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Indoor Air Pollution

Curriculum Unit 18.02.08
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Introduction

Breathing clean air is a fundamental requirement of life. The quality of air inside homes, offices, schools, hospitals and other public buildings is an essential determinant of a healthy life and people's well-being. Indoor air is a dominant exposure for humans. More than half of a person's air intake during a lifetime is air inhaled in the home. Humans spend most of their life indoors (in many regions more than 90%). It is therefore easy to understand that the most important environment in relation to our health is the indoor environment [1]. Thus, a significant amount of illnesses related to environmental exposures stem from indoor air exposure. Indoor air was believed to be a major environmental factor for more than a hundred years, from the start of the hygienic revolution, around 1850, until outdoor environmental issues entered the scene, and became dominant around 1960.

More than one third of the world's population - 2.9 billion people - still burn wood, charcoal and dung indoors to keep warm and cook food. The World Health Organization (WHO) estimates that 4.3 million people in 2012 lost their lives due to indoor air pollution. The new report from the UN Climate Panel recognizes that "at present the worldwide burden of human ill-health from climate change is relatively small compared with effects of other stressors." Estimates from the WHO and others suggest that between 30 and 150 times more people are killed due to indoor air pollution than global warming. Yet, the latter dominates the headlines [2].

Central environmental issues today are outdoor air quality, energy use, climate change, air, soil and water pollution, deforestation, acid rain, ozone layer depletion, waste management, genetically modified organisms (GMO's) and sustainable buildings, but not indoor air quality (IAQ). Many political figures name climate change the "defining issue of our times" and "perhaps the world's most fearsome weapon of mass destruction." Yet, the biggest environmental killer we face is actually indoor air pollution.

There is mounting evidence that exposure to indoor pollutants is the cause of excessive morbidity and mortality. In developing regions indoor unvented burning of biomass for cooking is the cause of at least 2,000,000 deaths a year (mainly women and children), and in the developed world indoor air quality is a main cause of allergies, airway infections, other hypersensitivity reactions and, through indoor radon, asbestos, and environmental tobacco smoke, can lead to cancer. Allergies, airway infections and sick building syndrome are associated with, e.g., ''dampness'', a low ventilation rate, and plasticizers [7]. In the future more emphasis must be given to IAQ and health issues.

The environment within a shelter is often more polluted than outdoor air due to indoor sources such as human, chemical and microbial emissions, open fires (still a major source of indoor air pollution in many developing regions) chemical off gassing from building materials, smoking, indoor activities, etc. This was and is the basis of the need for ventilation [1]. One important mechanism of improving IAQ is therefore removal of indoor sources. During the breakthrough of modern hygiene, from mid-19th century, indoor environmental issues received much attention, as did the quality of drinking-water and the treatment of sewage (e.g., linked to plagues such as cholera and tuberculosis). The main purpose of buildings is to create a climate more suitable for persons and processes than the outdoor climate. Consequently, a second control of IAQ, the ventilation in buildings, was created to dilute and remove the pollutants produced indoors.

In this unit, students will learn about main indoor pollutants, their origin and effects on human health. They will also learn the difference between the inorganic and organic indoor pollutants and we will address a few basic concepts about organic chemistry.

By exposing students to the basic concepts of indoor air pollution, introducing them to the health effects of main indoor air pollutants and making them aware of the importance of a good indoor air quality, teachers can contribute to the well-being of their classrooms and help to reduce the risk of health problems among student population. In addition, by understanding the consequences of short and long term exposure to indoor air pollutants, the students can become proactive and take measures to reduce the indoor air pollution in the classroom. Last, but not least, it is a teacher’s hope that introducing these concepts at an earlier age (middle school), will help to spark students’ interest in chemistry and mathematics.

Unit Content

This unit will include an overview of the main sources of indoor air pollution (breathing and carbon dioxide emissions in highly occupied classrooms, cigarette smoking, use of electronic cigarettes and emissions of organic compounds resulted from the use of cleaning agents, building materials, etc.). Students will learn about the differences between inorganic and organic compounds, aromatic hydrocarbons, perform experiments and do computations to solve real life problems involving moles, concentration, volume and rates of change for different chemicals. They will use carbon dioxide monitors to compare and contrast the carbon dioxide concentrations inside and outside the classroom, as well as studying what happens when a classroom is ventilated properly.

1. Sources of Indoor Air Pollution

Part 1 is a review of indoor air pollutants. Indoor pollution sources that release gases or particles into the air are a primary cause of indoor air quality problems. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough fresh outdoor air to dilute emissions from indoor sources. High temperature and humidity levels can also increase concentrations of some pollutants through the higher release rate of some chemicals with temperature or the growth of mold on damp building materials. The following source descriptions provide emphasis on the air pollutants (asbestos, carbon monoxide, formaldehyde and pressed wood products, lead, nitrogen dioxide, radon, indoor particulate matter and sources such as secondhand smoke/tobacco smoke, stoves, heaters, fireplaces and volatile organic compounds) [8].

Asbestos is a mineral fiber that occurs in rock and soil. Because of its fiber strength and heat resistance it has been used in a variety of building construction materials for insulation and as a fire-retardant. Asbestos has been used in a wide range of building materials, such as roofing shingles, ceiling and floor tiles, paper products or asbestos based cement products.

Elevated concentrations of airborne asbestos can occur after asbestos-containing materials are disturbed by cutting, sanding or other remodeling activities. Improper attempts to remove these materials can release asbestos fibers into the air in buildings, increasing asbestos levels and endangering people living in those homes.

Exposure to asbestos increases the risk of developing lung disease including cancer. That risk is made worse by smoking. In general, the greater the exposure to asbestos, the greater is the chance of developing harmful health effects.

Carbon monoxide (CO) is an odorless, colorless and toxic gas. Because it is impossible to see, taste or smell, CO can kill humans before they are aware it is in their home. The effects of CO exposure can vary greatly from person to person depending on age, overall health and the concentration and length of exposure.

Carbon monoxide is produced during the incomplete combustion of wood and fossil fuels. Sources of CO include: unvented kerosene and gas space heaters, leaking chimneys and furnaces, back-drafting from furnaces, gas water heaters, wood and gas stoves, fireplaces, generators and other gasoline powered equipment, automobile exhaust from attached garages and tobacco smoke

Exposure to carbon monoxide leads to the formation of carboxyhemoglobin in the blood, which inhibits oxygen intake. At low concentrations, the health effects are fatigue and chest pain; at higher concentrations, impaired vision and coordination, headaches, dizziness, confusion and nausea. CO exposure is fatal at very high concentrations.

Formaldehyde (HCHO) is a colorless, flammable gas at room temperature and has a strong odor. It is an important chemical used widely by industry to manufacture building materials and numerous household products. Also, formaldehyde is a by-product of combustion and other natural processes. Thus, it may be present in substantial concentrations both indoors and outdoors. Formaldehyde can cause irritation of the skin, eyes, nose, and throat. High levels of exposure may cause some types of cancers [12].

Lead (Pb) has long been recognized as a harmful environmental pollutant. Lead is particularly dangerous to children because their growing bodies absorb more lead than adults do and their brains and nervous systems are more sensitive to the damaging effects of lead. Babies and young children can also be more exposed to lead because they often put their hands and other objects that can have lead from dust or soil on them into their mouths. Children may also be exposed to lead by eating and drinking food or water containing lead or from dishes or glasses that contain lead, inhaling lead dust from lead-based paint or lead-contaminated soil or from playing with toys with lead paint. Before the health effects and environmental distribution of lead were fully understood it was used in paint, gasoline, water pipes, and many other household products.

Nitrogen dioxide (NO_2) The two most prevalent oxides of nitrogen are nitrogen dioxide (NO_2). NO_2 is a highly reactive oxidant and is corrosive. The primary sources indoors are combustion processes, such as unvented combustion appliances (gas stoves), appliances with defective installations, tobacco smoke and kerosene heaters. Nitrogen dioxide acts mainly as an irritant affecting the eyes, nose, throat and respiratory tract [13].

Extremely high-dose exposure (as in a building fire) to NO_2 may result in pulmonary edema and diffuse lung injury [13]. Continued exposure to high NO_2 levels can contribute to the development of acute or chronic bronchitis. Low level NO_2 exposure may increase the risk of respiratory infections, especially in young children. Average level in homes without combustion appliances is about half that of outdoors. In homes with gas stoves, kerosene heaters or un-vented gas space heaters, indoor levels often exceed outdoor levels.

Radon (Rn) is a naturally occurring radioactive gas that can cause lung cancer. Is seeps into buildings from the surrounding soil and rocks. In some cases, well water may be a source of radon. The U.S. EPA ranks indoor radon among the most serious environmental health problems facing humans today. After smoking, it is the second leading cause of lung cancer in the United States causing an estimated 21,000 lung cancer deaths a year.

A nationwide survey of radon levels in schools estimates that nearly one in five has at least one schoolroom with a short-term radon level above the action level of 4 pCi/L (picoCuries per liter) - the level at which U.S. EPA recommends that schools take action to reduce the level. U.S. EPA estimates that more than 70,000 schoolrooms in use today have high short-term radon levels [9].

Indoor particulate matter (also referred to as PM or particle pollution) is a complex mixture of solid and/or liquid particles suspended in air. These particles can vary in size, shape and composition. The U.S. EPA is especially concerned about particles that are 10 micrometers in aerodynamic diameter or smaller (PM_{10}) because these particles are inhalable and too small to rapidly settle out of indoor air. Once inhaled, particles can affect the heart and lungs and in some cases cause serious health effects.

Indoor particulate matter can be generated through cooking, combustion activities (including burning of candles, use of fireplaces, use of unvented space heaters or kerosene heaters, cigarette smoking) and the re-suspension of floor dust due to indoor high occupant activity. A recent study indicate that 70% of indoor fungal aerosol particles and 80% of airborne allergenic fungi were associated with indoor emissions. On average, 81% of allergenic fungi from indoor sources come from occupant-generated emissions [5].

2. Is CO_2 an Indoor Pollutant?

Part 2 will address carbon dioxide in buildings. Because humans produce and exhale carbon dioxide (CO_2), concentrations in occupied indoor spaces are higher than concentrations outdoors. As the ventilation rate (i.e., rate of outdoor air supply to the indoors) per person decreases, the magnitude of the indoor-outdoor difference in CO_2 concentration increases. Consequently, peak indoor CO_2 concentrations, or the peak elevations of the indoor concentrations above those in outdoor air, have often been used as rough indicators for outdoor-air ventilation rate per occupant. The need to reduce energy consumption provides an incentive for low rates of ventilation, leading to higher indoor CO2 concentrations [3].

The graph below (Figure 1) shows that in the absence of ventilation, CO_2 concentrations in a room with closed windows and doors could increase to 1000 ppm within 45 minutes of enclosure.

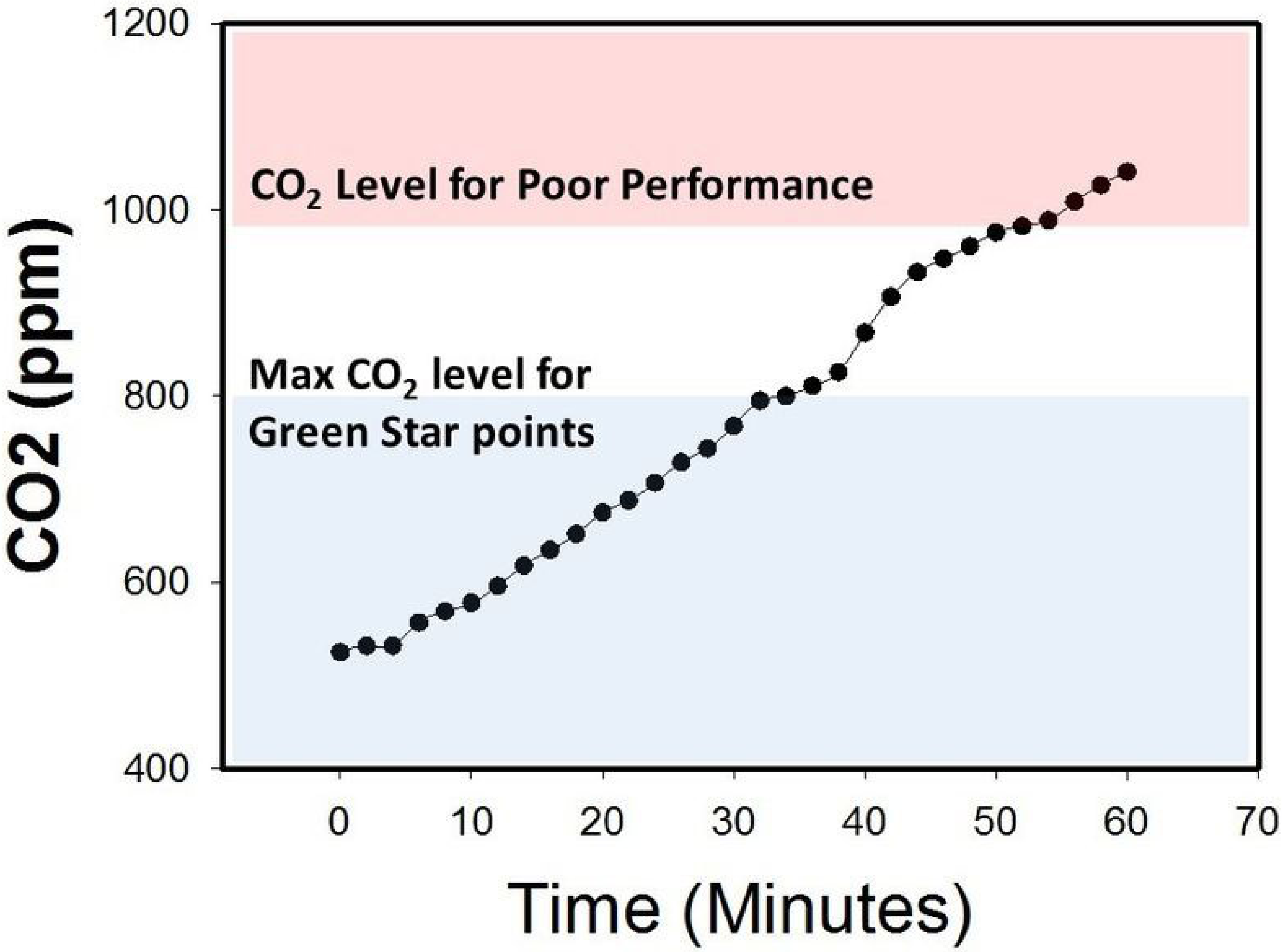

Figure 1. Carbon Dioxide concentration in a closed room with no ventilation. Source: https://en.wikipedia.org/wiki/File:Edaphic_Scientific_CO2_Levels_for_HVAC_and_IAQ.jpg

Concentrations of CO_2 inside highly occupied buildings range from outdoor levels up to more than 3,000 ppm. Prior research in industrial settings has documented direct health effects of CO_2 on humans, but only at concentrations much higher than those found in normal classrooms indoor settings. CO_2 is the key regulator of respiration and arousal of behavioral states in humans. The initial effects of inhaling CO_2 at higher concentrations are increased partial pressure of CO_2 in arterial blood and decreased blood pH [3]. CO_2 concentrations greater than 20,000 ppm cause deepened breathing; 40,000 ppm increases respiration markedly; 100,000 ppm causes visual disturbances and tremors and has been associated with loss of consciousness; and 250,000 ppm CO_2 (a 25% concentration) can cause death. Maximum recommended occupational exposure limits for an 8-hr workday are 5,000 ppm as a time-weighted average, for the Occupational Safety and Health Administration (OSHA 2012) and the American Conference of Government Industrial Hygienists.

A recent study conducted at the Lawrence Berkeley National Laboratory (LBNL) has challenged the conventional wisdom that no health effects result from the CO_2 concentrations typically found in occupied settings such as school classrooms [3]. Twenty-two participants were exposed to CO_2 at 600, 1,000, and 2,500 ppm in an office-like chamber. Each group was exposed to these conditions in three 2.5-hr sessions, all on 1 day, with exposure order balanced across groups. At 600 ppm, CO_2 came from outdoor air and participants' respiration. Higher concentrations were achieved by injecting ultrapure CO_2. Ventilation rate and temperature were constant. Under each condition, participants completed a computer-based test of decision-making performance as well as questionnaires on health symptoms and perceived air quality. Participants and the person administering the decision-making test were blinded to CO_2 level. Data were analyzed with analysis of variance models and the results are presented in Figure 2.

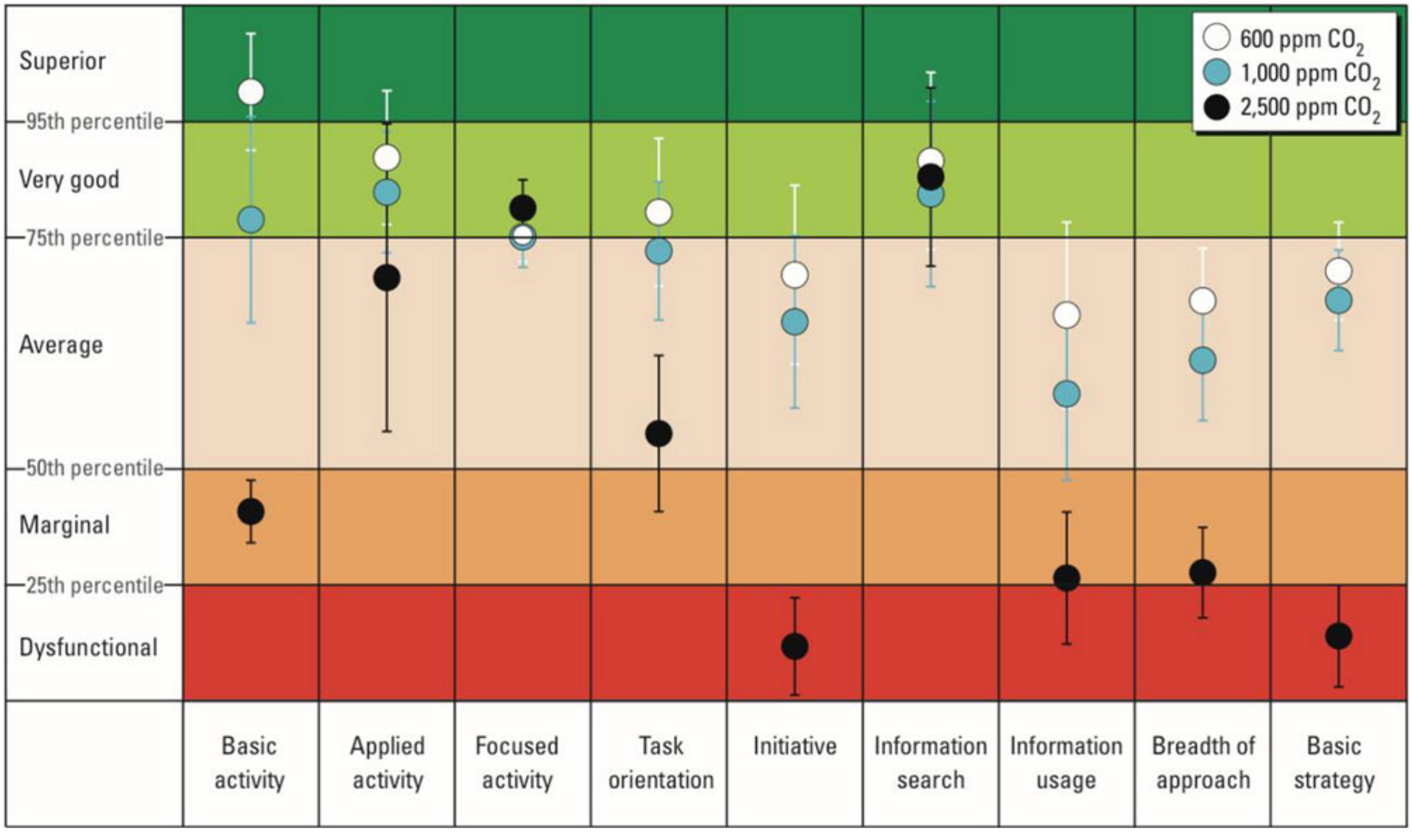

Figure 2. Impact of Carbon Dioxide on human decision-making performance. Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3548274/

The results were as follows: relative to 600 ppm, at 1,000 ppm CO_2, moderate and statistically significant decrements occurred in six of nine scales of decision-making performance. At 2,500 ppm, large and statistically significant reductions occurred in seven scales of decision-making performance (raw score ratios, 0.06–0.56), but performance on the focused activity scale increased.

The conclusions of the study was that direct adverse effects of CO_2 on human performance may be economically important and may limit energy-saving reductions in outdoor air ventilation per person in buildings [3].

Volatile Organic Compounds (VOC)

Indoor volatile organic compounds, or VOCs, are carbon-containing organic chemicals present in indoor air. They come from a large number of indoor sources including building materials, furnishings, consumer products, tobacco smoking, human emissions, and indoor chemical reactions. Pollutants from attached buildings such as garages may also enter indoor living spaces. Outdoor air is also a source of indoor VOCs. Volatile organic compounds are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects [15]. Concentrations of many VOCs such as benzene, carbon tetrachloride, perchloroethylene are consistently higher indoors than outdoors. EPA's Office of Research and Development found levels of about a dozen common organic pollutants to be 2 to 5 times higher inside homes than outside, regardless of whether the homes were located in rural or highly industrial areas. EPA studies indicated that while people are using products containing organic chemicals, they can expose themselves and others to very high pollutant levels, and elevated concentrations can persist in the air long after the activity is completed [15].

Organic chemicals are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, degreasing, cosmetic and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds when used, and, to some degree, when they are stored.

The use of VOC can have many adverse health effects, which may include: eye, nose and throat irritation, headaches, loss of coordination and nausea, damage to liver, kidney and central nervous system.

Some organics can cause cancer in animals, some are suspected or known to cause cancer in humans. A number of the VOCs that are present in indoor air have been shown to cause cancer in animals exposed to high concentrations. A few of these VOCs - for example, formaldehyde and benzene - are considered by many authorities to be proven or probable human carcinogens.

Products like paint strippers, adhesive removers and aerosol spray paints contain methylene chloride. This chemical is known to cause cancer in animals. Also, methylene chloride is converted to carbon monoxide in the body and can cause symptoms associated with exposure to carbon monoxide [15].

Benzene is a known human carcinogen. The main indoor sources of this chemical are: environmental tobacco smoke, stored fuels, paint supplies, automobile emissions in attached garages [15].

An organic compound used widely in dry cleaning industry is perchloroethylene. In laboratory studies, it has been shown to cause cancer in animals. Recent studies indicate that people breathe low levels of this chemical both in homes where dry-cleaned goods are stored and as they wear dry-cleaned clothing. Dry cleaners recapture the perchloroethylene during the dry-cleaning process so they can save money by re-using it, and they remove more of the chemical during the pressing and finishing processes. Some dry cleaners, however, do not remove as much perchloroethylene as possible all of the time [15].

Other organic chemicals that are present in all purpose cleaners, glass and surface cleaners, household cleaners and polishes are ethylbenzene, toluene, styrene, carbon tetrachloride, dioxane, acetaldehyde, acetophenone, methyl ethyl ketone (2-Butanone) [11].

Building occupants, as well as cleaning personnel, are exposed to a wide variety of air borne chemicals when cleaning agents and air fresheners are used in buildings.

There is substantial evidence that individuals whose occupations include regular cleaning activities in buildings have an increased risk of adverse respiratory health effects and asthma. There is limited evidence that increased non-work-related use of household cleaning sprays by home occupants increases the risks of the same health effects [10].

Cleaning product and air freshener constituents can react with oxidants to generate secondary pollutants. A secondary pollutant is a compound that results after a chemical reaction between primary pollutants (usually volatile and semivolatile organic compounds) and a powerful oxidant (e.g. ozone).

Ozone from outdoor air is a common initiator for indoor gas-phase oxidation processes. Reactions of ozone with constituents containing unsaturated carbon–carbon bonds are much faster, and serve as a larger source of secondary pollutants, than reactions with constituents containing only saturated carbon-carbon bonds. For example, terpenes can react rapidly with ozone in indoor air generating many secondary pollutants, including toxic air contaminants such as formaldehyde. Furthermore, ozone-terpene reactions produce the hydroxyl radical, which reacts rapidly with other organic chemicals, leading to the formation of other potentially toxic air pollutants. Indoor reactive chemistry involving the nitrate radical and cleaning-product constituents is also of concern, since it produces organic nitrates as well as some of the same oxidation products generated by ozone and hydroxyl radicals.

Because of their potential contributions to urban photochemical smog, product manufacturers and air quality regulators have estimated organic compound emissions from the use of cleaning products. Although cleaning agent use causes a small portion of total outdoor organic compound emissions, the health consequences from this usage appear to be out of proportion to the emissions. This reflects the fact that the proportion of emissions inhaled is much higher when those emissions occur in buildings rather than outdoors.

Another source of indoor air pollution that drew the attention of specialists for the past decade is represented by a group of chemicals called brominated flame retardants. These organic compounds are part of polybrominated diphenyl ethers (PBDEs) family and have been used in high volumes to reduce the flammability of polymers and resins commonly found in furniture and electronic components [16]. Many studies have reported on their universal presence in the environment, from the detection in U.S. house dust to the presence in human tissues and informed about their potential toxicity, both in animals and in humans. They have an impact on thyroid, liver and kidney morphology in adult animals and some neurological and musculoskeletal symptoms in humans [17]. While most of them have been voluntarily withdrawn or banned from commercial or household use, one of the mixtures, decabrominated diphenyl ether (DecaBDE) continues to be produced and used in high volumes. Due to the fact that the use of PBDEs has grown so much controversy, many U.S. state legislatures are currently considering banning of phasing out all types of brominated flame retardants [16].

The table below (Figure 3) shows the main indoor contaminants presented in this unit, their sources and their adverse effects.

Pollutant	**Sources**	**Adverse Effects**
Asbestos	Insulation, construction materials	Risk of chest, abdominal cancers and lung diseases

Benzene	Tobacco smoke, stored fuels, paint supplies, automobile emissions (in garages)	Carcinogen
Carbon Dioxide	Exhaled breath	Headaches, fatigue, drowsiness, eye and throat irritations, cognitive impairment, decision-making problems
Carbon Monoxide	Unvented gas heaters, leaking chimneys and furnaces, wood and gas stoves, fireplaces, cigarette smoke, automobile exhaust	Headaches, fatigue, dizziness
Formaldehyde	Adhesives, fabric treatments, stains, varnishes	Irritations to respiratory system, eyes, nose and throat Carcinogen
Indoor particulate matter (PM)	Cooking, candles, fireplaces, unvented space heaters, cigarette smoking	Heart and lung diseases
Lead	Pipes, paint	Impairment of mental and physical development; blood cells, kidney, central nervous system problems
Nitrogen dioxide	Combustion processes, tobacco smoke, kerosene heaters	Eyes, nose, throat irritant Risk of respiratory infections
Ozone	Office equipment, air cleaners	Chest pain, asthma
Polycyclic aromatic hydrocarbons	Tobacco smoke, gas cooking	Lung cancer
Phtalates	Adhesives, vinyl floors, wood finishing products	Obesity, potentially causing cancer
Radon	Uranium decaying in soil	Carcinogen
Volatile Organic Compounds (VOC)	Furniture, carpets, paint, cleaners, solvents, glues, building materials	Headaches, fatigue, eyes, nose, throat and skin irritations

Figure 3. List of main indoor pollutants, their sources and adverse effects

Classroom Activities

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1. What is Indoor Air Pollution?

(one class period)

Learning objectives

Students will be able to identify the main indoor air pollutants, their sources and explain the general health effects of indoor air pollution

Materials and teacher-developed resources

- Paper, pencils, software (ActivInspire / Promethean)

Learning activities

For the first part of the lesson, students will read the article “On the History of Indoor Air Quality and Health”. Then, the teacher will split the students in groups of three or four and conduct a class discussion about the topics mentioned above. Ask students to describe the differences in air pollution at home and in classroom (if any). For homework, ask students to write a paper about the steps they can take to control and reduce indoor air pollution.

2. Modeling the concentration of Carbon Dioxide concentration in a classroom

(two class periods)

Learning objectives

Students will answer the following question: “How much a classroom must be ventilated in order to keep the concentration of carbon dioxide at a low level”?

Materials and teacher-developed resources

- Paper, pencils, software (ActivInspire / Promethean *)*
- Carbon Dioxide monitors

Learning activities

Using the carbon dioxide monitors, students will observe and record the concentration of carbon dioxide in their classroom over a period of three days. They will use the collected data to calculate the mass balance of gases entering and exiting the classroom to find the equation for the optimal air exchange rate (for the given volume of the classroom) that keeps the carbon dioxide concentration at a low level.

The mass balance for removal of any indoor contaminant can be expressed by the following equation:

$\Delta M / \Delta t = Q \times C_0 - Q \times C_f + G – L$

where

ΔM is the change of mass of contaminant inside the classroom during the time interval Δt (measured in mg/min)

Q represents the fresh airflow rate into the classroom that is equal to the exhaust airflow rate (measured in m^3/min)

C_0 is the outdoor (initial) concentration of contaminant entering the classroom (measured in mg/m^3)

C_f is the final concentration of contaminant exiting the classroom (measured in mg/m^3)

G represents the generation (emission) rate of contaminant in the classroom (measured in mg/min)

L represents the loss rate (filtration or deposition) of a contaminant in the classroom (measured in mg/min)

Assuming that airflow (Q) and generation (G, L) rates are constant and the room is at steady state ($\Delta M / \Delta t$ is

0), the equation becomes

$L – G = Q (C_0 - C_f)$

Solving for the flow rate, in the differential format, the equation becomes:

$Q = (L – G) / (C_0 - C_f)$

Because flow rate represents the ratio between volume and time (Q = V / t), if we know the volume of the classroom (m^3), we can find the air exchange rate (Q/V)

$Q/V = 1/t = (L-G) / V(C_0 - C_f)$ in min^{-1}

3. Organic vs. Inorganic Compounds Lesson plan

(one class period)

Learning objectives

Students will be able to distinguish between inorganic and organic compounds and describe the main differences between the two classes of compounds.

Materials and teacher-developed resources

- Paper, pencils, software (power point presentation)
- Few 100 ml jars containing sugar, table salt, ethylic alcohol, coffee, water, a piece of metal, wood, paper, a small dish containing copper sulphate

Learning activities

The teacher will explain that organic compounds can be found in living organisms and mainly contain carbon and hydrogen. These compounds are very complex and come in huge number. The inorganic compounds, with few exceptions, do not contain carbon and hydrogen, their molecules are less complicated and come in smaller number compared to organic compounds. The most organic compounds contain the C-H bonds under different types (simple, double, triple) and the teacher will give examples. With the teacher's help, students will identify the most commonly used organic and inorganic compounds. Also, the teacher will point out that there are some organic compounds (carbon tetrachloride, urea) that do not contain carbon-hydrogen bonds and that there are some inorganic compounds (carbon oxides, carbides, carbonates) that contain carbon. Finally, the teacher will provide the students with a list of chemicals and ask students to identify the inorganic and organic compounds.

4. Organic Compounds Nomenclature Lesson plan

(one class period)

Learning objectives

Students will be able to name the simplest organic compounds according to IUPAC system.

Materials and teacher-developed resources

- Paper, pencils, software (power point presentation)

Learning activities

The teacher will explain the rules that guide the naming of organic compounds and help students name the alkanes (saturated hydrocarbons with a single bond between carbon atoms), alkenes (unsaturated hydrocarbons with at least one double bond between carbon atoms) and hydrocarbons with side groups (groups that come off of the main carbon-carbon chain).

5. Aromatic Compounds Lesson plan

(two class periods)

Learning objectives

Students will be able to define, name and recognize monocyclic and polycyclic aromatic compounds . They will identify the aromatic compounds that are indoor air pollutants.

Materials and teacher-developed resources

- Paper, pencils, software (power point presentation)
- Two small bottles containing benzene and toluene

Learning activities

The teacher will introduce the characteristics of aromatic compounds and explain the basic structure of benzene, C_6H_6 (the simplest aromatic compound), a very stable compound with a structure of a ring in which the electrons are equally shared by all six carbon atoms. Students will learn about the physical and chemical properties of aromatic compounds, naming and rules for numbering substituents on the benzene's ring. Also, the teacher will introduce the formulas and structures of compounds with double benzene rings (naphthalene) and triple benzene rings (anthracene, phenanthrene *).* On the second class period, the students will discuss and identify the steps to reduce indoor exposure to the aromatic compounds.

Resources

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Appendix (Implementing District Standards)

CT New Generation Science Standards

HS-ESS3-3. New technologies can have deep impacts on society and the environment, including some that were not anticipated.

HS-ESS3-4. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

HS-ETS 1-4. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions - including energy, matter, and information flows - within and between systems at different scales.

HS-LS2-1. Use mathematical and/or computational representations of phenomena or design solutions to support explanations.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

District Standards

D 13. Explain how the structure of the carbon atom affects the type of bonds it forms in organic and inorganic molecules.

D 26. Describe human efforts to reduce the consumption of raw materials and improve air and water quality.

D INQ.3 Formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment.

D INQ.6 Use appropriate tools and techniques to make observations and gather data.

D INQ.8 Use mathematical operations to analyze and interpret data, and present relationships between variables in appropriate forms.

D INQ.10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic.