6,000 Molecules of Li_2O in Every Pint of the World's Oceans...So What?

By John Allen Paulos

A little calculation illustrates how small an amount of contaminant is required to give the impression of a serious risk. Assume the earth's oceans contained pristinely pure water and that some environmental demon were to spill into them a pint of some awful chemical — say Li_2O for the sake of fantasy — and then systematically churn them up, so that the chemical was evenly distributed throughout. (A liquid pint is a bit more than the volume of a typical can of soda.) A few years later an inspector from an environmental agency removes a pint of water from an ocean somewhere and indignantly announces that there are X molecules of Li_2O in this pint of formerly pure water. What would be your guess of the approximate value of X?

Let me sketch for you how to use arithmetic, a smidgen of geometry, and a smattering of chemistry to come up with a very rough order-of-magnitude estimate of this number. (Skip this and the next two paragraphs if you abhor this kind of stuff.) Note first that the surface area of the earth is approximately $2x10^8$ square miles. (The radius, r, of the earth is about 4,000 miles, and the surface area of a sphere is $4\ r^2$.) Knowing that 75 percent of the earth's surface is covered with water at an average depth of about 2 miles, we determine that the volume of water in the world's oceans in cubic miles is $3x10^8$. Multiplying this figure by $5{,}280^3$, the number of cubic feet in a cubic mile, we find that the volume of the water in the world's oceans is, in cubic feet, about $4.4x10^{19}$. Since there are about .017 cubic feet in a pint, the volume of the ocean is approximately $2.6x10^{21}$ pints.

Continuing, note that there are about 29 cubic inches per pint and roughly .06 cubic inches in 1 cubic centimeter; thus there are approximately (29/.06=) 480 cubic centimeters in a pint of water or, equivalently, 480 grams of water, or, using the fact that a mole of water weighs about 18 grams, about 25 moles of water in a pint. Each mole of water contains Avogadro's number ($6x10^{23}$) of molecules, so a pint of water contains $1.5x10^{25}$ molecules of water. (There are more direct routes to this number, whose size explains why it is so easy to make a mountain out of a mole spill.)

So a pint of the now polluted oceans contains how many molecules of Li_2O? The fraction of the ocean's volume that is Li_2O is $1/2.6x10^{21}$. And this is also the fraction of the chemical in a pint of ocean. Since a pint contains about $1.5x10^{25}$ molecules, we multiply these two numbers and see that almost 6,000 molecules of the vile Li_2O reside in every pint of the world's oceans.

That pint of Li_2O (a volume slightly bigger than that of a soda can, remember) dropped into pure oceans of the world and spread about uniformly resulted in almost 6,000 molecules of the stuff appearing in every pint we retrieved. The point of this tiny orgy of calculation and dimensional analysis is that it doesn't take much to come up with a frightening headline. One part out of $2.6x10^{21}$ probably doesn't sound like much even to an alarmist, but 6,000 molecules per pint would almost certainly rouse anxiety among many.

North America—and, in the 'West,' the death rates from other diseases are falling rapidly. For most non-smokers, the health benefits of modern society outweigh the new hazards. Apart from tobacco (and in places, HIV), the Western world is a remarkably healthy place to live"....[4]

Pollution

Synthetic pollutants are feared by much of the public as major causes of cancer, but this is a misconception. Even if the worst-case risk estimates for synthetic pollutants that have been made by the EPA were assumed to be true risks, the proportion of cancer that EPA could prevent by regulation would be tiny.[105] Epidemiological studies, moreover, are difficult to conduct because of inadequacies in exposure assessment and failure to account for confounding factors like smoking, diet, and geographic mobility.

Indoor air is generally of greater concern than outside air because 90 percent of people's time is spent indoors, and the concentrations of pollutants tend to be higher than outdoors. The most important carcinogenic air pollutant, however, is likely to be radon, which occurs naturally as a radioactive gas that is generated as a decay product of the radium present in trace quantities in the earth's crust. Radon enters houses primarily in air that is drawn from the underlying soil. Based on epidemiological studies of high exposures to underground miners, radon has been estimated to cause as many as 15,000 lung cancers per year in the US, mostly among smokers due to the synergistic effect with smoking.[106-8] Epidemiological studies of radon exposures in homes[109-10] have failed to demonstrate convincingly an excess risk....