performance and decrease in sick days, more than makes up for the additional costs.¹³ They found that doubling the ventilation rate cost less than \$40/person per year in all climate zones tested. Using an Energy Recovery Ventilation system (ERV) reduced energy costs and in some cases provided a net savings so energy conservation and health and productivity can be maintained. In the 40CFM per person case, using an ERV neutralized the environmental impact. At that ventilation level, performance was increased by 8% which is equivalent to a \$6500 increase in employee productivity each year. This also reduced sick days and improved the health of employees. The health benefits exceeded the per person energy cost relative to salary.¹⁴ Research in CA schools found students were calmer and had a greater attention span in classrooms with greater outside air.¹⁵ Recent research shows reducing conventional CO₂ levels from ~900+ppm (20 CFM outside air/person) to ~560ppm (40 CFM Outside air per person - Green +) is associated with significant increases in cognitive function per research and reducing conventional TVOCs ~500ug/M³ to ~50ug/M³ is associated with significant increases in cognitive function.¹³ Increasing outside air increases performance, decreases sick days, improves health and based on the cost savings and increases in productivity is well worth the investment. CO₂ is effectively reduced by an increase in outside air. VOCs can be reduced by carefully using potted plants in the workspace and possibly reduces CO₂, but more research is needed for this.¹⁶ The increased outside air to above 20 CFM/person is above the minimum standard in ASHRAE 62.1-2013 (Ventilation Rate Procedure), however even an increase to 20 CFM/person from a lower value of 5CFM/person will decrease sick days, costs and respiratory infections.^{11,12}

Another way to reduce VOC's is to select paints, coatings, adhesives, sealants, flooring and insulation according to the limits set in the California Department of Public Health (CDPH) Standard Method v1.1-2010. Also select furniture and furnishings to the limits in ANSI/BIFMA e3-2011 Furniture Sustainability Standards Sections 7.6.1 and 7.6.2 Tested per Standard Method M7.1-2011. VOCs can also be reduced with carbon and HEPA filters.

Small particles can be reduced with MERV 13 or higher media filters. Savings and productivity gains from improved interior air quality are estimated to be \$25-150 Billion/year in the US.¹⁴

There are relatively inexpensive air quality monitors which can be purchased which monitor CO₂, TVOCs, PM, temperature and humidity so that one can confirm the indoor air pollution status.

Air Quality Review Questions:

1. Indoor air can have up to _____ times the concentration of outdoor pollutants as outdoor air, per the US Environmental Protection Agency as in the statement presented in this course?
 - a. 10
 - b. 20
 - c. 5
 - d. 2

2. There is research which associates increased outside air with decreased sick days, decreased respiratory infections and _____ as in the statement presented in the course?
 - a. Increased tobacco smoke
 - b. Decreases marijuana smoke
 - c. Decreased costs
 - d. Increased Ozone

3. Research at Harvard University School of Public Health associates an increase in cognitive function with an increase in outside air per person from _____ as in the statement presented in the course.
 - a. 20 CFM to 40 CFM
 - b. 20 CFM to 25 CFM
 - c. 20 CFM to 30 CFM
 - d. 20 CFM to 35 CFM

4. What are three factors associated with increases in cognitive function as presented in the course?
 - a. Increased outside air, increasing conventional CO2 levels from 560 ppm to 900+ppm and reducing conventional Total Volatile Organics from 500ug/M3 to 50ug/M3
 - b. Increased Marijuana smoke, reducing conventional CO2 levels from 900+ppm to 560ppm and reducing conventional Total Volatile Organics from 500ug/M3 to 50ug/M3
 - c. Increased outside air, reducing conventional CO2 levels from 900+ppm to 560ppm and increased Ozone levels.
 - d. Increased outside air, reducing conventional CO2 levels from 900+ppm to 560ppm and reducing conventional Total Volatile Organics from 500ug/M3 to 50ug/M3.

2.2 Water Quality

In the American Society of Civil Engineers 2013 Report Card for America's Infrastructure, they gave a D+ for drinking water.¹⁷

The EPA sets Maximum Contaminant Level Goal (MCLG) and the legally enforceable Maximum Contaminant Level (MCL), however in recent testing of tap water across the country, these levels have been exceeded.¹⁸ To make matters worse, there are many areas using private water treatment systems which are not regulated under the Safe Drinking Water Act's Lead and Copper rule nor are routinely tested for lead.¹⁹

Due in part to the aging infrastructure, tap water in the US may be compromised by metals which leach out of the pipes and pipe solder - including copper, lead and other metals. Due to insufficient treatment, disinfection by-products and pollution, there may be organic chemicals in the drinking water such as polyfluorinated and halogenated hydrocarbons. There are also microbes in the drinking water due to insufficient disinfection.

Even low levels of lead in the drinking water are associated with cognitive impairment in children^{20, 21} and high levels in adults are associated with hypertension, lowered kidney function, nerve disorders, reproductive problems, risk factors for heart disease, and reduced fetal growth in pregnant women.^{22,}
²³ High levels of copper are associated with symptoms including: irritation of eyes, nose and mouth; stomach cramps, nausea, vomiting and diarrhea.²⁴

Polyfluoroalkyl Substances (PFAS) in the drinking water have been associated with cancer, obesity, high cholesterol and endocrine disruption. Over 6 million Americans in 33 states were exposed to US EPA's lifetime health advisory quantities for PFAS – these quantities are the safe limit one can be exposed to in a lifetime. These PFAS chemicals are linked to civilian airports, industrial sites and military fire training areas, as they are used in aqueous foams used for firefighting and wastewater treatment plants and are included because the PFASs are not removed at the plants. The chemicals are widely used and extremely resistant to degradation and have resulted in the presence of these compounds in the environment in water, air and dust. The 2011–2012 U.S. National Health and Nutrition Examination Survey reported detectable serum PFAS concentrations in virtually all individuals (97%!)^{25,26} With regards to drinking water, research also shows an association of Disinfection Byproducts (DBP, which includes halogenated hydrocarbons) and adverse pregnancy outcomes. A maternal exposure to trihalomethanes (THMs, halogenated hydrocarbons) shows an increased risk of small for gestational age (SGA) and slightly increased risk of pregnancy loss.²⁷ Other organic contaminants include: Styrene, Benzene, Ethylbenzene, Polychlorinated Biphenyls, Vinyl Chloride, Toluene, Xylenes, Tetrachloroethylene.

There are also microbes in the drinking water. During the 2013-2014 season there were 42 drinking water outbreaks including 1006 illnesses, 124 hospitalizations and 13 deaths. Legionella was responsible for 57% of the outbreaks and 13% of illnesses, and chemicals/toxins and parasites together accounted for 29% of outbreaks and 79% of illnesses. Eight outbreaks caused by parasites resulted in 289 (29%) cases, among which 279 (97%) were caused by Cryptosporidium and 10 (3%) were caused by Giardia duodenalis. Chemicals or toxins were implicated in four outbreaks involving 499 cases, with 13 hospitalizations, including the first outbreaks associated with algal toxins.²⁸ Top ten causes of outbreaks in drinking water:

1. Giardia
2. Legionella
3. Norovirus
4. Shigella
5. Campylobacter
6. Copper
7. Salmonella
8. Hepatitis A
9. Cryptosporidium
10. E. coli, excess fluoride (tie) (CDC)

To provide clean drinking water in workspaces either provide a dispenser within 100 feet of all areas of the office space or drinking water filtered through an NSF filter which has activated charcoal for taste and odor, sediment filtration and certification for microbial cyst removal.

Water Quality Review Questions

5. Fill in the blank for the statement in the course. In the American Society of Civil Engineers 2013 Report Card for America's Infrastructure, they gave a _____ for drinking water.
 - a. A+
 - b. B+
 - c. C+
 - d. D+

6. Fill in the blank for statement in the course: Due to insufficient treatment, Disinfection By-products and pollution there may be organic chemicals in the drinking water such as _____.
 - a. Lead
 - b. Copper
 - c. Iron
 - d. Polyfluorinated and Halogenated hydrocarbons

7. Fill in the blank in the statement presented in the course with all that apply: Polyfluoroalkyl Substances (PFAS) in the drinking water have been associated with _____.
 - a. Weight loss
 - b. Low cholesterol
 - c. Cancer, Obesity, High Cholesterol and endocrine disruption
 - d. Obesity, High Cholesterol and endocrine disruption

8. What are the top three causes of outbreaks in drinking water per top ten list in this course.
 - a. Copper, Salmonella and Hepatitis A
 - b. Shigell, Campylobacter and Copper
 - c. Norovirus, Shigella and Campylobacter
 - d. Giardia, Legionella and Norovirus

2.3 Thermal Conditions

Per research, when thermal conditions - temperature and humidity – are outside target standards, it can lead to a loss of productivity and health issues. Workspace productivity and comfort is influenced strongly by temperature and humidity according to office workers in a European study.²⁹ Temperatures outside target temperatures have health impacts. A study on workspace thermal conditions related to health found that when thermal conditions including ventilation, humidity, and temperature were not within an acceptable range, office workers

experienced headaches, dry eyes and throat irritation.³⁰ There are increases in Sick Building Syndrome symptoms including: negative moods, increased heart rate, respiration, and CO₂ partial pressure in the lungs and lower saturation of O₂, and feelings of fatigue, when people feel excessively warm in workspaces and buildings.³¹ High temperatures also increase the risk of heat stroke. On the other hand, high temperatures decrease the survivability of viruses in the air and thus decreases the transmission of virus infections to others, decreasing the rate of infection.

Lower temperatures increase the survivability of viruses/coronaviruses in the air and thus leads to increased infection transmission.³² Studies on mice also show that the immune system in the nose is reduced in colder temperatures so cold viruses can reproduce more efficiently there.³³

Temperature also affects productivity and cognitive performance.

In a study of a 70 (140 fifth grade classrooms in the same district) elementary school district with 3,109 students in the southwestern United States, they found that there was an increase of 12-13 points in the students mean mathematics scores associated with each 1°C decrease in temperature within the range of 20-25° Celsius (68 - 77 degrees Fahrenheit).³⁴

SBS symptoms were reduced with lower humidity and temperature – within an acceptable range - thus an indication that lower temperature and humidity would increase office performance.³⁵ In one study they found if people felt warm - in this study 86F - they felt more SBS symptoms, negative mood and they were less inclined to work hard - their task performance was reduced compared to a neutral temperature of 71.6. These effects on health and performance appear to be physiological rather than a result of subjective feelings of discomfort.³⁶

Humidity affects health. Research shows the relationship between relative humidity (RH) and the airborne transmission of Covid 19. Based on earlier studies, a relative humidity of 40–60% was found to be optimal for human health in indoor spaces.³⁷ Virus transmission indoors is dependent on humidity.³⁸ In the pursuit of energy conservation and cost control, building design has excluded optimal humidity - but at a cost to health and productivity. The extra costs related to adding humidity in the drier months are balanced by a reduction in sick days and loss of productivity related to SBS symptoms and infections. There are some energy efficient ways of increasing humidity in the drier months discussed below.

Research shows that Absolute Humidity (AH) is associated with the survival and the transmission of the influenza virus - low absolute humidity increases the survival time of the virus and increases the transmission of the flu virus. A negative change in AH is associated with the beginning of the Influenza season and the positive change is associated with the end of the influenza season. Low AH dehydrates the virus making it smaller and lighter and aerosolized, causing it to stay in the air longer which increases the virus transmission. With a high AH the virus is hydrated and becomes bigger and heavier and falls from the air quicker and thus decreases virus transmission.³⁹

Temperature and humidity may also influence disease transmission.⁴⁰ Cold and dry environments - less than 40% relative humidity - in the fall through spring have been found to significantly facilitate the spread of the influenza virus because low humidity levels permit virus particles, to be less hydrated and smaller and less dense, to stay in the air longer and low temperatures prolong the virus shedding period. It was found to be critical to maintain a minimum relative humidity of 40% with added humidification during this COVID 19 pandemic to reduce the infection transmission rate. Low humidity below 40% relative humidity can dry out mucous membranes and

create openings in the throat and nose for microbes to enter and infect the individual. On the other end of the spectrum, warm humid environments >60% RH are conducive to mold and fungal growth.⁴¹ High humidity decreases viruses in the air.⁴² Research shows the relationship between relative humidity and the airborne transmission of the Covid 19 virus. Keep humidity between 40-60% to reduce odors, mold growth and reduce airborne disease transmission including Covid 19 and increase productivity.³⁷

SBS symptoms were reduced with lower humidity and temperature in a range thus an indication that lower temperature and humidity would increase office performance. Low humidity can increase a cooling affect, feeling cooler than the temperature would feel, while high humidity can make one feel warmer than the temperature would feel.³⁵

Spaces should meet thermal comfort standards for temperature and humidity throughout the day. Provide individual level thermal control, where possible. In terms of humidity, one can use air conditioning or a dehumidifier to lower humidity to the optimal level between 40% and 60% relative humidity. In the drier months one can use a humidifier to raise humidity to the optimal level. The humidifier can be a part of the HVAC system or a freestanding unit which there are 3 basic types: warm mist including some vaporizers; cool mist including evaporative and some vaporizers; and ultrasonic.⁴³

Cool Mist with a fan including evaporative and some vaporizer humidifiers.

Positive factors: Safer for children and pets; Low maintenance and easy cleaning; filters water; can add inhalants for cold and flu; lower cost; good for asthma and allergy.

Negative factors: bacterial growth possible; minerals can accumulate; noise from fan.

Warm Mist from heated then cooled water including some vaporizers.

Positive factors: Lower bacterial growth; lower mineral accumulation; inhalants for colds and flu; lower noise.

Negative Factors: burn risk for children; uses more energy; difficulty in cleaning.

Ultrasonic uses high frequency vibrations to generate a cool mist.

Positive factors: uses much less energy; no noise; no burn risk; easy cleaning and low maintenance; good for asthma and allergies.

Negative factors: bacteria growth can occur; minerals may accumulate; expensive.

There should be UV microbe control in the humidifier to minimize the production of mold spores or other microbes. Another more energy efficient way to increase humidity in the drier months is to use an indoor fountain - this will also contribute to better health and productivity through a biophilic environment. Plants also can increase interior relative humidity. An indoor air quality (IAQ) monitor can aid in maintaining relative humidity between 40%-60%. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) also recommends that indoor relative humidity be maintained at or below 65% [ANSI/ASHRAE 2017].

Thermal Conditions Review Questions:

9. Indicate all that apply to the summary statement in the course: There are increases in sick Building Syndrome symptoms including: _____ when people feel excessively warm in buildings.
- Negative mood and increased heart rate.
 - Increased respiration, and increased CO₂ partial pressure in the lungs
 - Lower saturation of O₂ in the lungs and feelings of fatigue.
 - All of the above
10. Fill in the blanks per statement in the course: _____ temperatures increase the survivability of coronaviruses in the air and thus leads to _____ infection transmission.
- Higher; increased
 - Lower; decreased
 - Higher; Decreased
 - Lower; Increased
11. Fill in the blanks per the statement in the course: Research shows that Absolute Humidity (AH) is associated with the survival and the transmission of the influenza virus - _____ absolute humidity _____ the survival time of the virus and increases the transmission of the flu virus.
- Low; Decreases
 - High; Decreases
 - High; Increases
 - Low; Increases
12. Fill in the blank as per statement in course: In a study of a 70 elementary school district with 3,109 students in the southwestern United States, they found that there was an increase of 12-13 points in the students mean mathematics scores associated with each 1°C decrease in temperature within the range of 20-25° Celsius (_____ degrees Fahrenheit)
- 75 to 66
 - 77 to 64
 - 77 to 66
 - 77 to 68

2.4 Dust

Dust is a collecting source for indoor exposure of chemicals, allergens (pets, rodents, pests and pollen), viruses, bacteria, mold spores and building materials containing harmful substances including lead. Exposure to dust can be from the air through inhalation, the direct contact of the skin and through ingestion of dust from hands, directly or indirectly. In dust there can be Persistent Organic Pollutants (POPs) which are resistant to breakdown in the environment and stay in dust long after the source of the pollutant is gone.⁴⁴ It is estimated that an adult can ingest 100mg dust in a day, while children can ingest up to 200mg dust in a day.⁴⁵ Studies have shown that the amount of a chemical in dust is associated with the amount of the chemical in a person's blood who spends significant time in proximity to the dust.⁴⁶

Chemicals in Dust:

Chemicals can migrate out of consumer and commercial products into the air and into dust. Some chemicals which are prevalent in dust include flame retardants. Flame retardants are found in furnishings and building materials. They can build up in the body and are endocrine disruptors which interfere with the reproductive system and are associated with thyroid disease.

Plasticizers: Phthalates are found in PVC, vinyl tile, school supplies, hair spray, skin care products and nail polish to make them flexible. Phthalates are classified as Endocrine Disrupting Chemicals (EDCs). They are associated with endocrine system problems, fertility problems, respiratory diseases, childhood obesity and neuropsychological disorders.⁴⁷

Stain repellants: Polyfluorinated Alkyl Substances (PFASs): They are found in carpets, fabrics, paints and non-stick cookware. They are associated with cancer, obesity, high cholesterol and endocrine disruption.

Lead: The primary route of exposure for lead is from dust from paint chips and tracked in from outside.

Pest Control Chemicals: Pyrethroids: Pyrethroid exposure has been associated with cancer.⁴⁸

Other Pest Control Chemicals: Organophosphates (OP)s. Organophosphate, exposure has been associated with adverse reproductive health effects and thyroid disease.⁴⁹ In addition, Glyphosate, an OP anti-biotic in Roundup weed killer has been found in dust from non-agricultural homes. Glyphosate has been found to block the shikimate pathway in plants, bacteria and fungi and thus block essential amino acid and protein synthesis thus robbing plants of nutrients for consumption. Also, this robs the microbiome in the soil and Gastrointestinal (GI) track reducing the healing nutrients they supply and undermining the tightness of the blood-brain barrier and GI barrier. These leaky barriers then allow toxins and antigens to enter the body and therefore a chronic inflammation reaction involved in the disease process.

A meta-analysis found links between indoor pesticide chemicals and urinary tract infections, inner ear infections, acute lymphoblastic leukemia, acute myelocytic leukemia, and non-Hodgkin's lymphoma, in a children health study.⁵⁰

Allergens: Allergens can come from pets, rodents, pests and pollen and can cause an immune response in children and adults and a significant impact to human health. Dogs, cats and rodents can produce allergens which can cause allergic reactions. Cockroaches can produce an allergen and people can become allergic to it: one study on asthmatic children shows exposure to this allergen is a risk factor for hospitalization.⁵¹ Dust mites can produce an allergen (Der p1) which can have a significant impact on health including: asthma attacks, hay fever and sinus symptoms⁵². Bacteria, viruses and mold spores can be transmitted via resuspension of dust in the air.⁵³

There are many building related chemicals found in indoor dust. One study found 45 chemicals in 5 classes (Phthalates, Phenols, Flame Retardants, Fragrances and Fluorinated Chemicals) from the consumer and building materials in dust and are associated with endocrine/hormone disruption, cancer and reproductive toxicity. The top ten chemicals found in indoor dust include: Phthalates: DEHP, DEHA, BBzP, DnBP, DiBP; Fragrance: HHCB; Flame Retardant: TPHP, TDCIPP, HBCDD; Phenol: MeP.⁵⁴

All of these components mentioned above can result in a reduction of productivity from illness and loss of work time or even chronic conditions which involve a loss of concentration.

There are simple methods to reduce toxic dust in a workspace or building including:

1. A cleanable entryway system composed of grills, grates or slots for easy cleaning below as wide as the entry and about 10' in direction of travel or cleanable rollout mat the width of the entry and 10' long.
2. A MERV 13 outdoor air filtration and a MERV 8 for indoor air filtration system
3. Entryway seal with revolving doors or vestibule.
4. Cleanable flooring: No wall-to-wall carpet, only removeable rugs, carpet tiles or hard surfaces. Use mops, rags and dusters on non-porous surfaces and vacuum with HEPA rated filter on other surfaces.
5. Large trash cans over 30 gallons should have tight lids. All non-refrigerated perishable food is in a sealed container.
6. Use materials and furnishings with reduced levels of: Phthalates, Fire Retardants, Polyfluoroalkyl substances and Phenol.
7. Pesticide and Herbicide use based on chapter 3 of San Francisco Environment code Integrated Pest Management Program (IPM).
8. Monitor Air Quality particularly PM 2.5 to PM 10 which includes most dust particles.

Review Questions Dust:

13. Select all that apply to the list of simple methods to reduce toxic dust in a workspace or building as presented in the course:
 - a. A cleanable entryway system composed of grills, grates or slots for easy cleaning below as wide as the entry and about 10' in direction of travel, or, cleanable rollout mat the width of the entry and 10' long
 - b. A MERV 13 outdoor air filtration and a MERV 8 for indoor air filtration system and Entryway seal with revolving doors or vestibule.
 - c. Cleanable flooring: No wall-to-wall carpet, only removeable rugs, carpet tiles or hard surfaces. Use mops, rags and dusters on non-porous surfaces and vacuum with HEPA rated filter on other surfaces.
 - d. All of the above.

2.5 Lighting Quality

There are visual and non-visual impacts of lighting on health and productivity. Visual impacts relate to light levels and glare and the rod and cone receptors in the eyes. Non-visual impact relates to blue light and special receptors in the eyes called retinal ganglion cell photoreceptors. In the pursuit of energy conservation there has been a reduction of glass area or the transmittance of glass to reduce heat gain in the warmer months and heat loss in the cooler months, but it has had a negative effect on daylighting and thus on productivity and health as indicated below. There are ways to use higher transmittance glass more efficiently for daylighting described below and thus less heat gain and heat loss and the use of low e glass helps as well. In a study, office workers' exposure to blue-enriched fluorescent light (17,000 K) vs. white light (4,000 K): those exposed to the blue-enriched fluorescent

light (17,000 K), reported greater alertness, better mood, concentration and sleep quality compared to working in standard office lighting (4000K).⁵⁵ There is a wavelength in sunlight (blue/green 480-490nm or Melanopic Lux) which blocks melatonin (sleep hormone) production and activity, theoretically making one more awake and alert as well as resetting the circadian rhythm so that one is more awake in the morning and has a better/deeper sleep at night thus positively impacting health as well as productivity. There is a photosensory system in the eyes, in addition to the rods and cones, which detects blue light - there are widely spaced intrinsically photosensitive retinal ganglion cells (**ipRGCs**), also called photosensitive retinal ganglion cells (pRGC), or melanopsin-containing retinal ganglion cells (mRGCs)- with receptors which are sensitive to blue light through a vitamin A photopigment melanopsin. This projects through the retinohypothalamic tract to the paired Hypothalamic nuclei and then to the suprachiasmatic nuclei. The suprachiasmatic nuclei are oscillators in the circadian system which transmit information about lighting and circadian time to the pineal gland (and other locations in the brain) which synthesizes the hormone melatonin when the timing indicates the onset of a sleeping period. This modulates rhythms of sleep and wakefulness, body temperature and alertness and the hormones melatonin (time to sleep) and cortisol (time to wakeup).⁵⁶ To strengthen alertness in the morning and sleep quality at night, it is important to have strong light during the day starting at waking and low light levels in the evening preceding sleep. Daylight exposure of at least 1250 Lumens per square meter (Lux) throughout the daylight hours and windows at work has been associated with better sleep time and mood, reduced sleepiness, lower blood pressure, increased physical activity. Lack of natural light has been associated with sleep and depressive symptoms.^{57,58,59} Office workers under a comparison of electric vs. natural lighting have experienced less glare and sleepiness and more alertness and cognition early in the day under natural lighting compared to when they were under electric lighting.^{60, 61}

Studies on students in classrooms indicate natural light positively affects health, attention and performance including scholastic performance.⁶² Using LEDs can allow for greater control of the light spectrum and amplitude for health issues and productivity. The LED spectrum can be manipulated so there is more blue light at the beginning of the day and shift to less blue light toward the end of the day, simulating the sun, thus increasing alertness early in the day and preparing for a better sleep toward the end of the day.⁵⁶ Conventional LEDs have a discontinuous spectrum with a peak between 450 nanometer (nm) and 470nm. A LED light was created which simulated the daylight spectrum and was used in a small study of young males which found that daylight LED exposure was associated with more visual comfort, more alertness and a happier mood in the morning and evening than with conventional LEDs. Further, the daylight LED exposure was associated with more Delta slow wave electroencephalogram activity (0.75–4.5 Hz) which was significantly higher after daylight-LED exposure than conventional-LED exposure during the night after the exposure.⁶³ In another study, researchers looked at nurses' health and productivity in hospital workspaces which generally do not have windows. They found that the hospital work areas with windows and daylight were associated with lowered blood pressure, increased oxygen saturation, a positive effect on circadian rhythms with less morning sleepiness (as per body temperature) compared with similar work areas without windows.⁶⁴ Another study compared the sleep quality of office workers in windowless offices with office workers in offices with windows and found, compared to the group without windows, office workers with windows in the offices had more light exposure during the work week, a trend towards more physical activity and longer sleep duration as measured by actigraphy.⁶⁵

Then there is the visual impact of lighting on health and productivity. The movement to open offices and widespread use of Visual Display Terminals (VDT) has increased glare from light reflected off the VDT screen and into people's eyes and blue light exposure from the VDT screens and is associated with

health and productivity problems including: severe eye strain. There is severe eye strain from reflected light off of paper text as well. In a study (the 2016 Digital Eye Strain report) of 10,000 US adults they found 65% overall self-reported prevalence of digital eye strain symptoms. Digital eye strain is reported more frequently when people used two devices at the same time vs. one device - prevalence of 75% vs. 53%.⁶⁶ According to the 2013 Kazi personal control lighting study with 1500 working adults, 79% of employees experience at least one visual disturbance at work. Most respondents experience tired eyes; 33% experience glare off their computer screen, dry eyes and blurry vision; 18% say their eyes tear; 16% experience glare off of personal devices; 16% report glare from outdoor surfaces. The rest don't experience any of these. Of the respondents, 29 percent report headaches from visual problems. The study estimates that workers lose 15 minutes a day of productivity with eye strain issues and this amounts to about \$2000.00/year for each affected employee. A study on the impact of dry eye on work productivity indicates that the loss of productivity is about 3.27% above control. The estimated cost is \$799.00 per person associated with dry eye per year.⁶⁷

Improving health and productivity related to the visual lighting, particularly with VDTs, can be achieved through architectural design by:^{68,69,70}

1. Using more Daylight. 55% of space receives a minimum of 300 Lux for 50% of the year. 10% or less of space can receive more than 1000 Lux for 250 hours each year. Exterior window area to be 20% - 60% of exterior window wall. Above 40% window area requires exterior shading devices. Window area between 40% - 60% of exterior wall area is above 7' above the floor and has visible transmittance of 60% or more. Window area below 7' above the floor has visible transmittance of 50% or less.
2. Reducing the use of fluorescent lighting.
3. For workstations located within 15' of exterior windows, orienting workstations to be parallel (within 20 degrees) to windows so bright light isn't in front or behind workstations. 75% of all workstations are within 25' of daylight windows or atrium; 90% of all workstations are within 41' of daylight atrium or windows
4. Using controllable blinds to control day lighting in windows below 7' above the floor, or interior light shelves reflecting light to ceiling or, micro mirror film reflecting light to ceiling or, external shading devices controlled by occupant or variable opacity glass (for example electrochromic glass) reducing transmissivity by 90%.
5. Using indirect lighting.
6. To mitigate dry eye, maintain relative humidity between 40% and 60% and temperatures between 68F and 72F.
7. Having screens on VDTs with blue filters.
8. Minimum 215 LUX on a horizontal surface 30" above floor. May be dimmed with daylight. Task lighting if ambient light at workstation is below 300 Lux.⁶⁹
9. Appropriate Shielding of light sources⁶⁸
10. Light Reflectance Values (LRV): Ceilings: .8 for 80% area; Walls: .7 for 50% of area; Furniture: .5 for 50% of area;

Improving health and productivity related to non-visual lighting can be achieved by first using more daylight and as a complement to daylighting, use more blue enriched artificial light such that the exposure to students and workers has a strong total exposure throughout the day including a combination of sunlight and the melanopic lux contribution from artificial light. At least 250 equivalent melanopic lux is present within at least 75% of workstations, on a vertical plane, 4' above floor, facing occupant.⁷¹

Review Questions Lighting Quality:

14. Which statement is in the course:
- Office workers under electric and natural lighting have experienced **more** glare and sleepiness and more alertness and cognition early in the day under natural lighting compared to when they were under electric lighting Incorrect. Have reported experiencing less glare.
 - Office workers under electric and natural lighting have experienced less glare and **more** sleepiness and more alertness and cognition early in the day under natural lighting compared to when they were under electric lighting
 - Office workers under electric and natural lighting have experienced less glare and sleepiness and **less** alertness and cognition early in the day under natural lighting compared to when they were under electric lighting Incorrect. Less sleepiness and more alertness.
 - Office workers under electric and natural lighting have experienced less glare and sleepiness and **more** alertness and cognition early in the day under natural lighting compared to when they were under electric lighting
15. Which study statement is in the course:
- Studies on students in classrooms indicate **electric light** positively affects health, attention and performance including scholastic performance.
 - Studies on students in classrooms indicate natural light **negatively** affects health, attention and performance including scholastic performance.
 - Studies on students in classrooms indicate natural light **insignificantly** affects health, attention and performance including scholastic performance.
 - Studies on students in classrooms indicate natural light positively affects health, attention and performance including scholastic performance.
16. Select all statements which apply as presented in the course: Improving health and productivity related to the visual lighting, particularly with VDTs, can be achieved through architectural design by:
- Using more Daylight. 55% of space receives a minimum of 300 Lux for 50% of the year. 10% or less of space can receive more than 1000 Lux for 250 hours each year. Exterior window area to be 20% - 60% of exterior window wall. Above 40% window area requires exterior shading devices. Window area between 40% - 60% of exterior wall area is above 7' above the floor and has visible transmittance of 60% or more. Window area below 7' above the floor has visible transmittance of 50% or more.
 - Reducing the use of Fluorescent lighting.
 - For workstations located within 15' of exterior windows, orienting workstations to be parallel (within 20 degrees) to windows so bright light isn't in front or behind workstations. 75% of all workstations are within 25' of daylight windows or atrium; 90% of all workstations are within 41' of daylight atrium or windows;
 - All of the above.

2.6 Views

Studies show health, cognitive and productivity benefits from views of natural landscapes from office or classroom windows. In addition, having plants visible from work areas also showed health, cognitive and productivity benefits.

Studies on students in classrooms with windows with views of the natural landscape rather than classrooms which had no windows or windows with views of buildings, had a faster recovery from stress and mental fatigue and had higher test scores for attention.⁷² A new study gives evidence on an association between nature and wellbeing, augmenting existing evidence of a positive association between subjective wellbeing and exposure to green or natural environments in daily life.⁷³ Another study associates exposure to a natural environment and a reduction of cravings through a reduction of negative affect. A reduction of negative affect has health and productivity benefits.⁷⁴ Three studies found that exposure to natural scenes rather than urban scenes decreased the tendency to discount the future or value the future less thus reducing behavior to make changes. There is a tendency to value immediate rewards rather than future rewards. This tendency has impacted individual and society issues like: obesity, drug abuse, pollution, lack of conservation of natural resources and healthcare not focused on disease prevention but rather treatment of disease. Valuing the future consequences of a decision is an important element of good judgement.⁷⁵ In a study, three experiments were done looking at the impact of a green (with plants) and a lean office environment (without plants) on subjective perception on air quality, concentration and workplace satisfaction and on objective measures of productivity. In all three experiments, there is an enhanced outcome in the green offices. Participants finished tasks in the green offices faster than the lean offices with an increase of productivity of 15% in the green offices vs. the lean offices.⁷⁶ Another study showed an association between nature contact at work and reduced stress and reduced health complaints.⁷⁷

Improving health and productivity through views from offices or classrooms can include incorporating windows which emphasize views to natural landscapes. In addition, creating planting landscapes inside buildings which are visible from work areas is another strategy. On a smaller scale having plants at office desks can work as well.

Review Questions Views:

17. Fill in the blank per the study statement in the course: Studies on students in classrooms with windows with views of the _____ rather than classrooms which had no windows or windows with views of buildings, had a faster recovery from stress and mental fatigue and had higher test scores for attention.
 - a. Playground
 - b. Plaza
 - c. Basketball courts
 - d. Natural Landscape

18. Select all that apply per course statement: Improving health and productivity through views from offices or classrooms can include:
 - a. Incorporating windows which emphasize views to natural landscapes
 - b. Creating natural landscapes inside buildings which are visible from work areas is another strategy
 - c. On a smaller scale having plants at office desks can work as well
 - d. All of the above

2.7 Noise Levels

A sound which is loud or unpleasant or which causes a disturbance, is one definition of noise. There is much research on the impact of noise on health and productivity. Noise can come from the outside and come into a building or could be generated from the inside of a workspace or building. Noise from the outside includes: traffic, aircraft, landscaping equipment, snow blowers and sounds associated with construction. Noise can be generated on the inside of buildings including: HVAC equipment, office equipment, industrial equipment, vacuum cleaners, construction and conversations. There are auditory and non- auditory noise effects on health. Auditory effects on health include noise induced hearing loss which can occur immediately or over time by exposure to noise. Up to 24% of adults and 17% of teens have elements in their hearing tests which indicate hearing loss related to exposure to noise. Generally, sound levels below 70 dBA are unlikely to cause hearing loss, but sounds above 85 dBA can cause hearing loss. Hearing loss occurs because hair cells involved in the hearing process are damaged or die and do not grow back. Hearing loss can in turn reduce productivity through communication, attention and concentration problems leading to stress and fatigue.⁷⁸

Non-auditory impacts of noise exposure on health are numerous. It is estimated that up to 104 million individuals have been exposed to the equivalent of >70 dBA over 24 hours and at risk for hearing loss. In addition, it is calculated that 145 million people in the US have been exposed to noise levels between 55-60 dBA which increases the risk of heart disease and hypertension.⁷⁹ Non-auditory impact from noise exposure is associated with annoyance, sleep disturbance, daytime sleepiness, patient outcomes and staff performance in hospitals, increased occurrence of hypertension and cardiovascular disease, and impairs cognitive performance in schoolchildren.⁸⁰ Exposure to traffic noise during the day is associated with increased hypertension mortality in women.⁸¹ Exposure to traffic noise during the day is also associated with all cause mortality where exposure to noise levels are above 60dB for adults and with hospital admissions for elderly having strokes.⁸² Residential traffic noise exposure over a long period of time is associated with increased risk for diabetes, larger waist circumference, higher body mass index and obesity.^{83,84,85}

The exposure of children to environmental noise is associated with: behavioral problems, irritability, fatigue, increased hyperactivity and emotional symptoms.⁸⁶

Environmental noise exposure on children is associated with annoyance responses, lower well-being and stress responses, such as increased levels of adrenaline and noradrenaline. Studies suggest that noise might alter cardiovascular function in and limited evidence for an effect on low birth weight. Children's cognitive skills at school appear to be affected by noise at school according to accumulating evidence, these cognitive skills include: reading and memory, and their effects are seen in standardized test scores.⁸⁷ Many studies have shown environmental noise is negatively associated with children's learning experiences and cognitive performance.⁸⁸

There are auditory and non-auditory effects from noise on performance for children and adults: Auditory effects from noise on performance include: hearing loss and communication, attention, distraction, difficulty in hearing others speaking in conversations and concentration difficulties. Office workers are exposed to more noise and the resulting work interference because about 70% of offices in the United States now have open workspaces.⁸⁹ About 1,200 senior executives and their employees were surveyed and they discovered that 53% of their employees said that background noise lowered their work productivity and work satisfaction.⁹⁰

Background noise exposure in the workplace can increase accidents.⁹¹ During difficult and complex work, background noise exposure can reduce the worker performance and productivity.²

Non-auditory interference of noise on performance include: annoyance, sleep disturbance, daytime sleepiness, fatigue, stress responses, such as increased levels of adrenaline and noradrenaline and lower work satisfaction.

Design factors so workspaces/buildings mitigate health and production robbing noise.⁹³
Government Services Administration (GSA)

1. Site Noise:

If a building is located near loud noise sources such as traffic and airports, the windows may need to be more soundproof to reduce sound infiltration from the outside such that at about 1 hour before normal business hours, the sound pressure level of sound from the outside should be less than 50dBA. An acoustic consultant may be consulted to achieve the goal.

2. Interior noise:

- a. Develop a plan to establish quiet work areas segregated from louder conversation areas.
- b. Mechanical equipment should follow Noise Criteria (The **Noise Criteria** (NC) specifies the maximum **noise** levels that can be present in each octave band of **noise**) for the following areas:

-Open workspaces: Max NC: 40.

-Closed workspaces: Max NC: 35.

-Conference rooms and Break rooms: Max NC: 25.

-Teleconference Rooms: Max NC: 20.

- c. Conference room reverberation time: .6 seconds.
- d. Sound reduction surfaces: Noise Reduction Coefficient (A **Noise Reduction Coefficient** is an average rating of how much **sound** an acoustic product can absorb. NRC):

-Ceilings: Open workspaces: NRC: .9

-Ceilings: Conference and teleconference rooms: 50% at NRC: .8.

-Walls: Open workspaces: 25% at NRC: .8.

-Walls: Open system Furniture partitions at NRC: .8.

-Walls: Closed workspaces, Conference and teleconference spaces: 25% at NRC: .8.

- e. Wall construction: Noise Insulation Class (Is the field version of Sound Transmission Coefficient [STC]. It is a measure of how much airborne sound transmission a wall

can block from one side to another. For example, a wall with a NIC of 50, can block 50 decibels of airborne sound transmission from one side to another. NIC:

-Closed workspaces: min NIC 35.

-Conference rooms: min NIC 53.

-Teleconference rooms: min NIC 53.

1. Seal top and bottom tracks

2. Stagger gypsum board joints

3. Pack and seal all wall penetrations

-Doorways should use:

1. Gaskets

2. Sweeps

3. Non-Hollow core doors.

Review Questions Noise Levels:

19. Select all that apply per study summary: Residential traffic noise exposure over a long period of time is associated with increased risk for:
- Diabetes
 - Larger waist circumference
 - Higher Body Mass Index and obesity.
 - All of the above.
20. Select all that apply for study summary: Children's cognitive skills at school appear to be affected by noise at school according to accumulating evidence, these cognitive skills include:
- Reading.
 - Memory
 - Standardized test scores
 - All of the above
21. Fill in the blank per the study summary: About 1,200 senior executives and their employees were surveyed and they discovered that _____% of their employees said that background noise lowered their work productivity and work satisfaction.
- 25
 - 30
 - 44
 - 53
22. Select all that apply to study summary: Non-auditory interference of noise on performance include:
- Annoyance, sleep disturbance, daytime sleepiness.
 - Fatigue, stress responses, such as increased levels of adrenaline and noradrenaline
 - Lower work satisfaction.
 - All of the above

2.8 Biophilic Environment

The increasing rate of urban development throughout the world decreases access to natural environments.⁹⁴ Also, decreasing access to natural environments is the amount of time spent inside buildings which by some reports is up to 90% of our time.⁹⁵ Some research has found that even short exposure to a biophilic indoor environment (a biophilic indoor environment included natural elements: plants, water, airflow, sunlight, natural materials, biomorphic patterns and long-distance natural view) was associated with lower systolic and diastolic blood pressure and skin conductance level (lower stress level) in comparison to their baseline measures. In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (blood pressure, heart rate, heart rate variability and skin conductance level) and higher creativity scores (faster reaction times and higher creativity based on cognitive tests).⁹⁶ In another study, the indoor biophilic environment (virtual exposure through headset and physical exposure) was associated with a decrease in participants' blood pressure compared to the non-Biophilic environment: 8.6 mmHg lower systolic and 3.6 mmHg lower diastolic blood pressure. Skin conductance decreased 0.18 μ S greater than the non-biophilic setting. Short-term memory improved by 14% in the Biophilic environment. Participants experienced a decrease in negative emotions and an increase in positive emotions after experiencing the biophilic setting. Participants who experienced the biophilic environment virtually had similar physiological and cognitive responses as when experiencing the actual environment. There is the possibility of reducing stress and improving cognition by using virtual reality to experience natural elements when access to nature is not possible.⁹⁷

We have already seen from the section on views of natural landscapes from workspaces are associated with health and productivity, including faster recovery from stress and mental fatigue, scoring higher on tests related to attention;⁷² increase of productivity of 15% in the green offices (with office plants) vs. the lean offices;⁷⁶ reduced stress and reduced health complaints.⁷⁷ In addition, participants in a biophilic environment had 14% better performance in short-term memory and improved emotions compared to their performance in the non-biophilic environment.⁹⁸

We have also seen the positive impact of natural light on health and productivity including: less glare and less sleepiness and more alertness and cognition;^{60,61} positive effects on health, attention and performance;⁶² lowered blood pressure, increased oxygen saturation, a positive effect on circadian rhythms and morning sleepiness;⁶⁴ A trend towards more physical activity and longer sleep duration as measured by actigraphy.⁶⁵

More outside air - airflow - is associated with decreased sick days, decreased respiratory infections and decreased costs;¹² increase in cognitive function;¹³ students being calmer with a greater attention span.¹⁵

Realizing the health and productivity benefits of Biophilic design can be done by incorporating the design initiatives in the previous sections under: Air Quality, Water Quality, Thermal Conditions, Dust, Lighting Quality, Views and Noise levels. In addition, natural materials, open spaces and patterns can be incorporated.

Exterior: 25% of site is landscaped grounds or roof garden with 70% plantings including tree canopies.

Interior: Potted plants or planted beds should be 1% of the floor area per floor; A plant wall area on every floor should be 2% of floor area. One water feature per 100,000 square feet that is minimum 6' high with visible and audible still and running water.⁹⁹

Review Questions Biophilic Environment:

23. Select the study summary presented in the course:
- In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, heart rate variability, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, heart rate variability, and skin conductance level**) and **higher creativity scores (higher creativity based on cognitive tests)**.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate variability, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**.
24. Fill in the blank per the study summary in the course: increase of productivity of _____% in the green offices *(with office Plants) vs. the lean offices;
- 5
 - 10
 - 15
 - 20
25. Fill in the blank per Biophilic guidelines in the course: Interior: Potted plants or planted beds should be _____% of the floor area per floor;
- 12
 - 10
 - 5
 - 1

2.9 EMF Exposure

In 1985 there were 385,000 cell phones in the US, now there are 300+ million cell phones. In 1980 there were 900 cell phone towers in the US, now there are 200,000+. EMF exposure can come through cell phones and towers, WiFi wireless routers, high transmission power lines, cordless phones, major appliances and TVs, smart meters, electrical wiring in buildings, electric clocks, baby monitors, other wireless devices. The FCC has set safety standards too high as levels a hundred times

lower are found to be causing damage to biological systems as magnetic fields are quantum fields operating through quanta of magnetic flux which are very small amounts of energy: 2.07×10^{-15} Weber (Wb). A majority of recent articles showing no biological damage from EMF exposure were found to be financially supported by the cell phone industry, while financially independent studies found biological damage. Stem cells are more sensitive to EMF than Fibroblast cells and the telecommunications industry tends to use Fibroblast cells for their research. Also pulsed microwave signals have greater effect than continuous signals. When a phone is searching or between on and off modes it releases more damaging signals than in continuous mode. In an insect study, intermittent exposure is associated with decreased reproductive capacity and alters the actin-cytoskeleton network of the egg chambers and the effect is also due to DNA fragmentation.¹⁰⁰ The notion that EMF has to be thermal or ionizing radiation to be dangerous to health is not true. Recent research suggests that the mechanism of EMF impact on health may be through magnetic field effects on charged molecules or parts of molecules in the body. Magnetic fields can penetrate deeply into the body. For example, changes in cell signaling: there are voltage gated Calcium (ion) channels on cell surfaces involved in cell signaling and there are 4 protons in the gate mechanism - alternating Magnetic Fields would cause these to vibrate as they are positively charged and magnetic fields cause charged particles to move thus impacting the signaling gate and thus signaling from therapeutic effects with nitric oxide-cGMP-protein kinase G pathway stimulation to pathophysiological effects as a result of nitric oxide-peroxynitrite-oxidative stress pathway. The evidence for this mechanism is that if a Voltage Gated Calcium (ion) Channel blocker is used, it blocks the effects of the EMF consistently.

EMF exposure should be minimized as research shows it can have a range of effects including: infertility in males and females, weakened immune systems, reduced ability to repair DNA and DNA breakage, detoxification abilities reduced,^{101,102,103} impaired learning in children,¹⁰⁴ behavior problems in young boys: OCD, anxiety, impaired cognition, anxiety, paranoid thoughts, aggression and Hostility;¹⁰⁵ EMF exposure has also been linked to inflammatory conditions and ion and free radicals in the brain which are some of the factors in neurodegenerative diseases;^{106,107} Ten studies in a meta-analysis, including 1492 samples indicate exposure to mobile phones was associated with reduced sperm motility and viability. The results were consistent in experimental *in vitro* and observational *in vivo* studies.¹⁰⁸ In another study, the total motile sperm count and the progressive motile sperm count decreased due to the increase of internet usage. In line with the total motile sperm count, progressive motile sperm count also decreased with wireless internet usage compared with the wired internet connection usage.¹⁰⁹ In another study, human sperm was exposed to a laptop antenna emitting 2.45 GHz. radiation and found that it was significantly associated with lower sperm concentration, motility and morphology grading.¹¹⁰ 50 Hz magnetic field and 915 MHz microwaves under specified conditions of exposure induced responses in lymphocytes from healthy and hypersensitive donors that were similar but not identical to stress response induced by heat shock.¹⁰⁹ In another study, rats exposed for 2 h to continuous-wave 2450 MHz microwaves (SAR 1.2 W/kg), increases in brain cell DNA single-strand breaks were observed immediately as well as at 4 h postexposure.¹¹¹ In a study on the effect of 50Hz magnetic field on human neuronal cells they found cells produced NOS and O₂- oxidants but were compensated by the antioxidant catalase (CAT) activity. When 50Hz is also joined by a peroxide induced oxidative stress the CAT activity declined. This means that 50Hz Magnetic field induces oxidant stress but is normally compensated by CAT but if other oxidant stress occurs then CAT activity declines and there is net increase in oxidative stress and inflammation and thus DNA repairs are reduced.¹¹² In a mouse study, the extremely low frequency EMF may stimulate the immune system phagocytosis and consequently free radical production and thus increasing free radical reactions and the possibility of DNA damage and potential tumor development. This free radical activity can inhibit the activity of Melatonin. The

free radicals and effect on Melatonin can explain the link between EMF and Leukemia. The phagocytosis and free radicals can explain the link between EMF and immune system stimulation.¹¹³ In a study on rats, they found excessive exposure to EMF was associated with cognitive impairment and deposits in the brain similar to deposits in brains of people with Alzheimer's disease. In a mouse study of in utero exposure to 9.417 GHz Microwave EMF, they found that the male offspring demonstrated decreased learning and memory, but not the females.¹¹⁴ In a study on Radio frequency environmental exposure to 10 year old boys, the level of exposure was within the guidelines but the group receiving levels above the median level was associated with: lower scores for verbal expression/comprehension and higher scores for internalizing and total problems and obsessive-compulsive and post-traumatic stress disorders, in comparison to those boys living in areas with lower exposures.¹¹⁵ In another mice study, male mice were exposed to EMF for the last week of gestation and 7 days after that. The exposed mice demonstrated a lack of normal sociability and preference for social novelty while maintaining normal anxiety-like behavior, locomotion, motor coordination, and olfaction. Exposed mice also demonstrated decreased exploratory activity. These results associate Autism Spectrum Disorder (ASD) behavior in mice with perinatal exposure to Extremely Low Frequency EMF. We need to look more carefully at the rise in Cell Phone use (esp. use during pregnancy) and compare it with the rise in ASD incidence as the rise in cell phone use happens to correspond with a rise in Autism Spectrum Disorders from the 1990's.¹¹⁶ In a study on rabbits, exposure to 2.45 GHz EMF (WiFi carrier frequency) for one hour, 10 inches from the heart was associated with increased heart rate and blood pressure and interference with dopamine and epinephrine efficacy on the cardiovascular system.¹¹⁷ A study looks at the measurement of EMF absorption into a head using a plastic model and shows that it underestimates EMF absorption in adults and particularly the smaller and thinner skull heads of children. The measurements use specific absorption rates (SAR) which apply to heat induction which is not how the EMF damage is done. In addition, children have a higher density of stem cells which are more sensitive to EMF. Also, Testicles and Ovaries are more sensitive to EMF damage than other tissues.¹¹⁸ Children developing in the womb especially including their testicles, ovaries and brains are the most sensitive to EMF. Based on two decades of epidemiological studies, an increased risk for childhood leukemia associated with Extremely Low Frequency fields has been consistently observed such that the International Agency for Research on Cancer inserted them in the 2B section of carcinogens in 2001. There are many rat studies on the effect of WiFi and cell phone EMF associating EMF exposure with additional oxidative stress and DNA damage in Testicles.^{119,120,121,122,123,124,125,126,127} There is enough evidence from animal and human studies on EMF exposure and health outcomes to support caution about exposure to EMF in workspaces. In a study on adolescents, cell phone use was associated with verbal and figural memory tasks at baseline and after one year were completed using a standardized, computerized cognitive test battery. A decline in memory performance over one year was associated with cumulative duration of wireless phone use and more strongly with RF-EMF dose.¹²⁸ In a study of cell phone users over 10 years there was a significant association with migraines and vertigo.¹²⁹ In a study of migraine sufferers and productivity, *the* migraine sufferers lost a total of 1,301 hours of work while actually present on the job and 974 hours from absenteeism. There is also a condition called Electromagnetic Hypersensitivity (EHS): common symptoms of EHS include headaches, cognitive difficulties, sleep problems, dizziness, depression, fatigue, skin rashes, tinnitus and flu-like symptoms. EHS is recognized as a disability and accommodated in the American's with Disabilities Act.¹⁴⁰

In a 2010 report by the emerging risk team at the insurer Lloyds of London, they said that the potential health damage claims to insurers from cell phone and wireless radiation exposure would be comparable to the claims from asbestos.¹⁴²

There is a significant disagreement between the National Institute for Occupational Safety and Health (NIOSH) where high Federal limits for worker exposures to EMFs have been recommended or established in the United States,¹³⁰ and WHO (World Health Organization) which uses the International Commission on Non-Ionizing Radiation Protection (ICNIRP) where limits are established for various frequencies and the European Union which uses the ICNIRP standards to some extent.¹³¹

For example, the United States has the highest public EMF exposure limit – Power Flux Density (mW/m²) - for Radio Frequency Radiation (RFR) at 900 MHz, higher than: Japan, ICNIRP, Canada, Russian Federation, Israel, China... The US has an exposure limit six times the exposure limit in Russia and 60 times the exposure limit in Bulgaria. In addition, at 1800 MHz the US and Japan have the highest EMF exposure limit, higher than all countries – 10 times Russia and Israel exposure limit and 100 times Bulgaria's exposure limit. At 2100 MHz the US has the highest exposure limit – 100 times the exposure limit of Russia and Bulgaria. No federal policy is in force in the US related to 60Hz EMF energy. There are significant policies in other countries for 50Hz which is more bioactive than 60 Hz. (WHO) The US Federal Communications Commission has not updated their radiation standards since 1996. In 2013 the American Academy of Pediatrics warned the FCC that their standards didn't reflect the sensitivity that pregnant women and children have to EMF. The FCC declined to update their standards. The 1996 standard for cell phone output is <1.6 watts per kilogram body weight. Many cell phones now have been tested to have a higher output than that standard. The US still regards the EMF hazard is from thermal damage even with thousands of papers showing that non-thermal levels of EMF are associated with health damage, particularly in children and during pregnancy.

Approaches to mitigate EMF exposure in workspaces and buildings include:

1. Use hard wired routers instead of WiFi or keep WiFi routers at least 20' from people. Use cables for necessary technology.
2. Wiring inside buildings should be EMF shielded. Devices plugged in to outlets should be 3 prong/grounded.
3. Don't use cell phones in crowded areas.
4. Shield cell phones from EMF. Don't carry phones in pockets.
5. Turn off Bluetooth and turn on Airplane mode as much as possible on cell phones which cuts off the pulsing communication with cell phone towers.
6. Use spices with high phenolic content to protect against EMF induced Peroxynitrite biomolecular damage including: cardamom, cinnamon, cloves, cumin, nutmeg, paprika, rosemary and turmeric.¹³² Use Magnesium supplements to balance increased Calcium from EMFs effect on Voltage Gated Calcium Channels.
7. Don't use cordless phones.
8. Metal exteriors: roof and walls and low e glass can protect interior from EMF when near exterior sources of EMF.

Review Questions EMF Exposure:

26. Select all that apply to the study summary: In a study on Radio frequency environment exposure to 10 year old boys, the level of exposure was within the guidelines, but the group receiving levels above the median level was associated with: _____, in comparison to those boys living in areas with lower exposures.
- Lower scores for verbal expression/comprehension
 - Higher scores for internalizing and total problems
 - Obsessive-compulsive and post-traumatic stress disorders
 - All of the above.
27. Fill in the blank based on the study summary in the course: Based on two decades of epidemiological studies, an increased risk for childhood leukemia associated with _____ Frequency fields has been consistently observed such that the International Agency for Research on Cancer inserted them in the 2B section of carcinogens in 2001.
- Radio
 - High
 - Low
 - Extremely low
28. Fill in the blank for the study summary: In a study on adolescents, cell phone use was associated with Verbal and figural memory tasks at baseline and after one year were completed using a standardized, computerized cognitive test battery. A decline in memory performance over _____ was associated with cumulative duration of wireless phone use and more strongly with RF-EMF dose.
- a week
 - a month
 - 6 months
 - a year

3.0 Covid 19 Transmission Factors

Social distancing and wearing masks will reduce the transmission of Covid 19 in more humid months, but in the drier months of late fall, winter and early spring there is an additional challenge. When the indoor humidity gets below 40%, more of the Covid-19 virus (and other viruses) will build up in the drier, smaller, aerosol form about .12 microns in diameter or less thus increasing the risk of spreading the virus through an aerosol suspension in the air. When the relative humidity is between 40-60% more of the virus is in the bigger droplet form which is heavy and falls to the ground after traveling a few feet. The smaller form of the virus builds up into the air when the humidity is below 40% in a workspace over a few hours (half-life ~ 3 hours in the air) and in order for a mask to filter this out it has to be tight fitting and have greater filtration like a N95 mask.¹³³

Depending on the time spent in the workplace, the occupancy, the masks others are wearing and ventilation characteristics, this will determine what kind of mask to wear to protect an individual. A

tightly fitting surgical mask or N95 mask will block most of the exhaled virus (95%+) as the air between one's mouth and mask has a high Relative Humidity thus the virus is mostly in the large droplet form (Diameter ,1um to 1000um, normally 5 um).^{134,135} Other strategies which can influence the mask characteristics needed include the amount of outside air, air filtration performance and the use of germicidal Ultraviolet -C (UVC) lights in the ventilation system. Depending on the frequency of air replacements of outside air helps mitigate the amount of virus in the air. In the previous air quality section, it was reported that increasing outside air from 20 CFM to 40 CFM per person decreases the risk of respiratory infections. Depending on the frequency of air replacements through a HEPA air filter will also reduce the amount of virus in the air significantly. The top grade HEPA filter filters at almost 100% efficiency at .1 micron particle size - the SARS CoV2 virus is ~.125+_ um at HEPA filters maximum filtering efficiency.^{136,137} UVC light at 254 nm can inactivate the Covid 19 virus at almost 100% efficiency depending on the amount of light and distance from the light source. It can be incorporated in HVAC ducts to deactivate the virus in the return air. There are also far UVC light 207-222nm which may deactivate Covid-19 viruses in ambient air with low damage to materials, skin and eyes but this is still in the experimental stage.¹³⁸ The goal is making sure a workday's exposure to the virus through the filtration of a mask is as small as possible, we don't know the exact number of viruses needed to become infected, some recent research suggests as few as 10 viruses.¹³⁵ From research on similar viruses we know that somewhere between 150 and 1000+ viruses can initiate an infection.

The most important transmission route for the SARS CoV2 is through direct transmission - person to person - through droplet transmission. That is why social distancing 6+ feet and wearing a mask is most important in RH between 40-60%. The secondary transmission through aerosol can be managed through maintaining relative humidity between 40% - 60% causing most of the virus to be in a large droplet form thus falling to the floor in a few feet; In addition, the use of HEPA filters can mitigate the aerosol form of the virus if the humidity is below 40%. UVC lights can augment or possibly replace HEPA filters in the return air ducts - there is a question concerning the production of Ozone by UVC light which is harmful so unless this is determined for a particular UVC light, it would be safer to use the HEPA filters. The tertiary transmission route is from surfaces to mouth, nose or eyes. Recent research has shown this is a less important route of transmission, but still a viable route. The virus is viable on surfaces for about 72 hours maximum on plastic and stainless steel surfaces and less on other surface materials.¹³³

CDC Recommendations on Disinfection of high touch surfaces:

1. Normal routine cleaning with soap and water will decrease how much of the virus is on surfaces and objects, which reduces the risk of exposure.
2. Disinfection using EPA-approved disinfectants against COVID-19 can also help reduce the risk. Frequent disinfection of surfaces and objects touched by multiple people is important.
3. When EPA-approved disinfectants are not available, alternative disinfectants can be used (for example, 1/3 cup of bleach added to 1 gallon of water, or 70% alcohol solutions). Do not mix bleach or other cleaning and disinfection products together—this can cause fumes that may be very dangerous to breathe in. Keep all disinfectants out of the reach of children.

A new study of a polymer or oligomer available in wipes, sprays, masks PPE can inactivate the virus with near UV or visible light activation. The virus proteins coat binds to the polymer/oligomer and then releases reactive oxygen species (ROS) which then attacks the protein coat, mRNA and other virus molecules.¹³⁹

Review Questions Covid 19 Transmission Factors:

29. Fill in the blank per the study summary: The smaller form of the virus builds up into the air when the humidity is below 40% in a workspace over a few hours (half-life ~ _____ hours in the air) and in order for a mask to filter this out it has to be tight fitting and have greater filtration like a N95 mask.
- 8
 - 6
 - 4
 - 3
30. Fill in the blank per the study summary statement: The top grade HEPA filter filters at almost 100% efficiency at .1 micron particle size - the average virus is _____um at HEPA filters maximum filtering efficiency.
- ~.03
 - ~.05
 - ~.1
 - ~.125

4.0 Sample Workspace Audit

WORKSPACE: Newly renovated office space in a building: ~22,000 SF suite with 4 of 75 occupants present.

Materials and Methods:

The Air quality measurements were made with an Air quality Monitor at one central location. Light levels were made with a Light Meter at a range of workspace locations lights off and on. EMF measurements were made with an EMF Monitor at workspace locations. Sound levels were made with a sound level meter at workspace locations.

Results:

Measurements were made on June 23, 2020 10:00 - 11:00 AM.

Outside Temp: ~79 F,

Outside Relative Humidity ~68%.

Air quality

(related to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards unless otherwise noted):

Formaldehyde: ~.040 mg/m³ = 32 ppb > 27 ppb

TVOC ~.165 mg/m³ < .500 mg/m³ (Allen et al, 2016) The measurement of TVOCs at .165 mg/m³ is much lower than .500 mg/m³ above (should lower in 2-3 months of out-gassing of materials), thus associated with cognition/productivity benefits, but when it is fully occupied it would be higher than the baseline.

Particulate matter: 2.5 micron: $\sim .002 \text{ mg/m}^3 < .015 \text{ mg/m}^3$; 10 micron: $\sim .002 \text{ mg/m}^3 < .050 \text{ mg/m}^3$. The measurement of Particulate matter (PM) 2.5 was on the low level: $.002 \text{ mg/m}^3 < \text{ASHRAE 62.1 - 2013 level } .015 \text{ mg/m}^3$.

CO2 level $\sim 507 \text{ ppm} < 800 \text{ ppm}$ (WELL) However, the space was not fully occupied as there were only 4 people in the space at the time. The measurement of 507 ppm CO2 in the suite is good, but with only 4 occupants it would indicate that when it is fully occupied, the CO2 levels would be much higher than 560 ppm thus associated with less cognition and productivity benefits. The CO2 level reflects the level of outside air ventilation in the space particularly at full occupancy: the lower the CO2 level is, down toward outside levels of 350 to 450 ppm, the higher the outside air ventilation needed to achieve that at full occupancy. This is of course important during this COVID 19 pandemic. It can be mitigated by increasing outside air intake through altering the dampers of the base building or expediently by occupying the space with less people to achieve the 40 CFM of outside air per person green + goal.

Thermal Conditions:

Temperature: $73 \text{ F} < 77 \text{ F}$ but greater than 68 F which is optimal.

Humidity: 54% Relative Humidity, between 40% - 60% RH, measured during a humid period but not a dry period.

Lighting Quality:

Light level and spectrum: Light Locations: a. Lights on: toward wall 48" above floor in front of workstation (typ.): 282 lux (lx) a'. Electric Lights off or daylight: 127 lx toward wall. b. Lights on: 240 lx toward wall. b' Lights Off: daylight 12 lx toward wall. c. Lights on: 278 lx toward wall. c Lights off: daylight 21 lx toward wall.

Melanopic Ratio = Melanopic Lux/Photopic Lux. For suite LED 3500K lighting (see Table 1 for Melanopic ratio) = $\sim .62$; Equivalent Melanopic Lux (EML) = daylight + $(.62) \times$ (electric light lux). EML for location a= 223 lx EML for location b= 153 lx EML for location c= 180 lx < minimum 200 EML from 9:00AM - 1:00PM daily (WELL)

The measured daylight levels in the suite were very low, 12 -127 lx, because of the dark tinted windows and tall buildings surrounding the building, compared to the 1250 Lux of daylight and were mostly not above - 153 lx, 180 lx and 223 lx - the minimum for Equivalent Melanopic Lux (EML) - total amount of light in the blue wavelength range of 480-490 nm - 200 EML on a vertical surface 48 inches above the floor at the work space (WELL).

Noise Levels:

The background sound in the new space - 42 - 46 dB - was above the preferred 35 dB for unoccupied spaces. The sound levels need to be measured at full occupancy and particularly vulnerable for lower productivity are the people occupying the open work stations - preferred average <45 dB background noise (WELL) but are above this level while not being fully occupied (4 people in space). Chronic exposure to higher sound levels approaching 55-60 dB is stressful, distracting and increase the risk for hypertension and possibly diabetes and a higher BMI. This can be mitigated by modifications to the HVAC system to be quieter and a higher sound absorption (NRC) in the open system furniture and in the office in general by adding sound absorption panels.

Sound level Locations: a. 44 dB b. 46 dB. c. 42 dB Ideally should be <35 dB before occupancy.

EMF Exposure:

Identification of electromagnetic field and magnetic field hot spots: Location:

1. 93 Volt/Meter (V/M) .38 micro/Tesla (uT) > World Health Organization's (W.H.O.) caution levels above .3 - .4 uT.
2. 105 V/M
3. 94 V/M .24 uT
4. 91 V/M .26 uT
5. 61 V/M .32 uT In W.H.O.s caution levels above .3 - .4 uT

There were 5 elevated EMF hotspots - above 40 V/M - identified at the work stations even though the computers in general were disconnected.

Location #1 at .38 uT and location #5 at .32 uT was in World Health Organization's (WHO) caution range of above .3 to .4 uT. It would be worth exploring further to see what frequency the EMF is - 60Hz or higher.

Biophilic Environment:

Moderate Biophilic Environment: Earth tones with a serene feel; Carpet flooring and wood flooring; wood like cabinets, wood doors, wood like wall surfaces; Window view with buildings and some urban trees.

A water feature in the drier months could improve the Biophilic environment and the humidity.

Dust:

No walk off mat at entry to keep dust from getting into the space - Cleaning surfaces after vacuuming with HEPA filter? The relatively low density of PM 10 and PM 2.5 and low VOC measurements indicates a minimal level of dust in the air.

Discussion on audit:

It is important to realize these measurements are a snap shot at a particular time and will vary under a variety of conditions: the weather outside, new finishes, fixtures, furniture and the occupancy are some of the most significant conditions. Measurements of humidity sound and CO2 should also be done when a space is fully occupied and in the winter when it is the driest time of the year. VOC and Formaldehyde measurements should be done again in 2-3 months to allow for out-gassing of new materials.

5.0 Summary

It is important to understand the full extent of the risks and benefits of the factors for healthy workspaces and buildings to fully appreciate the factors in the design process of the workspaces and buildings. In the heat of the design process, weighing literal costs vs. benefits, it is critical to understand the true weight of the factors in terms of real productivity benefits and minimizing morbidity and mortality. Without that clarity, it can be very hard to near impossible to defend extra costs or effort

related to incorporating healthy factor optimization. For example, providing extra humidity in the drier months which may increase costs up front but reduces costs overall by reducing annoyances like dry eye and throats, headaches, respiratory infections and sick days. There are similar issues with increased outside air, but the investment in energy recovery ventilation (ERV) systems, can turn into a net savings in addition to savings related to increased cognitive function and productivity and decreased respiratory infections, chronic conditions and sick days. There are also cost or design intent issues with the other factors which have productivity benefits and mitigation of morbidity and mortality risks, as previously discussed in the course.

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Chris Hubbard Biography:

Chris Hubbard AIA, LEED-AP, CNU-A, CAM has been a principal and co-founder of WHA Architecture and Planning since 1990. He has over thirty-seven years experience in all phases of residential, commercial, government, interior and walkable mixed use projects with an interest in creating healthy environments. Mr. Hubbard specializes in pedestrian centered, Biophilic (wellness promoting) architecture and planning, particularly the development of rich, dynamic, human scaled places and wellness promoting Architecture, which are sympathetic to a given context. He is also a scientist who researches the connection between Architecture and Planning and health. He is a New Urbanist architect and planner and CNU Charter and accredited Member producing New Urbanist documentaries and video lectures and speaking on CNU panels. Currently he has designed a variety of TOD, residential buildings from custom single-family attached/detached houses to mid rise mixed-use condominiums in the Arlington Metro corridor and Embrey Mill a 1000 acre, mixed use, walkable community with 2000 mixed dwelling units, 1.5 million square foot mixed commercial and civic elements. His projects, reviews and interviews have been published in architectural publications and catalogues. He has a Masters in Architecture and a Bachelors in Biochemistry from Virginia Tech and is a licensed Architect in Virginia and Massachusetts, LEED-AP, CNU Accredited and NCARB certified.

He also worked on a fellowship/PhD in Biochemistry at the Medical College of Virginia. In addition, he holds a Masters in Physiology and Biophysics with an Emphasis in Complementary and Alternative Medicine from Georgetown University Medical Center. He is currently sponsored as an associate researcher at the Georgetown University Medical Center researching the impact of architecture and planning on health. He is also researching the mechanism of acupuncture meridians. Chris was recently invited to and participated in a 3 day Dietary Supplement Practicum at the National Institutes of Health furthering his knowledge of orthomolecular health mechanisms.

Table 1: Melanopic Ratio

To calculate the equivalent melanopic lux (EML), multiply the visual lux (L) by this ratio (R): $EML = L \times R$. For example, if incandescent lights provide 200 lux in a space, they will also produce 108 equivalent melanopic lux. If daylight is modeled to provide the same visual brightness (200 lux), it will also provide 220 equivalent melanopic lux.¹⁴¹

CCT (K)	Light Source	Ratio
2950	Fluorescent	0.43
2700	LED	0.45
2800	Incandescent	0.54
4000	Fluorescent	0.58
4000	LED	0.76
5450	CIE E (Equal Energy)	1.00
6500	Fluorescent	1.02
6500	Daylight	1.10
7500	Fluorescent	1.11

Review Question Answers:

1. Indoor air can have up to _____ times the concentration of outdoor pollutants as outdoor air, per the US Environmental Protection Agency as in the statement presented in this course?
 - a. 10, Incorrect not 2
 - b. 20, Incorrect not 2
 - c. 5, Incorrect not 2
 - d. 2, Correct – 2 is mentioned

2. There is research which associates increased outside air with decreased sick days, decreased respiratory infections and _____ as in the statement presented in the course?
 - a. Increased tobacco smoke. Incorrect - not mentioned and more likely decreased tobacco smoke.
 - b. Decreased Marijuana smoke. Incorrect – not mentioned in statement.
 - c. Decreased Costs. Correct – Outside air is associated with decreased costs including reduction of sick days and increased performance.
 - d. Increased Ozone. Not mentioned in statement and more likely decreased Ozone.

3. Research at Harvard University School of Public Health associates an increase in cognitive function with an increase in outside air per person from _____ as in the statement presented in the course.
 - a. 20 CFM to 40 CFM – Correct this was mentioned in statement and in the research.
 - b. 20 CFM to 25 CFM – Incorrect, not mentioned in statement or research.
 - c. 20 CFM to 30 CFM – Incorrect, not mentioned in statement or research.
 - d. 20 CFM to 35 CFM – incorrect, not mentioned in statement or course.

4. What are three factors associated with increases in cognitive function as presented in the course?
 - a. Increased outside air, increasing conventional CO₂ levels from 560 ppm to 900+ppm and reducing conventional Total Volatile Organics from 500ug/M³ to 50ug/M³. incorrect – these are presented in the course but reducing conventional CO₂.
 - b. Increased Marijuana smoke, reducing conventional CO₂ levels from 900+ppm to 560ppm and reducing conventional Total Volatile Organics from 500ug/M³ to 50ug/M³. Incorrect – Marijuana smoke wasn't mentioned as a factor.
 - c. Increased outside air, reducing conventional CO₂ levels from 900+ppm to 560ppm and increased Ozone levels. Incorrect – Ozone wasn't mentioned as a factor for increased cognitive function.
 - d. Increased outside air, reducing conventional CO₂ levels from 900+ppm to 560ppm and reducing conventional Total Volatile Organics from 500ug/M³ to 50ug/M³. Correct – these factors were mentioned as associated with increased cognitive function.

5. Fill in the blank for the statement in the course. In the American Society of Civil Engineers 2013 Report Card for America's Infrastructure, they gave a _____ for drinking water.
- A+ Incorrect – not in statement in course.
 - B+ Incorrect – not in statement in course.
 - C+ Incorrect – Not in statement in course.
 - D+ Correct – in statement in course.
6. Fill in the blank for statement in the course: Due to insufficient treatment, Disinfection By-products and pollution there may be organic chemicals in the drinking water such as _____.
- Lead – Incorrect. Lead is an inorganic chemical and not in statement.
 - Copper – Incorrect. Copper is an inorganic chemical and not in statement.
 - Iron – Incorrect. Iron is an inorganic chemical and not in statement.
 - Polyfluorinated and Halogenated hydrocarbons Correct. These are organic chemicals in the statement.
7. Fill in the blank in the statement presented in the course with all that apply: Polyfluoroalkyl Substances (PFAS) in the drinking water have been associated with _____.
- Weight loss. Incorrect. Obesity not weight loss.
 - Low cholesterol. Incorrect. High Cholesterol.
 - Cancer, Obesity, High Cholesterol and endocrine disruption. Correct. All per statement in course.
 - Obesity, High Cholesterol and endocrine disruption. Incorrect. C is a better answer as it includes Cancer as well which is in the course statement.
8. What are the top three causes of outbreaks in drinking water per top ten list in this course.
- Copper, Salmonella and Hepatitis A. Incorrect. They are 6,7 and 8.
 - Shigell, Campylobacter and Copper. Incorrect. These are 4,5 and 6 on the list.
 - Norovirus, Shigella and Campylobacter. Incorrect. These are 3, 4 and 5 on the list.
 - Giardia, Legionella and Norovirus. Correct. These are 1,2 and 3 on the list.
9. Indicate all that apply to the summary statement in the course: There are increases in sick Building Syndrome symptoms including: _____ when people feel excessively warm in buildings.
- Negative mood and increased heart rate. Incorrect. Not all that apply.
 - Increased respiration, and increased CO₂ partial pressure in the lungs. Incorrect. Not all that apply.
 - Lower saturation of O₂ in the lungs and feelings of fatigue. Incorrect. Not all that apply.
 - All of the above. Correct. All that apply to statement in the course.

10. Fill in the blanks per statement in the course: _____ temperatures increase the survivability of coronaviruses in the air and thus leads to _____ infection transmission.
- Higher; increased. Incorrect. Higher temperatures lower survivability.
 - Lower; decreased. Incorrect. Lower temperatures lead to increased infections.
 - Higher; Decreased. Incorrect. Higher temperatures decrease survivability of coronaviruses and lead to decreased infection.
 - Lower; Increased. Correct. Lower temperatures increase survivability of coronaviruses and lead to increased infections.
11. Fill in the blanks per the statement in the course: Research shows that Absolute Humidity (AH) is associated with the survival and the transmission of the influenza virus - _____ absolute humidity _____ the survival time of the virus and increases the transmission of the flu virus.
- Low; Decreases. Incorrect. Low AH increases the survival time of the virus.
 - High; Decreases. Incorrect. High AH decreases the survival time of the virus but doesn't increase the transmission.
 - High; Increases. Incorrect. High AH decreases the survival time of the virus.
 - Low; Increases. Correct. Low AH increases the survival time of the virus and increases the transmission of the virus.
12. Fill in the blank as per statement in course: In a study of a 70 elementary school district with 3,109 students in the southwestern United States, they found that there was an increase of 12-13 points in the students mean mathematics scores associated with each 1°C decrease in temperature within the range of 20-25° Celsius (_____ degrees Fahrenheit).
- 75 to 66 Incorrect. Lower upper and lower temperatures.
 - 77 to 64 Incorrect. Lower limit lower
 - 77 to 66 Incorrect. Lower limit lower.
 - 77 to 68 Correct. Range per study.
13. Select all that apply to the list of simple methods to reduce toxic dust in a workspace or building as presented in the course:
- A cleanable entryway system compose of grills, grates or slots for easy cleaning below as wide as the entry and about 10' in direction of travel, or, cleanable rollout mat the width of the entry and 10' long
 - A MERV 13 outdoor air filtration and a MERV 8 for indoor air filtration system and Entryway seal with revolving doors or vestibule.
 - Cleanable flooring: No wall-to-wall carpet, only removeable rugs, carpet tiles or hard surfaces. Use mops, rags and dusters on non-porous surfaces and vacuum with HEPA rated filter on other surfaces.
 - All of the above, correct, these are all simple methods to reduce toxic dust

14. Which statement is in the course:

- a. Office workers under electric and natural lighting have experienced **more** glare and sleepiness and more alertness and cognition early in the day under natural lighting compared to when they were under electric lighting Incorrect. Have reported experiencing less glare.
- b. Office workers under electric and natural lighting have experienced less glare and **more** sleepiness and more alertness and cognition early in the day under natural lighting compared to when they were under electric lighting
- c. Office workers under electric and natural lighting have experienced less glare and sleepiness and **less** alertness and cognition early in the day under natural lighting compared to when they were under electric lighting Incorrect. Less sleepiness and more alertness.
- d. Office workers under electric and natural lighting have experienced less glare and sleepiness and **more** alertness and cognition early in the day under natural lighting compared to when they were under electric lighting. Correct. This is the statement in the course.

15. Which study statement is in the course:

- a. Studies on students in classrooms indicate **electric light** positively affects health, attention and performance including scholastic performance. Incorrect. Natural light positively affects ...
- b. Studies on students in classrooms indicate natural light **negatively** affects health, attention and performance including scholastic performance. Incorrect. Natural light positively affects...
- c. Studies on students in classrooms indicate natural light **insignificantly** affects health, attention and performance including scholastic performance. Incorrect. Natural light positively affects...
- d. Studies on students in classrooms indicate natural light positively affects health, attention and performance including scholastic performance. Correct. Natural light positively affects...

16. Select all statements which apply as presented in the course: Improving health and productivity related to the visual lighting, particularly with VDTs, can be achieved through architectural design by:
- Using more Daylight. 55% of space receives a minimum of 300 Lux for 50% of the year. 10% or less of space can receive more than 1000 Lux for 250 hours each year. Exterior window area to be 20% - 60% of exterior window wall. Above 40% window area requires exterior shading devices. Window area between 40% - 60% of exterior wall area is above 7' above the floor and has visible transmittance of 60% or more. Window area below 7' above the floor has visible transmittance of 50% or more. Incorrect. D includes all statements which apply
 - Reducing the use of Fluorescent lighting. Incorrect. D includes all statements which apply.
 - For workstations located within 15' of exterior windows, orienting workstations to be parallel (within 20 degrees) to windows so bright light isn't in front or behind workstations. 75% of all workstations are within 25' of daylight windows or atrium; 90% of all workstations are within 41' of daylight atrium or windows; Incorrect. D includes all statements which apply.
 - All of the above. Correct. This includes all statements which apply.
17. Fill in the blank per the study statement in the course: Studies on students in classrooms with windows with views of the _____ rather than classrooms which had no windows or windows with views of buildings, had a faster recovery from stress and mental fatigue and had higher test scores for attention.
- Playground Incorrect. Not in statement and not natural.
 - Plaza Incorrect. Not in statement and not natural.
 - Basketball courts Incorrect. Not in statement and not natural.
 - Natural Landscape Correct. This is in the study statement.
18. Select all that apply per course statement: Improving health and productivity through views from offices or classrooms can include:
- Incorporating windows which emphasize views to natural landscapes. Incorrect. D includes all that apply.
 - Creating natural landscapes inside buildings which are visible from work areas is another strategy. Incorrect. D includes all that apply.
 - On a smaller scale having plants at office desks can work as well. Incorrect. D includes all that apply.
 - All of the above. Correct. This answer includes all that apply.
19. Select all that apply per study summary: Residential traffic noise exposure over a long period of time is associated with increased risk for:
- Diabetes Incorrect. More apply.
 - Larger waist circumference Incorrect. More apply.
 - Higher Body Mass Index and obesity. Incorrect. More apply.
 - All of the above. Correct. All apply.

20. Select all that apply for study summary: Children's cognitive skills at school appear to be affected by noise at school according to accumulating evidence, these cognitive skills include:
- Reading. Incorrect. More that apply...
 - Memory. Incorrect. More that apply.
 - Standardized test scores. Incorrect. More that apply.
 - All of the above. Correct. This includes all that apply.
21. Fill in the blank per the study summary: About 1,200 senior executives and their employees were surveyed and they discovered that _____% of their employees said that background noise lowered their work productivity and work satisfaction.
- Incorrect. Not in summary.
 - 30 Incorrect. Not in summary.
 - 44 Incorrect. Not in summary.
 - 53 Correct. Number in study summary.
22. Select all that apply to study summary: Non-auditory interference of noise on performance include:
- Annoyance, sleep disturbance, daytime sleepiness. Incorrect. More apply.
 - Fatigue, stress responses, such as increased levels of adrenaline and noradrenaline. Incorrect. More apply.
 - Lower work satisfaction. Incorrect. More Apply.
 - All of the above. Correct. All apply.
23. Select the study summary presented in the course:
- In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, heart rate variability, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**. Correct. Per study summary.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**. Incorrect. Missing heart rate variability.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate, heart rate variability, and skin conductance level**) and **higher creativity scores (higher creativity based on cognitive tests)**. Incorrect. Missing faster reaction times.
 - In a randomized, crossover virtual reality study, 30 participants experienced three different biophilic designed spaces, compared to the base case, participants had consistently lower level of physiological stress indicators (**blood pressure, heart rate variability, and skin conductance level**) and **higher creativity scores (faster reaction times and higher creativity based on cognitive tests)**. Incorrect. Missing heart rate.

24. Fill in the blank per the study summary in the course: increase of productivity of _____% in the green offices *(with office Plants) vs. the lean offices;
- 5 Incorrect. Not in summary.
 - 10 Incorrect. Not in summary.
 - 15 Correct. 15% in summary.
 - 20 Incorrect. Not in summary.
25. Fill in the blank per Biophilic guidelines in the course: Interior: Potted plants or planted beds should be _____% of the floor area per floor;
- 12 Incorrect. Not in guidelines.
 - 10 Incorrect. Not in guidelines.
 - 5 Incorrect. Not in guidelines.
 - 1 Correct. Number per guidelines.
26. Select all that apply to the study summary: In a study on Radio frequency environment exposure to 10 year old boys, the level of exposure was within the guidelines, but the group receiving levels above the median level was associated with: _____, in comparison to those boys living in areas with lower exposures.
- Lower scores for verbal expression/comprehension. Incorrect. More apply.
 - Higher scores for internalizing and total problems. Incorrect. More apply.
 - Obsessive-compulsive and post-traumatic stress disorders. Incorrect. More apply.
 - All of the above. Correct. All choices apply.
27. Fill in the blank based on the study summary in the course: Based on two decades of epidemiological studies, an increased risk for childhood leukemia associated with _____ Frequency fields has been consistently observed such that the International Agency for Research on Cancer inserted them in the 2B section of carcinogens in 2001.
- Radio Incorrect. Not in summary.
 - High Incorrect. Not in summary.
 - Low Incorrect. Not in summary.
 - Extremely low Correct. In the summary.
28. Fill in the blank for the study summary: In a study on adolescents, cell phone use was associated with Verbal and figural memory tasks at baseline and after one year were completed using a standardized, computerized cognitive test battery. A decline in memory performance over _____ was associated with cumulative duration of wireless phone use and more strongly with RF-EMF dose.
- a week Incorrect. Not duration in summary.
 - a month Incorrect. Not duration in summary.
 - 6 months Incorrect. Not duration in summary.
 - a year Correct. This is duration in summary.

29. Fill in the blank per the study summary: The smaller form of the virus builds up into the air when the humidity is below 40% in a workspace over a few hours (half-life ~ _____ hours in the air) and in order for a mask to filter this out it has to be tight fitting and have greater filtration like a N95 mask.
- 8 Incorrect. Not in summary.
 - 6 Incorrect. Not in summary.
 - 4 Incorrect. Not in summary.
 - 3 Correct. Number in summary Statement.
30. Fill in the blank per the study summary statement: The top grade HEPA filter filters at almost 100% efficiency at .1 micron particle size - the average virus is _____um at HEPA filters maximum filtering efficiency.
- ~.03 Incorrect. Not in summary.
 - ~.05 Incorrect. Not in summary
 - ~.1 Incorrect. Not in summary.
 - ~.125 Correct. In summary statement.