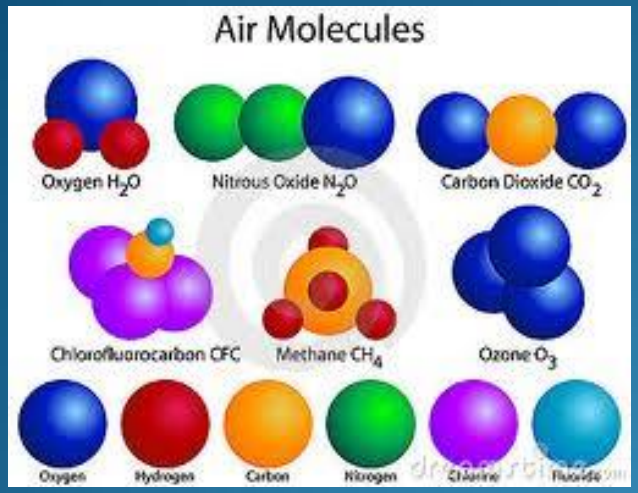
Kurt T. Johnson, Owner
Fresh Air Ventilation Systems, LLC
HRAI Certified Design and Installation of
Residential Mechanical Ventilation Systems
Board Member of The Maine Indoor Air Quality Council
kurt@freshairventilation.net

Can We Live Healthy without Good Lungs?

What is Fresh or Good Air?



Outside Levels of CO2
350 - 400 ppm

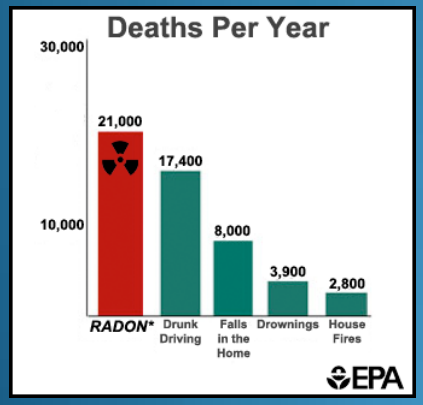
Exhalation air is about
14% Oxygen
4.4 % CO2

Component	Symbol	Volume	
Nitrogen	N_2	78.084%	99.998%
Oxygen	O_2	20.947%	
Argon	Ar	0.934%	
Carbon Dioxide	CO_2	0.033%	
Neon	Ne	18.2 parts per million	
Helium	He	5.2 parts per million	
Krypton	Kr	1.1 parts per million	
Sulfur dioxide	SO_2	1.0 parts per million	
Methane	CH_4	2.0 parts per million	
Hydrogen	H_2	0.5 parts per million	
Nitrous Oxide	N_2O	0.5 parts per million	
Xenon	Xe	0.09 parts per million	
Ozone	O_3	0.07 parts per million	
Nitrogen dioxide	NO_2	0.02 parts per million	
Iodine	I_2	0.01 parts per million	
Carbon monoxide	CO	trace	
Ammonia	NH_3	trace	

Air is a transporter

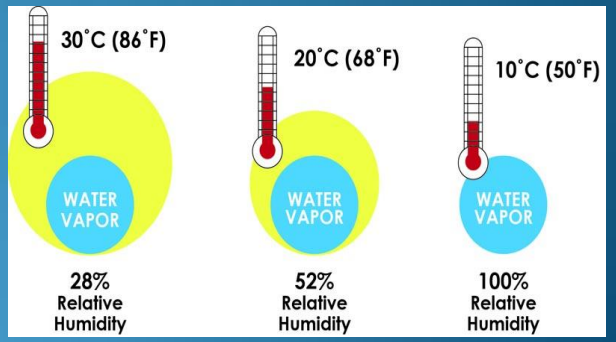
3 Main pollutants which air moves

Gases



Particles

Moisture



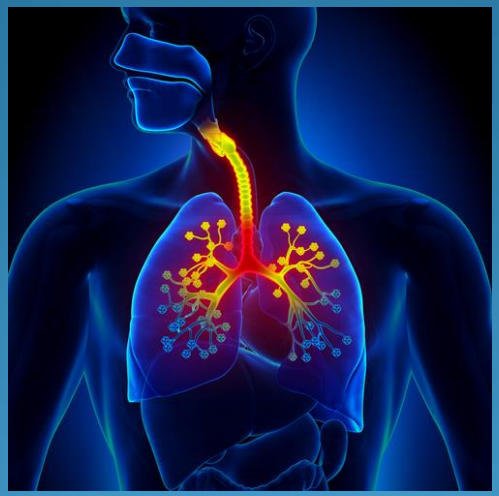
Other passengers

It also transports
disease
bacteria
viruses

- TB
- SARS
- Mumps
- Diphtheria
- Measles
- Smallpox
- Influenza
- Anthrax

Humans come equipped with a Ventilator

All of us breath constantly
- over 20,000 breaths each day
- 35 pounds of air.



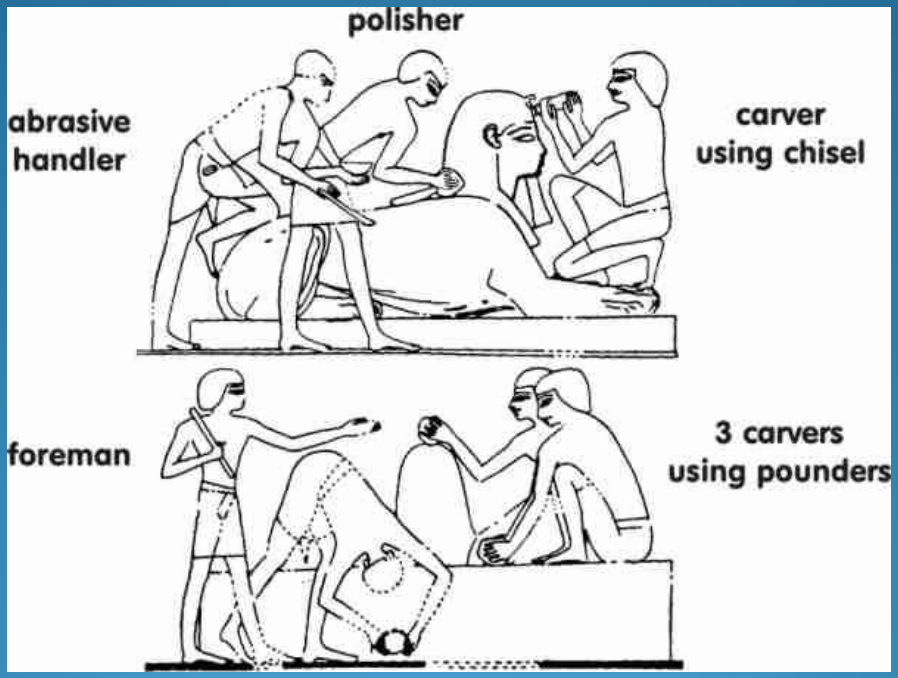
Normal metabolism creates CO_2
and other
pollutants we need to get rid of

What happens when air is not Fresh?

History of Ventilation

*'Those who cannot remember the past are condemned to **repeat** it.'*

Ancient Egyptians observed that stone carvers working indoors had a higher incidence of respiratory distress than those working outdoors did



"The History of Ventilation and Temperature Control", ASHRAE Journal Sept 1999 by John E. Janssen

Middle Ages - Early Radon effects

1530 - Paracelsus description of a wasting disease of miners *(Radon gas?)*

Mineralogist Georg Agricola recommended ventilation of mines to avoid this mountain sickness

1879 - the "wasting" was identified as lung cancer by Herting and Hesse in their investigation of miners from Schneeberg, Germany.

First Ventilation Code?

King Charles I of England in 1600 decreed that no building should be built with a ceiling height of less than 10 ft. and that windows had to be higher than they were wide.

The objective was to improve smoke removal.

Note: This was not the first building code.

Research Begins
What Constitutes bad air?

In the 17th century, Mayow placed small animals in a confined bottle with a burning candle.

The candle flame was extinguished before the animal was asphyxiated.

An animal survived about half again as long without the candle.

He concluded that the *igneo-aerial particles* of the air were the cause of the animals'demise.

CO_2 Discovered

1775 - Lavoisier identified Mayow's *igneo-aerial particles* as carbon dioxide (CO_2)

1777 - Lavoisier began his study of oxygen and carbon dioxide in the air of crowded rooms

He concluded that excess CO_2 rather than a reduction of oxygen caused the sensations of stuffiness and bad air.

The hypothesis was that excess CO_2 in the lungs interfered with their ability to absorb CO_2 from the blood

Body Odor discovered?

(1862) - Pettenkofer concluded that neither oxygen nor carbon dioxide were responsible for bad air.

Rather, biological contaminants were responsible for vitiation of the air. He believed, as did Saeltzer (1872) and others, that CO_2 was a useful surrogate for vitiated air.

First Ventilation Rates

1836 - a Cornish mining engineer, Thomas Tredgold published the first estimate of the minimum quantity of ventilating air needed - **about 4 cfm**

These calculations, based on measured flow rates, did not consider the CO2 or moisture concentration exhaled by the occupants.

Tredgold's estimate was intended to satisfy *metabolic needs*, but it erred on the side of too little ventilation for comfort

There was a growing dichotomy in the objectives for ventilation.

Should the objective be based on physiological needs or on comfort factors?

War and Disease

During the Crimean War, 1853-55, and a few years later in the U.S. Civil War, it was observed that there was a greater and faster spread of disease among wounded soldiers in crowded hospitals with poor ventilation.

- Wounded soldiers fared better when they were housed in tents or barns.
- Physicians wanted more ventilation to reduce the spread of disease.

matter, we can readily see that the purity of the air breathed, and the constant and prompt removal of the excretions borne out with it, must have much to do with the health and energy of the individual.

It is, therefore, well worth while for every man to understand that abundance of fresh air is not merely theoretically a good thing which is to be accepted, if it comes in his way, but that it is a necessity for the preservation of health and happiness, and that it is worth taking special pains to secure. It is also important that those who form and direct public opinion on this subject—physicians, architects, engineers, clergymen, teachers, school trustees, and legislators, should give more attention to this subject than most of them have heretofore done, and should look to it that the buildings which they plan, erect or manage, and especially those in which numbers of men, women or children are to be brought together, are so constructed and arranged that no one shall poison himself or others by the air which he expires.

I do not mean by this that every professional man should aim to be an expert on plans and specifications for ventilation, nor that he should rely on his own judgment as to the best way to secure it, but that he should insist on having it provided for, and should see that skilled-advice on the subject is obtained for all buildings in which he is interested.

The difficulties which architects and engineers find to be most prominent when they attempt to arrange a system of ventilation for a given building, mine, or other locality, are, first, the want of a definite generally recognized standard as to amount of air required ; and second, the extra cost of construction and maintenance which is involved in supplying, heating, and distributing this air.

The standards of satisfactory ventilation proposed by sanitarians are not as yet accepted in engineering text books, the authors of which seem disposed to think that much smaller amounts of fresh air than those proposed by Pettenkofer, Parkes and De Chaumont, are sufficient. So long as the question as to whether a given room or building is properly and sufficiently ventilated is to be decided by opinions based on personal sensations only and not upon the results of weight and measure of the constituents and temperature of the air which will be independent of personal equations, so long will it be impossible to obtain an authoritative and reliable answer. Upon the standard for air supply adopted depends, to a considerable extent, the expense of the means required to secure it.

If the question of expense could be entirely set aside ventilation would become a comparatively simple matter, for the resources of modern engineering are ample to produce a given standard of purity of the air in almost any building that can be constructed ; but to secure good ventilation in cold climates during the winter is expensive as to the mode of construction of the building itself, the apparatus required for the purpose, and as to its maintenance after the necessary conditions have been provided.

Among the first questions which the architect has to solve for each building which he plans or constructs in order to secure good ventilation are the following—viz.:

First. —How much money shall be allowed to secure ventilation in this case ?

First Ventilation Standard in USA

Engineers vs. Physicians

1893 – "*Ventilation and Heating* " by a physician named John Billings was first authoritative work.

- He calculated 50 cfm p/p to counter CO2 exhalation (200ppm)
- Others argued it could be done with 10 cfm
- Billings argued for 30 minimum and recommended 60 cfm
- concerned about the spread of disease, particularly tuberculosis.

1895, ASHVE (American Society of Ventilation Engineers) They recommended 30 cfm per person as the minimum ventilation rate. This required mechanical ventilation and placed responsibility for system design and construction on the engineers

The Battle begins

Engineers were concerned with providing comfort and reducing odors and CO_2 accumulation

While **Physicians** were concerned with minimizing spread of **disease**.

Multiple studies took place between 1893 - 1925

Schools, CO_2, Thermal Comfort, Humidity

vs.

Engineers take over

By 1925, 22 states required a minimum of 30 cfm per occupant of outdoor air.

There was a **growing resistance to heating large quantities of outdoor air for ventilation**. Recommended ventilation rates sometimes failed to discriminate between the outdoor airflow rate and the total supply

1925 - now ASHRAE – (American Society of Heating, Refrigerating, and Air Conditioning Engineers) published a guide setting the minimum ventilation rate to 10 cfm/p

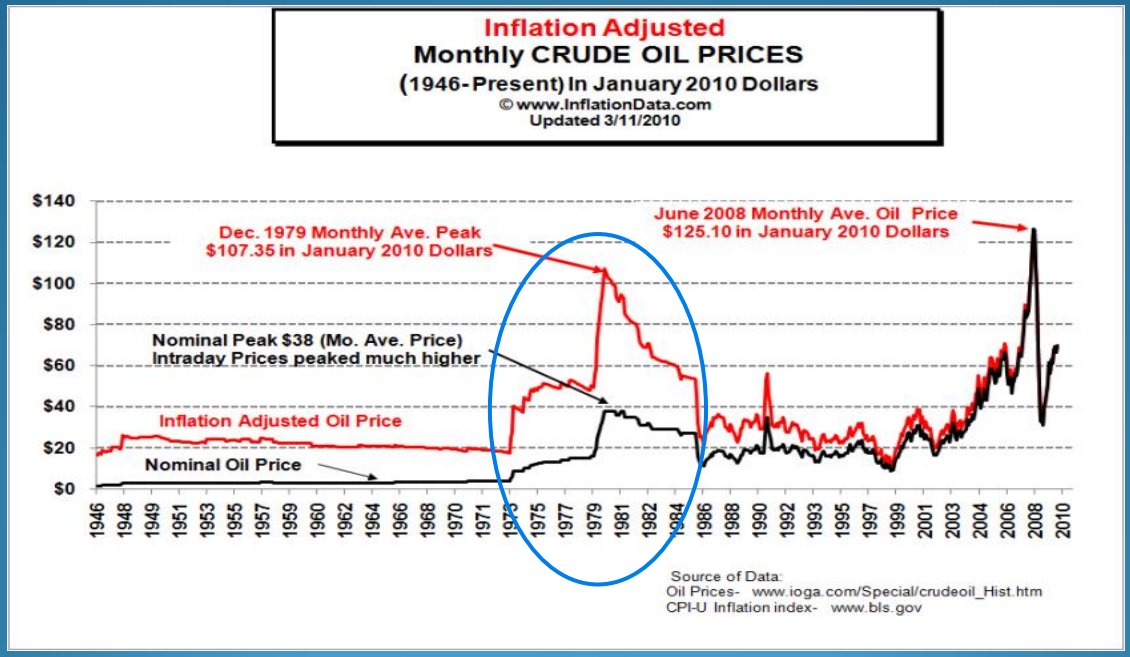
Lowered based on comfort, not disease

First ANSI/ASHRAE Standard

1973 - ASHRAE Standard 55 for thermal comfort and Standard 62 for ventilation

62-1973, Standards for Natural and Mechanical Ventilation - 10 cfm pp

also in 1973, Oil Embargo



Oil Prices peaked in 1980, so what happened to Standard???

Engineers vs. Smoking industry

1981 - Non smoke buildings minimum reduced to 5 cfm/p and buildings with smokers 20 cfm **remember the first rate at 4 cfm for comfort*

1984 - A 1984 World Health Organization (WHO) report suggested up to 30% of new and remodeled buildings worldwide may be subject of complaints related to poor indoor air quality.

1989 - when multiple studies found that 15 cfm/p of outdoor air was sufficient to reduce concentrations of tobacco smoke and odor to a level acceptable by 80% of the population, minimum raised/ lowered to 15 cfm/p for all buildings

- .35 ACH for residential

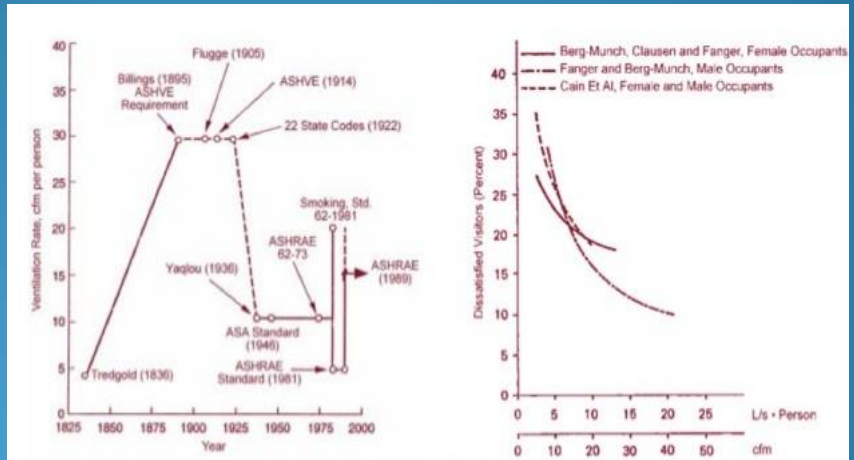


Figure 1. Minimum ventilation rate history (left) and odor acceptance studies in the early 1980s (right) (Janssen 1999).

Sick Building Syndrome

Before 1980, sick building syndrome was unknown.

By the 1990s, it was among the most commonly investigated occupational health problems in the United States.

Centers for Disease Control and Prevention (CDC)

% of all complaints relating to Indoor Air Quality

- 1978 = 0.5%
- 1990 = 52%
- Dramatic increase in Respiratory diseases

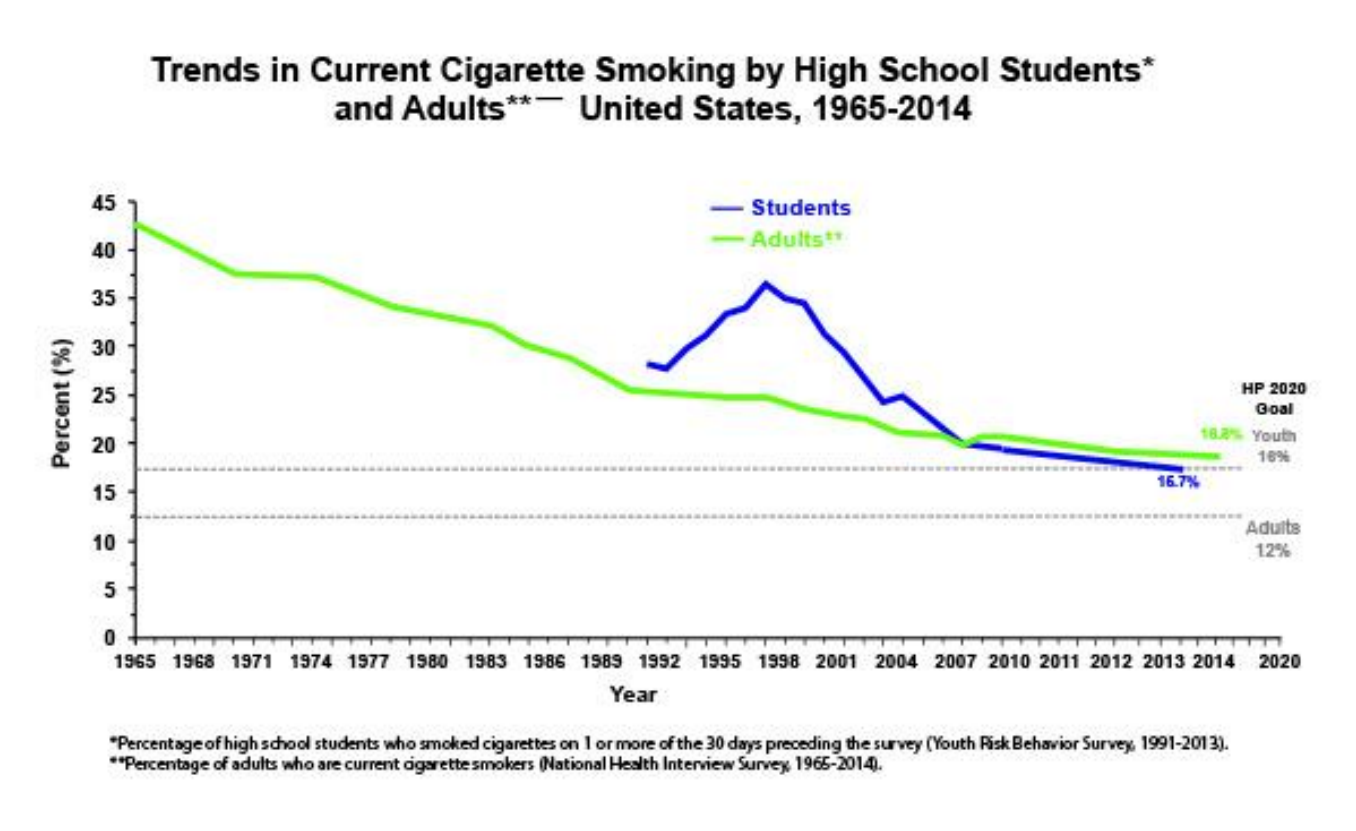
Afflicted by headaches, rashes, and immune system disorders, office workers—mostly women—protested that their workplaces were filled with toxic hazards; yet federal investigators could detect no chemical cause.

Does that seem a little odd?

meanwhile…….. between 1978 - 1992 Asthma rates triple!!!

while

Smoking rates decline



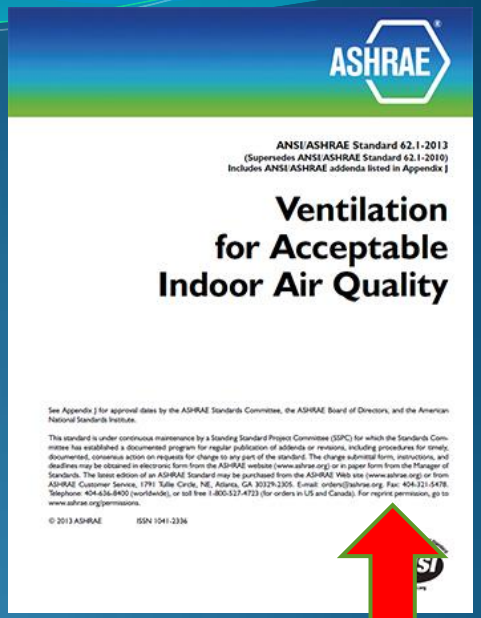
Smoking issue wanes with less smokers and laws banning use indoors

Current ASHRAE

still based on odor

ASHRAE 62.1 – Complex formula

- No single value often 12 – 14 cfm/p
- rate varies from 5 to 20 cfm/p depending on area



Disclaimer

ASHRAE uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in light of available information and accepted industry practices. However, ASHRAE does not guarantee, certify, or assure the safety or performance of any products, components, or systems tested, installed, or operated in accordance with ASHRAE's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be nonhazardous or free from risk.

Engineers continue to hold to lower rates

62.1 & 2 see relatively minor changes as Energy efficiency pressures to keep ventilation rates very low. Rates stay stagnant. *(just like air in many buildings)*

Note Since complaints were largely by women and buildings are largely designed and built by men, do our own biases get in the way of good judgment?*

Where are the doctors and studies to get us back to ventilation rates for health reasons ?

Health Concerns Reemerge

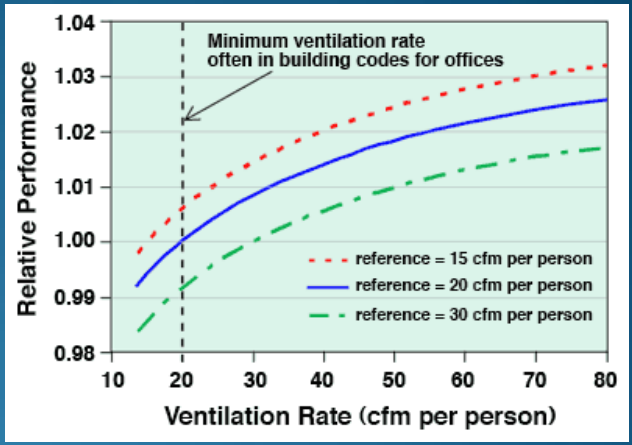
2011 An extensive literature review judged 27 papers that provided sufficient information on both ventilation rates and health effects to inform the relationship (Sundell et al. 2011).

- Higher ventilation rates of 53 cfm/person were associated with reduced prevalence of sick building syndrome symptoms, inflammation, respiratory infections, and asthma symptoms

- Short-term sick leave increased with lower ventilations rates.

ASHRAE has not made any changes to the minimum rate and is more likely to go down for energy reasons.
(Assumed leakage removal did not change the goal of .35ACH)

Ventilation increases = Better Performance



Studies in the workplace
Increase Ventilation = Increase
Performance, Worgocki 99, 00, 02

More recently
performance of 24 young adults was evaluated at ventilation rates of 10.6, 21.2, and 42.4 cfm per person.

The study was performed in a laboratory resembling an office with new finishing materials that are sources of volatile organic compounds.

- 8 hours under each of the three ventilation rates.
- performance in addition, text typing, and memorization tests increased 4.7%, 5.2%, and 8.0%, respectively. *source Lawrence Berkeley Labs*

Cost benefits of increased Ventilation

William Fisk at Lawrence Berkeley Labs created national estimates

Doubling ventilation in U.S. offices yields
Productivity gains = $37,000,000,000 Billion
Energy cost = $130,000,000 million

Economizers that ventilate to save energy
Gain $33,000,000,000 Billion
Cost of equipment $280,000,000 Million

Schools: increased ventilation improves
school work & test scores 3-16%

Higher ventilation rates increase productivity. A 1% increase in Productivity more than pays for the energy cost - *Fisk LBL*

Higher ventilation rates decrease absentee days. Depending on the Study, the range is from 1.6 days per employee ($500)
And
up to 1/3rd of all sick days

School Performance

Studies indicate the potential for 5% to 10% increases in aspects of student performance and moderately higher pass rates in standardized math and reading tests with increased classroom ventilation rates.

Ventilation rates in 50% of elementary school classrooms less than specified in codes thus the opportunities for increasing student performance by increasing ventilation rates may be substantial.

Hmmm, Where have I seen this before? Gettysburg

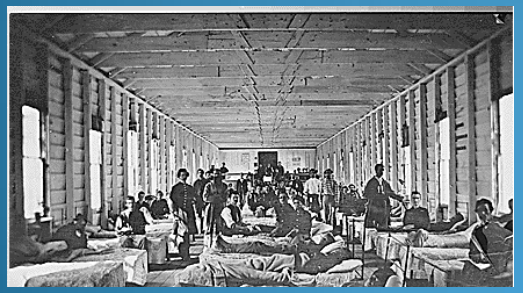
Three studies of ventilation and respiratory illness (one performed in military barracks, one in a jail, and one in a nursing home) found an increase in respiratory illness with very low ventilation rates compared to substantially higher ventilation rates

2.5 vs 20 cfm per person,

8 vs 26 cfm per person,

4 vs 8 cfm per person

The percentage increase in respiratory illness in buildings or spaces with the lower, compared to higher, ventilation rates ranged from approximately 50% to 370% (less fresh air = more sick people)



Where there is no guidance the people perish

Right now there is HUGE confusion for the consumer
Because
Right now there is Huge confusion in the building industry
Because
Right now there is Huge disagreements between the experts

Why????

Existing Codes or Standards or Suggestions

Air change every:
3 to 5 per day

Every 3 hours
Every 2 hours
Every 1 to 2 hours
Every hour

CFM Per Person:
4 - 60

Intent is always Prior to Content

What is the Goal?

Who decides?

Doctors/Health care people (Health)
or
Engineers / Energy people (Cost/Comfort)

Buildings are for People

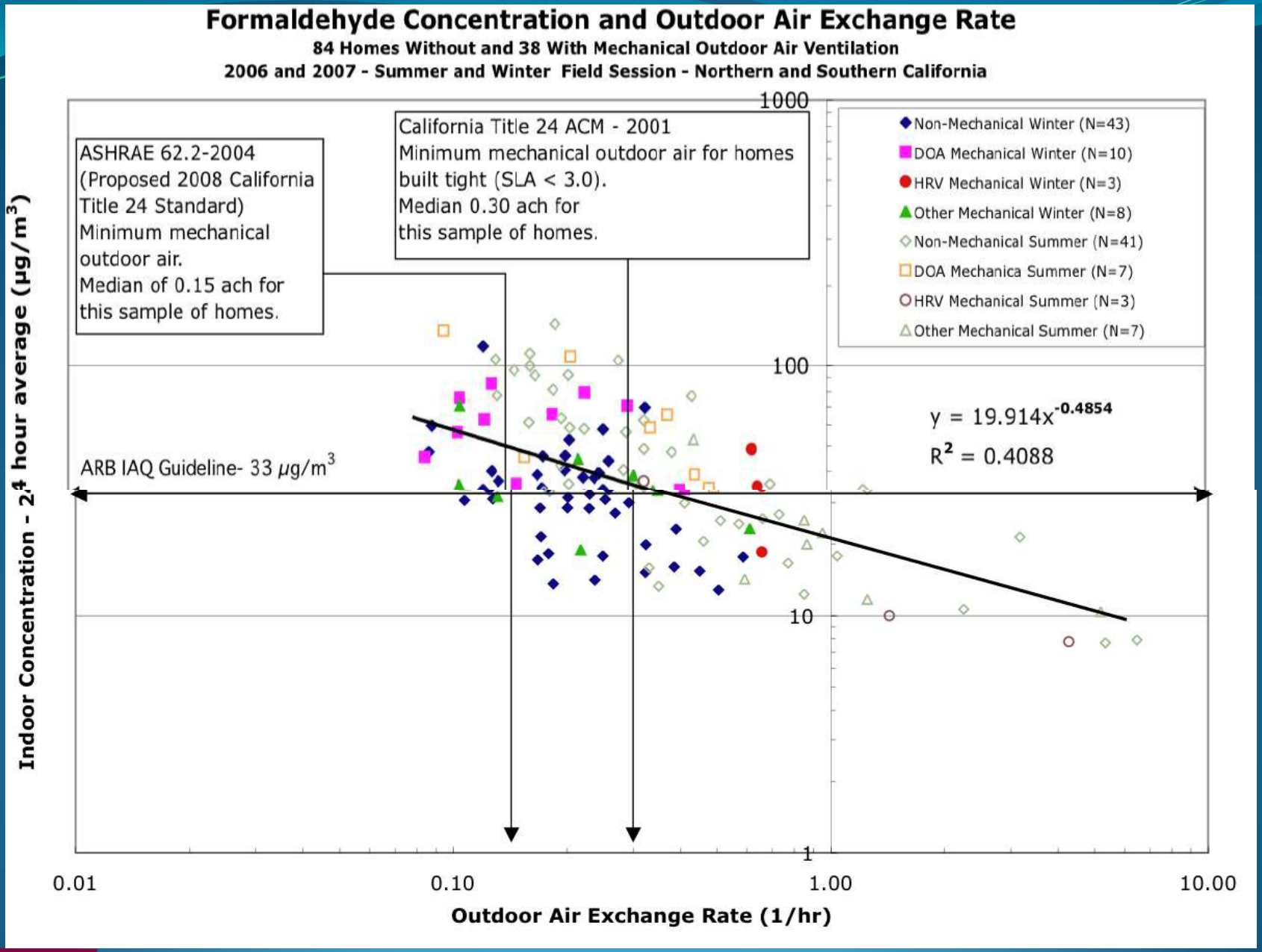
Providing a Healthy indoor environment needs to be #1 priority

What is needed to achieve this goal

- Reliable supply of fresh air
- Well distributed (each habitable room is part of the system)
    1. Vents are positioned to move air throughout the whole room *(especially where people are and where the breathing zone is)
    2. Pathways exist for air to freely flow
    3. System is active
    4. Maintenance is a must
- System is capable of distribution even when there is no demand for heating or cooling (coupling ventilation with H/AC can be problematic to ventilation)
- Operators need to understand the system and how and why to operate it.
- System **should not** be reduced or shut down for other less important reasons
    1. Cost (illness & health care is significantly more costly than energy)
    2. Comfort (illness & health care is significantly more costly than energy)
    3. Humidity (climate and use may dictate additional equipment to manage moisture. Stopping ventilation to solve moisture issues is a terrible idea)
    4. Etc.

If we are going to err

May we err on the side of health
and
not on the unhealthy side


Formaldehyde Concentration and Outdoor Air Exchange Rate
84 Homes Without and 38 With Mechanical Outdoor Air Ventilation
2006 and 2007 - Summer and Winter Field Session - Northern and Southern California
ASHRAE 62.2-2004
(Proposed 2008 California Title 24 Standard)
Minimum mechanical outdoor air.
Median of 0.15 ach for this sample of homes.
California Title 24 ACM - 2001
Minimum mechanical outdoor air for homes built tight (SLA < 3.0).
Median 0.30 ach for this sample of homes.
Non-Mechanical Winter (N=43)
DOA Mechanical Winter (N=10)
HRV Mechanical Winter (N=3)
Other Mechanical Winter (N=8)
Non-Mechanical Summer (N=41)
DOA Mechanica Summer (N=7)
HRV Mechanical Summer (N=3)
Other Mechanical Summer (N=7)
ARB IAQ Guideline- 33 µg/m3
y = 19.914x-0.4854
R2 = 0.4088
Indoor Concentration - 24 hour average (µg/m3)
1000
100
10
1
0.01
0.10
1.00
10.00
Outdoor Air Exchange Rate (1/hr)

Determine How Much Air

Home owner should decide what is most important

Healthy volume (53 cfm pp) vs. Min. Std. .35 ACH *or less*

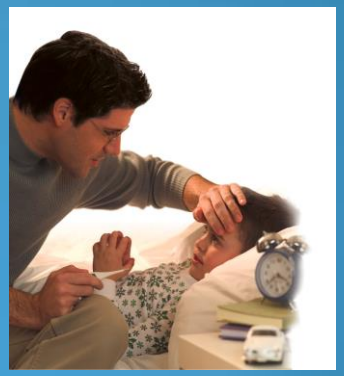
or

1 air change per hour vs. ⅓ air change per hour

150 cfm vs. 50 cfm
per 1000 sq ft of conditioned space

math - ⅓ ach = 1000 x 8'(ceiling ht.) = total cubic feet / 60 min. per hour = 1 ach / 3 = 45 cfm

Reduced respiratory issues vs. increase sick Leave (Sundell et al. 2011)



Design Basics

Supply Fresh air where people spend time

- bedrooms
- living room
- Dining room
- Den, etc
- also supply basement

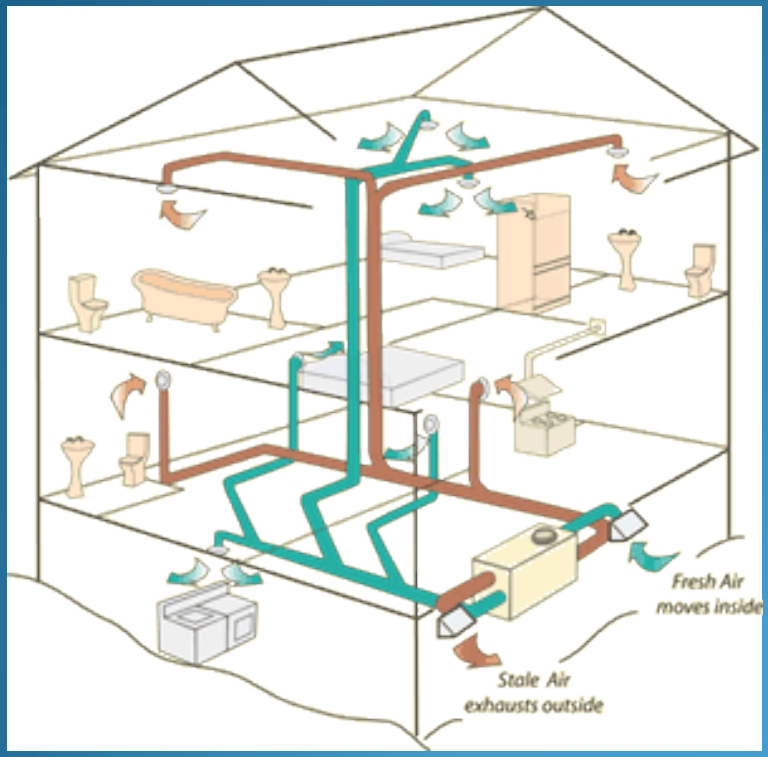
Exhaust closest to biggest polluters/ moisture

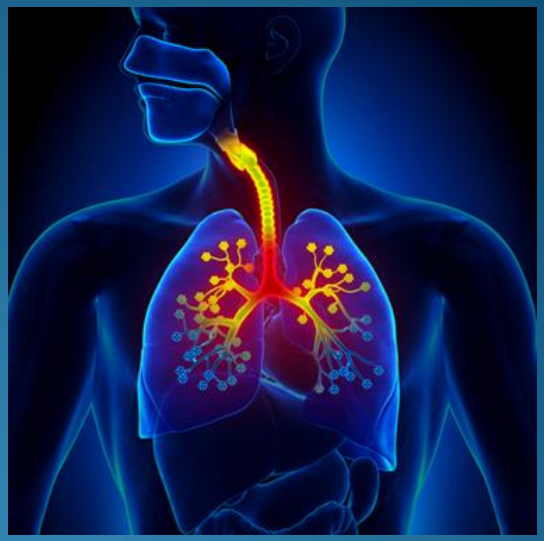
- Bathrooms
- Kitchen
- Laundry (maybe)
- also exhaust basement

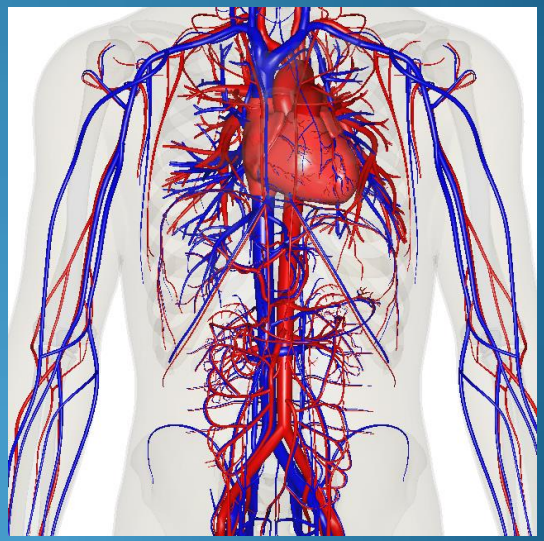
How about conditioned attic spaces? …. Yes

A system needs to consider the whole area

An effective system delivers the good air throughout the space and picks up the pollutants closest to the source for removal







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- US EPA https://www.epa.gov/indoor-air-quality-iaq

- VENTILATION AND INDOOR AIR QUALITY IN NEW HOMES ,California Air Resource Board , Offerman, Nov 2009

- Ventilation Rates and Sick Building Syndrome Symptoms, LBL National Labs https://iaqscience.lbl.gov/vent-syndrome

Conclusions

- Fresh Air is essential to good health
- A well designed, installed, operated and maintained system can provide an effective, energy efficient and reliable supply of fresh air for good health
- Reducing or stopping ventilation is proven to lead to increased rates of diseases including lung cancer and asthma. *Lung cancer is the leading killer of both men and women with an estimated 158K deaths in 2016 source: ALA*
- Increased absenteeism and reduced performance are associated with reduced ventilation rates in both schools and the workplace.
- To achieve a healthy environment, over 150 years of data supports ventilation rates that are 2 to 3 times the minimum rate set by ASHRAE. We need to agree on a healthy rate.
- Costs are low to provide healthy fresh air rates vs. consequences

Questions?

kurt@freshairventilation.net

Running Costs of Fresh Air Ventilation

With HRV/ERV

.35 ACH = $200 - $250 per year or $16 - $18 per month (avg. efficiency)
Most efficient = approx.. $12 per month *200T ERV

or

1 ACH = $600 - $750 per year or $50 - $60 per month
Most efficient = $408 per year or $34 per month

VS

Cost of
Monthly health insurance premium?
Monthly Cell phone bill? $100 +
Monthly Cable or Satellite bill? $100 +
Dinner for two? $50 +
Alcohol bill per month?
Gym monthly cost?
Vitamin monthly cost?
Lung Cancer = 1 - 5yr life span and $40K to $200K cost

Step # 4 - Calculate actual cost for ventilation with Heat Recovery and without (exhaust fan)

		Propane	Oil Cost	Elect Cost
Feb. (coldest mth)	Heat Recvry	$27.66	$14.45	$34.13
February	No Heat Recvry	$138.29	$72.25	$170.65
February	HRV Savings	$111	$58	$137
Yearly Cost	Heat Recvry	$190.14	$99.35	$234.65
Yearly Cost	No Heat Recvry	$760.57	$397.40	$938.59
Yrly Savings w/ heat recovery		$570.43	$298.05	$703.94

*Electrical cost to run a fan to move 120 cfm of air is similar between exhaust fans and HRV/ERV units.
75 watts = $7.02 p/month < 125 watts = $11.70 p/mth

So you can add **$80 to $140 per year additional cost of electricity** to run either a fan or a typical HRV/ERV at 120 cfm all year