APPENDIX A - OZONE TOXICITY

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Christian Friedrich Schonbein, in 1847, first noted the presence of an odorous gas near electric generators. He found that the gas had toxic effects on himself and experimental animals, and named the gas "ozone" after the Greek word meaning "to smell." Over 130 years later we are still trying to determine what ozone does to living systems and how it does it.

Much of what we know about the long-term effects of ozone on human health comes from the effects of ozone formed in photochemical smog. We assume that the effects of photochemical smog, a mixture of oxidants, are the same as the effects of natural ozone in the stratosphere. Much evidence is also available from laboratory experiments on humans and animals, most of which relate to the acute effects of ozone.

There is no doubt that ozone is extremely toxic. About 0.018 ounces of ozone in a 55 gal drum of air (ca. 0.40 parts per million by volume (ppmv)) would be enough to cause symptoms in some people. These symptoms would be nasal dryness, cough, pain beneath the breastbone, perhaps headache, and a burning sensation in the throat. Some people may also complain of eye irritation.

How does ozone produce these symptoms? Current concepts tell us that we must look at the molecular biology involved in order to have some understanding of ozone's effect. Molecules are made up of aggregates of atomic nuclei surrounded by orbiting electrons. These electrons exist in orbital pairs, with the members of each pair spinning in opposite directions. This opposite spin condition produces strong coupling between the electrons. When all orbitals have their full complements of electrons, the molecule is stable. When an electron acceptor takes away an electron, the electrons are uncoupled and a reactive free radical is formed. Living systems are characterized by free radical formation with an orderly electronic flow from acceptor to acceptor until finally the electrons are passed to oxygen.

When ozone (O_3) breaks down in water, as in the body, it forms a hydroxyl (OH.) free radical. This is a powerful electron acceptor and makes other free radicals of electron donors. These are aberrant free radicals and do not fit the normal orderly flow of cellular energy. Their disruptive effect produces metabolic disturbance that is reflected in altered cell function. If enough cells are affected, the symptoms of ozone toxicity with which we are familiar appear. In this regard, the effects of ozone resemble the effect of ionizing radiation which also produces free radicals. Radiation is much more effective because of its deeper penetration and widespread route of entry into the body.

How much ozone will cause enough damage to produce symptoms? The published literature tells us that normal people are generally not affected by less than 0.30 ppmv. At a concentration of approximately 0.30 ppmv effects measurable in the laboratory begin to appear. Between 0.30 and

0.50 ppmv reversible symptoms noticeable by the affected person begin to appear. Above 0.50 ppmv damage begins to appear that outlasts the period of exposure. Above 1.0 ppmv serious damage begins to occur with stupefaction reported to occur at about 5.0 ppmv. Thus, the critical dividing line between serious and mild effects is about the 0.50 ppmv level.

We can list several things regarding ozone toxicity for humans gleaned from the literature. (1) For normal people, the biological threshold for ozone effects (aside from odor) probably lies between 0.20 and 0.30 ppmv; (2) Effects are probably first detectable in blood; (3) Symptoms noticeable by the affected person appear between 0.30 and 0.50 ppmv; (4) Some people are more reactive to ozone than others. Asthmatics and people with allergies commonly react at lower levels of exposure than others, young people seem to be more sensitive than old people and smokers are less sensitive than nonsmokers; (5) It is commonly stated that ozone is an eye irritant. The consensus from the literature is that it is not; (6) Visual effects have been demonstrated in only one set of experiments; (7) Adaptation to ozone occurs but the mechanism is obscure; (8) Extrapulmonary effects (other than in blood) may occur but the mechanism is unknown; (9) The long-term effects of ozone on humans are not well defined; (10) Effects of ozone are more dependent on concentration than on duration of exposure; (11) Good evidence exists that free radical scavengers, such as vitamin E, mitigate the effects of ozone. Not much experimentation has been done on humans in this regard; (12) Ionizing radiation, high pressure oxygen, hydrogen peroxide, and ozone probably have similar basic toxic actions;

and (13) No report of human death from ozone exposure has been found in the literature.

Finally, it would facilitate comparisons of studies of the biological effects of ozone if exposure levels were expressed in terms of mass per unit volume instead of volume per volume. The reason for this recommendation is that at various altitudes the amount of air with which ozone is mixed changes, thus changing the volume per volume relationship. Expression of ozone levels as mass per volume (mg or μg per cubic meter) truly expresses the biological dose regardless of the altitude and requires no correction