Air Ion Research

Recently renewed interest in air ions (News and Comment, 30 Oct. 1980, p. 31) has two components: a scientific one and a commercial one. The latter focuses on the use of air ion generators as electrostatic precipitators of particulates suspended in air. Scientific interest, concerned with the possible effects of air ions on living forms, has been expressed in studies conducted in a few laboratories in various countries. One such is the Air Ion Research Laboratory at the University of California, where experiments with air ion effects on bacteria, protozoa, plants, insects, and small animals have been in progress for the past 25 years.

The cumulative data from all these programs provide a solid basis for accepting small air ions as biologically active agents. For example, 20 or more reports attest to the ability of small air ions to kill vegetative bacteria (*1*). Recently, this lethal action has been shown to involve the superoxide ion O_2^- in its hydrated form (*2*). In the past the putative actions of small air ions have been attributed to the accompanying electrical fields. This objection now has been overcome by experiments conducted in air ion-depleted air. Air ion action distinct from field effects was observed, and small air ions per se were shown to be biologically active agents (*3*). There is ample evidence that small air ions affect tissue levels of serotonin (*4*). Studies on serotonin and cyclic nucleotides in the cerebral cortex point to important mechanisms of air ion action in the brain (*5*). Air ions stimulate plant growth and air ion depletion slows growth. The biochemical reactions involved in plant responses to air ions have been partially deciphered (*6*).

It would be remarkable if air ions were able to affect such a wide variety of living forms and were not able to act on humans. So it is not surprising that disturbances in serotonin metabolism occur when the meteorological condition known as the *sharav* prevails in Israel. The hot dry wind is preceded by increasing levels of small, positive air ions in the atmosphere, and weather-sensitive individuals are afflicted with what is called (*7*) the serotonin irritation syndrome, a symptom complex explicable on the basis of overproduction of serotonin. In fact, extraordinary amounts of serotonin are excreted in the urine. Patients are helped by administration of serotonin antagonists or by treatment with small negative air ions.

As we see it, the growing interest of the scientific community in air ions will lead to advances in the following areas:

1) Establishing the range of the biological effects of air ions at the cellular and tissue levels.

2) Deciphering the mechanisms of air ion action.

3) Assessing the role of air ions in nature and in the modified environments of our culture. The latter would include such areas as living and working quarters, the zones adjacent to high voltage, direct current transmission lines where ion levels can be expected to rise, and so forth.

4) Stimulating clinical studies of air ions. There have been many attempts to use small negative air ions as a therapeutic modality, for example, for asthma and migraines. However, the available data are overwhelmingly anecdotal and do not meet the standards of double-blind, cross-over, experimental design required in the United States. Certainly, careful evaluation of clinical applications of air ions would appear to be in order.

Twenty years ago, several manufacturers sold their products with unwarranted health claims, and the necessity for the Food and Drug Administration to take action against them cast a shadow on all aspects of air ion study and development. We hope that the commercial exploitation of air ion generators now under way will not bring about a repetition of past events. Entirely apart from this phase of the subject there is a genuine need for continued scientific investigation of the biological effects of small air ions.

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Melvin First (Letters, 14 Nov. 1980, p. 714) states that "most negative ion generators emit copious quantities of ozone." Actually most currently available negative air ion generators produce very little ozone. Virtually all manufacturers meet or far exceed the U.S. government standard for ozone exposure. Corona discharge generators used in experiments at the University of California, Berkeley, were tested for ozone production and were found to produce < 88 picomoles of O_3 per minute. The devices tested were all very similar to commercial generators, and the low ozone production did not inhibit ion production, which was about 2×10^{13} electrons per second.

The bactericidal effect of negative ions is probably not due to ozone produced by the ion source as First states. Early Russian reports of bactericidal effects (*1*) have been repeated using tritium ion sources which produce no ozone (*2*). Many authors confirm this effect (*3*), and recently Kellogg *et al.* showed that superoxide anion (O_2^-) is involved in the bactericidal effect of negative ions from a corona source (*4*).

Regarding the ability of ion generators to clear particles from the air, research shows that the stability of aerosols is influenced by charging of the individual particles (*5*). A room with an ion generator is not a fieldless environment and typically has an electric field of 5 kilovolts per meter or more (*6*). Since aerosol particles acquire multiple charges from small ions (*7*), the effect of an ion generator on particle mobility in a charged room is quite large. Also, for a wall or ceiling to be an electrostatic "ground" it is only necessary for the surface to be significantly more conductive than the surrounding air. Thus, a wall with a resistance to ground of 10^4 to 10^6 ohms acts as a ground plane for air ions in the room (*8*).

It is extremely unlikely that an ion generator could cause sonic agglomeration of an aerosol, and we find no evidence to support this idea. Studies of sonic agglomeration (*9*) use sound pressures of 110 to 150 decibels. This sound pressure is so intense it is deafening or painful. The sound level produced by an ion generator is many magnitudes less than the acoustic energy necessary for sonic agglomeration, and is even less than the sound from a small portable radio.

Scientists studying air ions generally acknowledge that ion effects are poorly understood and that some published experiments lack adequate controls. This situation can only be corrected by more careful research which avoids past mistakes. It is also important that public information be as factual and unbiased as possible.

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R & D and Productivity

Rather sharply, between 1964 and 1965, the federal investment in research and development (R & D) went through a uniquely significant change in trend. For perhaps a century before 1964 the federal gross expenditure in R & D had been increasing exponentially relative to the federal budget at a rate of about 11 percent per year. It was about 1 percent of the budget in 1940, 2 percent in 1947, 4 percent in 1953, and 8 percent in 1960. It peaked in 1965 at about 12½ percent, which is a remarkably high proportion when one considers that about half the budget consists of unallocable items fixed by law. Since 1965 the budget share has decreased, also rather steadily and exponentially at a rate of about 6½ percent per year. In 1980 it was about 5½ percent, and it will probably decrease shortly to less than 5 percent. It is worth noting that the peaking out occurred even before the Mansfield Amendment cut off Defense-supported research. The same phenomenon of saturation occurred in the United Kingdom just before the adoption of their Rothschild Convention, which had a similar effect of motivating a sudden decompression that seems to have been happening anyway.

John Walsh writes (News and Comment, 13 Feb., p. 685) that Edward F. Denison suspects this R & D change may have something to do with the productivity problem. It has, however, long been known from the work of Freeman (*1*) and others that the empirical data for several industries in the United States and in the United Kingdom show that the R & D investment in industry goes up as about the cube of the growth rate. The marginal costs of innovation pressure are rather high. The name of the game in high technology is that growth is largely produced by product and process innovation. If we suppose that what the economists call productivity in our high technology industry is produced by the R & D in this way, we must infer that the 1964–1965 transition should have produced a change (taking the cube root of the R & D change) from a positive growth rate of about 3.7 percent to a negative one of about 2.2 percent, thereby producing a decline in the high technology sector of almost 6 percent each year below that produced traditionally before. Of course, not all our industry is high technology, but it seems clear that the expected decline resulting from saturation of federal R & D spending capacity can be held responsible for the major component in declining productivity and profitability of the industries involved. Since these are also a large part of the import/export balance of trade, as Boretsky has shown (*2*), it follows that this may be a similarly large factor in the turnaround of that balance and the consequent weakening of the dollar and inflation of the currency (at approximately the same rate of 6 percent per year).

Because of this plausible mechanism one needs to look closely at the reasons for the silent transition of 16 years ago. Denison sees that this was also the period when the steady 0.5 percent per year migration of agricultural labor into industry and services could hardly go further; what in fact happened is that the process then switched (circa 1965) to a rather slower migration from industry to the service sector, in what Daniel Bell calls the onset of a post-industrial society. Another part of the transition occurred because the federal R & D budget simply could not become greater than about a quarter of the allocable resources, and the Office of Management and Budget foot was firmly transferred from the accelerator to the brake. The universities also suffered a sudden transition at this time, although it was masked by the Vietnam War. Again for maybe a century the student population had grown exponentially at a rate of about 6 percent per year, mostly because the increasing enrollment rate was taking us from an elite to a democratized higher education. When half the young were going to college, no further growth was possible; very suddenly we stopped producing professors at a rate of 8 percent per year and needed only the 2 percent replacement rate for those leaving by retirement and death. This meant a lot for the R of R & D because a large part of the nation's R is performed in the universities; a cut of the needed training rate by a factor of 4 inevitably reduced graduate student research and our investment in this sort of future.

The university, budget, and employment crunches all happened almost simultaneously (circa 1964–1965), but there is a pipeline of 5 to 10 years between putting the R & D in and getting the economic impact out. It is entirely reasonable to my mind that the decline in the economy did not begin to be perceived until about 1973.

The moral of this story seems clear. If we wish to live in the affluent life-style of a post-industrial society, we must see to it that the service economy produces via high technology the profits and exports to pay for it. To do that we, alas, cannot possibly invest in R & D in the old style. The projection of the exponential curve up to 1964 would give us by now an investment of about 72 percent of the federal budget, which is ludicrously impossible. We might, however, do better than the current 5 percent, most especially on the R side of the ledger, where scientific technological innovation begins.

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