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*by Dr. W.B. Clapham, Jr.**

It is interesting after the strong statements made so far that this meeting is taking place in Ohio, a state whose Governor James Rhodes has often said that nobody knows where acid rain comes from. He recently came back from the National Governors Conference about a month ago saying he pulled the teeth out of a strong acid rain resolution. He has previously contended that acid rain is a fantasy created by the Environmental Protection Agency (EPA) to harrass Ohio and that blaming acid rain on Ohio is like blaming hurricanes on Florida.

I do not mean to suggest that these are the ravings of a madman, because they are not. They are, I think, an honest feeling of a governor who can and does avail himself of scientific expertise throughout the industry and the university system of his state and who I think believes he is speaking in the best interests of the State of Ohio. He could not say these things, nobody could say these things if there were unanimity of opinion in the scientific community, and there isn't.

No responsible observer questions that oxides of sulfur and nitrogen, sometimes known as SOx and NOx, are produced by combustion and emitted into the atmosphere. Most of them come from cars and from coal burning plants, either power plants or industrial plants.

There is an awful lot we don't know and I want to take a look at the questions which arise and try to assess their significance.

There is little agreement in the scientific community with regard to the transformation of SOx and NOx into acids and the effects on ecosystems. Anyone who expects all scientists to agree on anything, especially something as complicated as acid rain, doesn't understand scientists. The utility industry may sound very enlightened in calling for more research on acid rain until the scientific community can agree on what acid rain is, what it does, how long it takes to form, and so forth, but this argument doesn't hold water. Even its own scientists and engineers know better.

It will be an awful long time before we can agree on the kinds of matters our colleagues were talking about. As Mr. Roberts pointed out this morning we just don't have that time.

The scientific background of acid rain involves far more than physics, chemistry, biology. I believe we have to take a very close look at the uncertainties of our scientific knowledge and assess their significance.

Acid rain has policy implications that many other scientific issues

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don't, and the needs of the policy-makers are often very, very different from those of scientists.

It's one thing to look at measurable data as scientists are wont to do, but the significance of those data is that they influence governments and they influence courts. In regard to acid rain, the way in which scientific knowledge influences governments and courts is much more important, I think, than the current state of our knowledge, because the policy decisions will determine methods of control — how much money will be spent, and where and what the present status of the lakes is and whether and where future power plants will be built.

We all look at issues through colored glasses and the colors we see depend upon our backgrounds, our interests, positions, and beliefs. I think we need to make it clear where we are coming from if we are to communicate with each other. In my own case, I have been trained to take a broad view of acid rain, so that the phenomena that Drs. Martin and Cowling have been talking about need to be seen in the context of their public policy implications. I am convinced that the most useful scientific discussion for this panel is one directed toward these policy questions. Specifically, I think we need to discuss the state of our scientific understanding as it stands now and as it is likely to develop, and how it influences the kinds of decisions that are going to be made by governments or courts in North America.

We have different perspectives on issues. Scientists tend to look at cause-effect chains and try to look downstream in a very logical way. I begin with the premise that reality is something "out there". Regardless of what my client wants me to come up with or what I feel I want to come with I can't alter that reality.

Attorneys, on the other hand, analyze problems in a different manner. They begin with a problem and work upstream along the cause-effect chain to find its source. They seek, ultimately, a legal remedy rather than a scientific understanding of reality. Moreover, the adversary system in which attorneys operate demands vigorous advocacy of a client's position. Its end is conflict resolution, not the promotion of an objective understanding of reality.

If our goal is to deal responsibly with the problems posed by acid rain, I think we can structure four criteria for judging its scientific basis.

First of all, do the factors we can agree upon allow enough insight into the problem that we can make responsible decisions?

Second, can we expect to gain adequate understanding of the uncertainties in the short time frame within which decision-makers operate? In this country this year decisions will be made on the Clean Air Act. Clean Air Act discussion is not going to wait for scientific understanding on acid rain. Amendments to the Act will be formulated this year or maybe next year, but certainly no later. The law says this year.

Third, can we express the significance of scientific uncertainty in a meaningful way? Finally, and I say this in all seriousness, are we trying to solve the right problem?

First of all, I have identified a few factors about which there is considerable agreement. SOx and NOx are emitted from various sources in large and estimable quantities as Dr. Martin pointed out. They are transformed into strong acids. The measured pH of rainfall is often more acidic than would be expected for natural conditions. Lakes in several parts of the earth have become acidified. Some areas are more vulnerable than others to acid precipitation. Acidification of lakes has destroyed fish populations.

There are some other factors which we can agree on, but which raise serious analytical and methodological problems. For example the correlation between pH and nitrates and sulfates is often weak. Also, the sampling methods for wet desposition are much more effective than those for dry deposition, so it's hard to gather definitive information about the dry depositions. Finally, over the last 50 years there has been no standardization of sampling locations, methods and measurements.

We can identify several points of uncertainty concerning acid rain: First of all, as Dr. Martin suggested, the details of the chemical transformation pathways are a mess. Atmospheric chemistry tends to occur with a rather strange kind of chemical mix. The layman thinks of chemistry as taking a bunch of chemicals, mixing them together, and the mixture explodes. Atmospheric chemistry, however, is much more complex. It's likely that sulfur and nitrogen oxides behave as other atmospheric chemical species and react through the absorption of light energy forming highly reactive entities termed "free radicals" — especially active forms of the molecule. Pathways involving such intermediaries are speculative, since the intermediaries are short-lived and cannot be purified and shown in a discrete state. Many of the mechanisms are inferred from fog-chamber experiments that are deliberately simplified to provide some meaningful data. It seems clear that different mechanisms are involved at different times and that the rate of transformation may vary over an order of magnitude: it is most rapid — up to about five percent per hour — during the daytime in polluted atmospheres where particulate catalysts are available, and least rapid — less than one half percent per hour — at night. There is a significant body of evidence supporting this theory but it might not be the kind of demonstrative evidence that would sway a critical decision-maker untrained in science. You simply can't bottle the evidence, present it to the decision-makers, and declare "This is excited sulphur dioxide!" The only excited body in the hearing would be you, the witness.

The second ambiguity concerns the dynamics of large scale transport. Most discussions of acid rain begin with the assumption that the overwhelming proportion of acid rain is produced by anthropogenic sources. In fact, there are many natural producers of SOx and NOx. Volatile suflides are released from swamps and soils that can oxidize into sulfates. Plants also release nitrogen compounds that can be converted into nitorgen oxides, though not the most reactive type — President Reagan is simply wrong in categorizing plants as leading producers of acid rain. Volcanic sources of sulfur compounds are relatively less important that biogenic generators although they may be the predominant source in certain locales. Sea salts also produce sulfates, but they are not long-lived in the atmosphere. On the average throughout the world, it appears that natural sources account for approximately 40 to 60 percent of the atmosphere sulfur. In the industrialized northeastern United States, however, the level of atmospheric sulfur is about eight times the world average and anthropogenic sulfur constitutes over 90 percent of the total. I might add that Ohio produces about four percent of all anthropogenic sulfur emitted into the atmosphere throughout the world.

The third problem involves the increasing difficulty in tracing the fate of SOx and NOx in the atmosphere as long range pollutant transport becomes a global phenomenon. High levels of sulfate and nitrate, presumably anthropogenic in origin, move from continent to continent with the global flow of air masses. As an example, I recall hearing a report a few months ago that sulfur coming across the Atlantic Ocean was, in fact, the source of the sulfur that was plaguing Scandanavia.

Analytical methods and sampling stations to measure acid rain have changed since the 1950's. This has introduced some important methodological questions in documenting the cumulative effects of acid rain. The destruction of once productive lakes is a concrete and well documented fact. The fall in the pH of rainfall is not. It would be useful to be able to compare past data collections with each other and current data but this hasn't been done yet. At this time we must discount the numbers presented in the data to account for the fact that they were taken by different people in different places and by different analytical techniques. Although the old method of measuring pH levels has an error factor or two, it still provides strong evidence that the severity of acid rain has increased in the last 25 years. It does not, however, allow for an adequate formulation of a predictive model that would project various policy options and control strategies for the future. Such projective modeling is an extremely useful scientific tool but the deficiencies of our data reduce the accuracy and effectiveness of the available models.

The nature of the chronic effect of acid precipitation on ecosystems is not yet well known. When we think of acid rain we think of lakes losing their fish. It's dramatic and final. Acute problems like this, however, generally are accompanied by chronic — low level, long-term and subtle — problems. If our experiences with other environmental phenomena are any guide, the chronic problems are likely to be more significant than the acute ones. Some of these more subtle problems are understood to a degree, but it's not clear whether they can be generalized from one ecosystem to another, or what precisely their overall importance is.

The direct impact of acid rain on forests is not known very well either. There reportedly is one place in Germany where the effects are visible and can be documented but that seems to be the exception rather than the rule.

Increasing the acidity of water percolating through the soil can be expected to increase the rate of nutrient leaching, thus lowering chemical fertility. Sulfur and nitrogen, however, are both essential elements for plants. Therefore, acid rain may have a short term fertilizing effect even as it undermines long term fertility.

We know, for example, that percolating acidic water through soils or into lakes can mobilize heavy metals and other materials such as aluminum, which become quite toxic. In many cases fish are killed not by the acid but by the aluminum. We don't know if a similar mechanism affects the microflora and microfauna of soils, whose primary role is in nutrient cycling. Experimental evidence suggests that there is an effect and that acid rain has a subtle impact on biological solid fertility. We don't know, however, how prevalent the phenomenon may be.

Other significant factors which are as yet unclear regarding acid rain include: the dynamics and role of alkaline particles in the atmosphere; historical perpectives on factors determining SOx and NOx emissions; models to project accurate future estimates of SOx and NOx emissions; and the influence of various control technologies in long-range transport.

What's the significance of these factors? Just to say that we don't know something isn't enough, especially with a problem like acid rain which will be handled in the public policy arena, but may make little or no reference to the current state of scientific knowledge. It must be noted that a decision to do nothing is as much a policy choice as is one to control all pollution sources.

The real issue with the uncertainties in acid rain is not that they represent questions, but rather that they color our perceptions and decisions in less obvious ways than scientific knowledge does. We may recognize that a problem exists, but that problem is discounted because we do not know its true significance. How would we respond if we understood the issue completely? From what we know about acid rain, is it likely that increased knowledge would have a large or small influence on our decisions?

We can't answer these questions precisely, but scientists are trained to make preliminary judgments of this sort. Let us take a closer look at the uncertainties and see if we can come to some conclusions. Adding to our knowledge base would make some factors seem more important than they now seem, others less important, and would have no effect on still others. Considering all of the uncertainties and gaps in our current knowledge, as well as how society would view acid rain if we understand it thoroughly, it seems likely that complete understanding would lead us to conclude that acid rain is more of a problem than we currently suspect. Society would be more likely to increase the level of control rather than to conclude that it had been overly cautious. Of course, my list is not complete and it represents the feelings of only one person, but it gives a meaningful preliminary view of the significance of the unknowns triggered by acid rain.

When we act in response to natural phenomenon we implicitly respond to a belief regarding the state of the natural system. A particular natural condition is either true or false and we may conclude that it is true or false. We are correct if we conclude that it is true when it is actually true, or false when it is actually false. We are mistaken when we conclude it is true and it is actually false, or false and it is actually true.

In formulating public policy we operate under this same uncertainty. For example, it would be an error to require a control measure for acid rain in the belief that it would alleviate the problem if it would not, or not to require emission controls in the belief that they would not be effective if they would be. Is either of these errors preferable? North Americans traditionally prefer to err in the direction of protecting the public health and welfare and thus tend to prefer incurring the cost of an unnecessary preventive measure rather than risk the public well-being. There is no reason to believe that this preference would not be operative or would operate differently in the acid rain context.

Obviously we would prefer to avoid error and its attendant costs completely, but that is not possible with acid rain, even if we had adequate information on its causes and effects. Meanwhile, we must decide how to deal with the problem. It would appear that any responsible solutions to the acid precipitation problem based on our current understanding and concern will be vindicated by a more complete understanding of the issues.

Earlier I posed the question of whether we are dealing with the right issues? Acid rain is often presented as a phenomenon which kills fish and which may have other unquantifiable effects, but which doesn't really affect us directly. It's important to remember, however, that acid rain is the long-range manifestation of the SOx and NOx emissions which also cause short-range problems. Instead of concentrating on acid rain as a separate issue, it might be useful to consider it a critical sub-issue of the larger air pollution problem.

The death of fish and lakes is dramatic, but such destruction in Ontario and New York may not capture the attention of legislators from other provinces and states not suffering from or vulnerable to the effects of acid rain. Looking at the long and short range phenomena together, however, may be convincing. For example, the recent Ohio River Basin Energy Study (ORBES), based on sound meteorological approaches, concluded that the SOx emissions from the Ohio River Basin account for approximately eight thousand deaths annually and that SOx and NOx were directly responsible for crop losses of over one billion dollars. If you take a reasonable value of human lives, assuming that is possible, the short range costs of acid rain are over two billion dollars per year without considering damage to real and personal property. This morning Mr. Roberts mentioned two or three billion dollars of property damage. These estimates of the short range impact of acid rain, even if not completely accurate, demonstrate the order of magnitude of the phenonmenon's social costs and provide ample justification for implementing serious control measures immediately.

In summary, there is much about acid rain that we do not know. It is a very complex phenomenon that seems overwhelming in its uncertainty. Analyzing the significance of this uncertainty, however, suggests that we know enough about the phenomenon to proceed with policies to control it. Additional understanding of acid rain is likely to support the control measures we have implemented. Similarly, an analysis of acid rain and the related manifestations of SOx and NOx pollution supports reducing the total loadings of these oxides into the atmosphere. The issue is still controversial but it is much easier to build a scientific case for trying to deal with acid rain than delaying action until the uncertainties are solved. There are a lot of questions that we cannot answer satisfactorily yet, but the evidence is very compelling that we would probably be even more worried than we are now if we knew more than we do.

Thank you.