Case study title:	**Carbon Monoxide**
Target group:	**Clinicians, Public health professionals, general target group**
Linked to modules:	**Indoor air pollution**
Source of case study:	**CO Headquarters website** by David G. Penney, Ph.D.
Case handling:	**Use powerpoint presentation and/or handouts based on the case description. Stepwise approach.**

Introduction

Mrs. Laura Jones is a 33 year old homemaker. She and her husband Pete, 35 years old, live in a small city. She has a degree in accounting, while her husband has a Masters degree in Business Administration. They are no smokers.

They bought a house in a suburban area in 2004. The home was built in 1958. It was inspected and major appliances in the home were guaranteed for 5 years. The house has been painted outside and inside in the weeks before they moved into the house. The home has three bedrooms, a living room, a spare room. It is heated by a forced-air, natural gas furnace in the basement. Hot water is provided by a gas-fired water heater, also in the basement.

Beginning in the autumn of 2004, Laura Jones began having headaches and began feeling very tired. The two children, Lilian (12 years of age) and Eric (9 years of age), and her husband Pete occasionally awoke in the morning with headaches, dizziness, and nausea. They believed that they all had a touch of "flu" or had eaten bad food.

Mrs. Jones continued to feel "out of it" for the remainder of 2004 and into the spring of 2005. Her physician, Dr. Whitewash, gave her a "physical", obtaining chest X-rays, blood for complete CBC, and samples for a Pap smear test. He found nothing wrong, saying that "flu" has been going around.

QUESTION 1: What other non-infectious diseases could be related to these complaints, including indoor pollutants than can cause this complaints?

Answer 1: Exposure to compounds that have systemic effects on humans could be a cause. An environmental history taking has give some clues to which compounds could be around in the home. One might consider in this situation to check the appliances in the home for exposure.

The major indoor air pollutants that can cause this complaints is CO, Environmental Tobacco Smoke and Volatile Organic Compounds (VOC's).

ADDITIONAL INFORMATION

A furnace company who regularly serviced the heating system found that the equipment was in good working order. During the summer of 2005, Mrs. Jones and the whole family felt much better, although she and the children continued to have frequent headaches and to feel slightly fatigued. They felt better when they went away for vacation for two weeks.
In late October, 2005, Laura Jones again began to have frequent severe headaches and to become extremely fatigued. She was becoming so lethargic that she could not accomplish her normal housework. She was forgetting tasks that needed doing, and finding it increasingly difficult to maintain the family check book. She was also feeling depressed and defeated in her daily life.
On several visits to Dr. Whitewash she was told that there was nothing wrong with her. He said her perceived state was psychosomatic, and that she should seek counseling or schedule regular visits with a psychiatrist
By spring 2006, the Jones' children Lilian and Eric, previously excellent students, were on academic probation at school. Lilian, a 7th grader, was in danger of failing and being held back a year. Eric was now getting bad grades in her classes in elementary school and his teachers were concerned. Mr. Jones, who all his life had been an ambitious and successful employee at a national insurance company, believed he now was in danger of being fired.

QUESTION 2: What questions would you ask to sort out whether this complaints are related to indoor air pollution?

Answer 2:
It is important in environmental exposures to ask whether the timing of the symptoms relate to time spent in the home or work environment.
If the symptoms are more common at home, when did they start; were there any recent changes in the home such as renovations, new insulation, a move, new paint, furniture, plants or pets? Are symptoms related to hobbies, lighting a fire? Are they present when away from home, or on vacation? Do symptoms occur in other settings? Does anyone else at home have these symptoms?
It is heated by a forced-air, natural gas furnace in the basement. Hot water is provided by a gas-fired water heater, also in the basement

QUESTION 3: What would be your ideas about the diagnosis (differential) of this family's health problems?

Answer 3:
Other conditions to be considered would include:

1. carbon monoxide poisoning
2. migraines
3. cluster migraines
4. tension headaches
5. psychiatric: depression
6. anemia
7. organic psycho syndrome/ Chronic Toxic Encephalopathy
8. sleep apnoea

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ADDITIONAL INFORMATION

To gain extra space in their modest 1300 square foot home, the Jones family contracted to have a fourth bedroom added during the summer of 2006. Because the old furnace in the home was the original unit and would not be adequate to heat the new larger house, the contractor installed a new one. In doing so, he discovered that the heat exchanger in the old furnace was badly rusted through, that the near horizontal run of flue pipe to the chimney was also rusted through, and that the old brick chimney was oversize, unlined, and partially blocked near the top.
Upon learning of these problems, Mr. Jones asked that the old furnace be fired up and measurements of CO made by the gas company. He had recently seen a program on television about the dangers of CO and wanted to be sure. With the family safely outside, CO levels in the house were observed to attain 176 ppm after one hour.

QUESTION 4: What would you consider now to do medically?

Answer 4:
The whole family then went to see Dr. Whitewash, who drew blood for the measurement of carboxyhemoglobin. COHb levels came back at between 0.5% and 1.4%. The physician, not familiar with the effects of the gas, told them that since the CO was now out of their bodies, they would be well again.

The lung absorb CO, wich avidly combines with hemoglobin at 200 to 240 times greater affinity than does oxygen. Small amounts of CO are metabolized by oxidation to carbon dioxide . Approximately 85% of absorbed CO combines with hemoglobin; the remainder attaches to myoglobin and blood proteins.

At equilibrium, atmosferic CO levels of 50, 100 and 200 ppm, resp. 0,005%, 0,01% and 0,02%, produce average COHb levels of 8%, 16% and 30%. Normal value of COHb is 0,3 –3% at ambient air concentration. Cigarette smoke is a significant source of CO. In fact, chronic smokers often have CO levels of 5 - 9%. Although never documented, several authors suggest the possibility of chronic low-dose CO in children who live with smokers, as a result of secondary smoke.

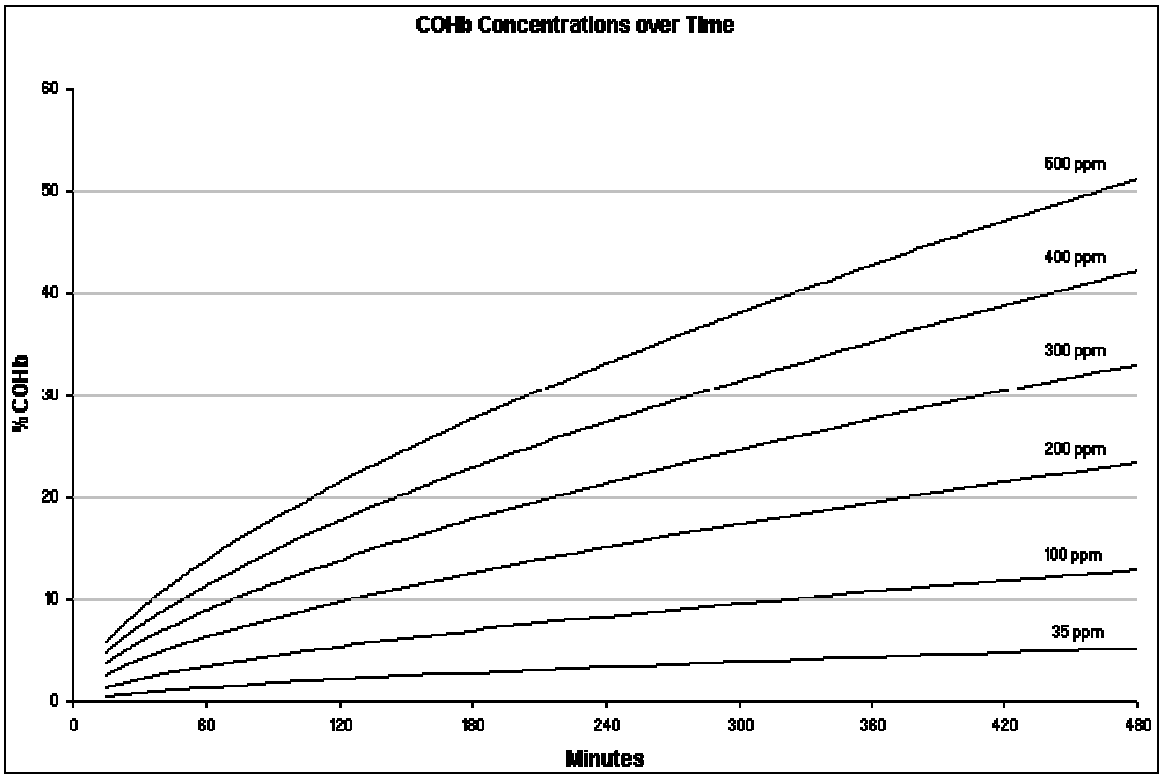
Equilibrium equation (after 6-8 hours) between COHb-level and inhalated CO concentration:
COHb (%) = [CO] (ppm) : 6

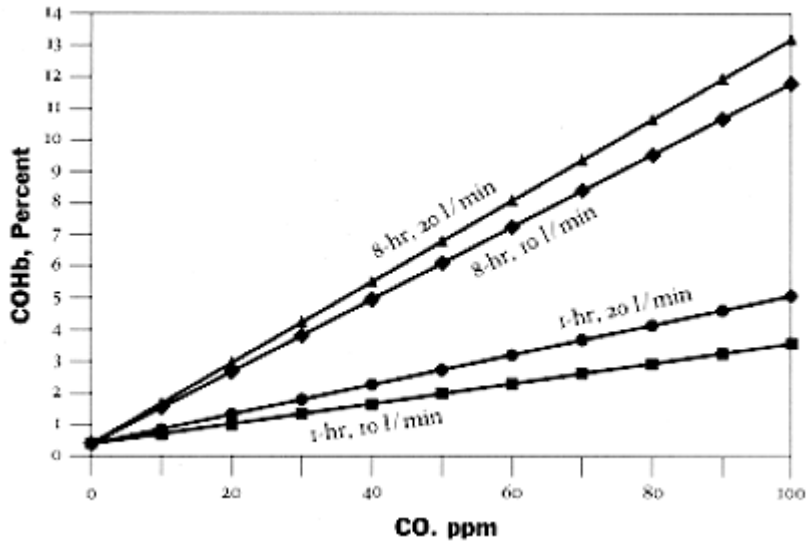
CO toxicity is potentially worsened by a reduced alveolar oxygen partial pressure (e.g. high altitude) increased alveolar ventilation (e.g. (increased activity) preexisting cardiovascular and cerebral vascular disease, increased affinity of hemoglobin to CO (eg. fetal hemoblobin), anemia, hypovolemia.

Elimination occurs predominantly through the lungs; the half-life of COHb in room air is 3 to 4 hours depending in minute ventilation. Administration of 100% oxygen shortens the COHb half-life to a mean value of 60-70 minutes (35-100). With hyperbaric oxygen the half –life is approximately 0,5 hours.

The clinical manifestations of a acute CO poisoning may vary from irritability to depression. General: headache, nausea, fatigue, weakness, vomiting, weakness, confusion and apathy; cardiovascular: chest pain, tachypnea, tachycardia, hypotension, pulmonary edema, arrythmias, cardiac arrest; neurologic: dizziness, ataxia, seizures, coma; other signs of CO-toxicity are retinal hemorrhages, metabolic acidosis.
It is important to know the concentration and length of exposure to predict adverse health effects. Concentration of CO also increases with level of activity. The minimum lethal CO blood concentration has not been established:

CO concentration (ppm)	Time of exposure	~COHb (%)	Health effects
0-9	>8 hours	< 2%	No measurable adverse health effects
9- 30	> 8 hours	3-5 %	Minimal adverse health effects, usually related to longs, heart, and nervous system, especially in more susceptible people (i.e. heart disease, ill elderly, very young, etc.). Exposure should not continue over 8 hours. Immediate action to determine source.
35 (0,0035%)	8 hours	6%	Maximum exposure in the workplace.
200 (0,02 %)	2-3 hours	10-15%	Mild headache, fatigue, nausea and dizziness
400 (0,04 %)	1-2 hours	20%	Serious headache, short of breath with activity, other symptoms intensify. Life threatening after 3 hours
800 (0,08 %)	45 minutes	30%	Dizziness, nausea, vomiting, tachycardia and convulsions. Unconscious within 2 hours. Death within 2 hours.
1600 (0,16 %)	20 minutes		Headache, dizziness and nausea. Death within 1 hour.
3200 (0,32 %)	5-10 minutes		Headache, dizziness and nausea. Death within 1 hour.
6400 (0,64 %)	1-2 minutes		Headache, dizziness and nausea. Death within 25-30 minutes.
12.800 (1,28 %)	1-3 minutes		Death


COHb Concentrations over Time
%COHb
Minutes
600 ppm
400 ppm
300 ppm
200 ppm
100 ppm
35 ppm
0
10
20
30
40
50
60
0
60
120
180
240
300
360
420
480


COHb, Percent
CO. ppm
8-hr, 20 l/min
8-hr, 10 l/min
1-hr, 20 l/min
1-hr, 10 l/min
0
20
40
60
80
100

ADDITIONAL INFORMATION

Mrs. Jones continued to suffer from severe headaches, fatigue, depression, and irritability. She also continued to have cognitive and memory problems, and began to develop muscle and joint pain, to hear a buzzing sound in her head (Tinnitus), and to have various visual problems. Mr. Jones continued to find it difficult to do his job. He could not make decisions (loss of executive functioning) and lost track of details in his work. The children continued to struggle academically and socially - cognitive testing at school suggested recent significant declines in I.Q. in both children.
The Jones family is attempting to recover from the health problems caused by their old, leaking furnace. They have been seen by a number of health professionals with varying results: neurologists, toxicologists, and neuropsychologists. To the Jones', it appears that few people in the medical community have much understanding of the long term health effects of chronic CO exposure. They have retained legal counsel and are discussing options which might lead to compensation from responsible parties. Fortuitously, they have kept the old furnace, flue and other parts as evidence.

What issues does this case study make?

- Have a thorough inspection when you buy a house, especially an older house.
- The multiple symptoms reported (headache, dizziness, nausea) should have increased suspicion of CO poisoning.
- Similar symptoms in several people should also increase suspicion of CO poisoning.
- A CO detector should have been purchased and installed in home.
- The physician should have been strongly encouraged to promptly order COHb tests.
- Furnace and "gas" inspectors should always test for CO.
- Fatigue and lethargy combined with headache are strong indicators of CO presence.
- If you can't get satisfaction with one physician, see another - a G.P. or a specialist with experience in CO poisoning.
- While the leaking furnace, flue ducts and faulty chimney were discovered by chance, Mr. Jones did the right thing to immediately have the house tested for CO.
- Blood samples for COHb measurement were taken way too late, ie. they must be done within 2-4 hrs. after leaving the site of the poisoning).
- The residual effects ellicited by all members of the Jones family are consistent with chronic CO poisoning.
- The health effects of the CO poisoning continue at least 1-1/2 years after the CO poisoning was discovered/ended.
- Mr. Jones was wise to have kept the faulty furnace, flues, and other parts, should legal action be necessary.