NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

CONF-720920-2

RELIABILITY IN SCIENTIFIC EVIDENCE BASED ON MULTI-TRACE FORENSIC NAA*

W. S. Lyon, E. Ricci, L. C. Bate, F. F. Dyer

Analytical Chemistry Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

INTRODUCTION

Analytical data from neutron activation analysis (NAA) are usually provided for the individual interpretation of scientific colleagues. The forensic activation analyst, however, must often evaluate his own results as they relate to certain legal or moral situations, since investigative officers, and courts of law are not usually competent to make judgments of the validity or meaning of scientific data. Usually we think of these situations as involving the guilt or innocence of an individual, but increasingly today the analytical chemist is called upon to present data in cases attempting to assign corporate responsibility for environmental pollution. An onerous moral responsibility results from such decisions since an individual's freedom may be at issue, or the future of some industrial operation.

In providing scientific evidence in court, two criteria for criminal identification must be met: (1) suspect's sample should be similar (i.e., "match") sample found at the scene of the crime; (2) samples related to other people in the same statistical population (potential suspects) should not generally match that found at the crime site. For an industrial case the same criteria are valid, except now the matching in (1) is between a pollutant sample and one from the suspect source, and in (2) samples from other sources should not match. The importance of valid statistical background data to realize the comparisons required by criterion 2 cannot be overemphasized. These data are largely unavailable. Even techniques used to meet criterion 1 deserve improvement. The statistical evaluation of such samples is beyond the scope of this paper and has been lucidly presented by Parker. (1,2)

MASTER

*Research sponsored by the U. S. Atomic Energy Commission under contract with the Union Carbide Corporation.

When two or more specimens are submitted for comparison by NAA they will usually fall into one of three classes: (a) materials about which we have no statistical background analytical data, (b) materials about which we have partial or inconclusive data, (c) materials with an excellent analytical data background. Ideally all cases would fall in category c; in practice, very few. Some examples of cases and/or situations that fall into these three categories in both individual and corporate investigation are given below.

A. Materials about which we have no statistical background data.

"The world is so full of a number of things

I'm sure we should all be as happy as kings."⁽³⁾

Considering the present lot of royalty today, perhaps the quotation has a truer but more different meaning than that suggested by the poet. For the world is indeed filled with numbers of things the trace element content of which we know nothing about. Thus most of our comparisons are in the unknown class. What can we say about such samples? Privately, perhaps some speculation; publically, nothing. In a recent criminal trial in the U.S.A.⁽⁴⁾ NAA evidence concerning trace element comparison of blood samples was admitted over strenuous defense objection. The defendant was convicted, and only upon appeal to the State Supreme Court was the verdict reversed, the court holding that the blood analysis was inadmissible since the technique was not proved. Those who attempted to introduce the evidence ended up by hurting not only their own cause, but the course of scientific NAA application as well.

A similar situation exists in pollution problems when one attempts to link an industrial concern with a contaminant (e.g. Hg) found in the air. Since we do not yet completely understand all the sources of Hg, how it reacts in its various forms, or even how to sample some potential pollutant sources (e.g. power generating plants), it is obvious we must be very careful in ascribing Hg pollution to a

particular source.⁽⁵⁾ Much of the Hg found in the atmosphere may come from degassing of crustal materials.⁽⁶⁾ Recent NAA results that show Hg contamination at approximately constant levels for over 50 years in some samples reinforces this caution.

B. Materials about which we have partial or inconclusive data.

"A little learning is a dangerous thing
Drink deep, or taste not the Pierian spring
These shallow draughts intoxicate the brain,
And drinking largely sobers us again." ⁽⁷⁾

Pope's admonition should be taken seriously by every NAA practitioner. When there is uncertainty in the background data there will be uncertainty in the comparison. In a U.S.A. case⁽⁸⁾ involving NAA comparison, reference was made to a journal article that purported to give statistical data on NAA analysis of tape used in a bombing. Concentrations of Na, Mn, Zn, and Sb in tapes produced during one day at one factory were shown. Unfortunately the authors failed to note:

1. Sodium is a common contaminant; thus, it should not have been used for comparison purposes because its values are always erratic and meaningless.
2. The authors also failed to see a correlation that existed between Mn and Zn (see Fig. 1); therefore one of these elements, say Mn, added little information and should have been withdrawn from the comparison study.
3. The remaining elements Zn and Sb showed totally unpredictable and irregular variations as large as 200% and 11,900%, respectively.
4. In view of this enormous variability of the results, the apparent differences found by the authors between samples from two manufacturers (only two samples for each manufacturer) could not have had significance. The data actually show that it would be very improbable to find two similar tapes from one single manufacturer -- a conclusion diametrically opposed to that stated in the paper!

A similar paper published later was concerned with results obtained by NAA of white bond paper and purported to show that identification of such paper was possible based on data from six elements. Table 1 is an analysis of these data obtained for a single sheet of paper. Deviations within one sheet of as much as 173% for one element would seem to make comparisons of this type meaningless.

Harbor pollution by oil and asphalt has long been a problem. Excellent work reported from Gulf Radiation Technology ⁽⁹⁾ shows that by use of NAA two oils can be identified as similar or dissimilar with a certainty of 99.999%. The authors have acquired a large data base of information and the overall quality of the work puts it in class (c) below. To compare samples of two oils from suppliers is much simpler than comparing an oil with an oil slick sample which may be contaminated with sea water, debris, and perhaps oils from several sources. The cautionary note here is to beware of treating as simple a system that may be very complex.

C. Materials with an excellent analytical data background.

"To see a world in a grain of sand
And a heaven in a wild flower
Hold infinity in the palm of your hand
And eternity in an hour."⁽¹⁰⁾

Glass (made from sand!) has been the subject of an exhaustive study by the Aldermaston group in England.⁽¹¹⁾ This (and additional) work is discussed elsewhere at this meeting. We will only remark that it is a model of careful and meaningful research in forensic NAA. The project at Gulf concerned with interpretations of trace patterns in a paper⁽¹²⁾ appears to be another excellent piece of work. Comparisons based on these data should be received in court cases with no reservations — at least for the present period. One wonders, however, how often this data base should be rechecked, updated, or completely redone. The preliminary

work on hair by the Aldermaston group⁽¹³⁾ is now five years old. It seems unlikely that it is representative of the population today.

Turning to environmental problems, recent experiments in analysis of air particulates by NAA indicate that it is often possible to establish the source of some air pollution. Workers at Los Alamos⁽¹⁴⁾ have sampled aerosols above three different copper smelters; they find that their trace element profiles are quite different. Re is the main constituent of two of these particulates (the third is void of Re), and of these two the next highest component in one is Sm, while Sm is absent in the other. Such data should make a strong argument in assigning responsibility for pollution. These same scientists have studied trace element profiles from many other pollutant sources including generating plants, mines, refineries, etc. Here again one must face the problem of multiple sources, but some evidence may be unequivocal.

CONCLUSION

NAA has been accepted in the courts and has been successfully used in a number of trials. An excellent review from a legal point of view documents these events.⁽¹⁵⁾ However, we are not without faults. Some individualistic solutions (such as hair) that once appeared to offer an easy road to criminal identification and prosecution are now viewed in a more realistic and sobering light. For there is, unfortunately a large gray area about which we think we know something but where our knowledge is actually limited by nature. It is in these shadowy realms that we must be most careful. Probably most biological material — such as blood and hair — and many inhomogeneous organic-inorganic mixtures — such as soil — will never be amenable to complete NAA identification. We should be careful not to make the mistakes with environmental investigation in the 70's that we made with criminal studies in the 60's. For, as the poet from the Highlands where we meet today said in a different context, realistic appraisal and honest interpretation of NAA data

" . . . wad frae monie a blunder free us
An' foolish notion."⁽¹⁶⁾

REFERENCES

1. Parker, J. B., Jour. Forensic Sci. Soc. 6, 33 (1966).
2. Ibid. 7, 134 (1967).
3. Stevenson, R. L., "A Child's Garden of Verses. Happy thought."
4. State vs. Stout, Appeal No. 56,070 Mo. Aug. 24, 1970.
5. Lyon, W. S., Bate, L. C., Emery, J. F., in Nuclear Activation Techniques in the Life Sciences, Proceedings of a Conference in Bled, Yugoslavia, 1972 (in press).
6. Weiss, H. V., Koide, M., Goldberg, E. D., Science 174, 692 (1971).
7. Pope, A., "Essay on Criticism."
8. U. S. vs. Stifel, Appeal No. 19,958, U. S. Court of Appeals for the Sixth Circuit, 1969.
9. Lukens, H. R. et al, Gulf-RT-A-10684 (1972).
10. Blake, W., "Auguries of Innocence."
11. Goode, G. C., Wood, G. A., Brooke, N. M., Coleman, R. F., AWRE-O-24/71, Atomic Weapons Research Establishment, Aldermaston, England (1971).
12. Lukens, H. R., Schlesinger, H. L., CONF 710402, Vol. II, 81 (1971).
13. Coleman, et al, AERE 086/66 Atomic Weapons Research Establishment, Aldermaston, England (1971).
14. Sedlacek, W. A., Guthals, P. R., Smith, H. L., LA-DC-13316 (1971).
15. Karjala, D. S., Calif. Law Rev. 59, 997 (1971).
16. Burns, R., "To a Louse."

TABLE 1

TRACE ELEMENT VARIATION IN WHITE BOND PAPER
VERSUS NAA PRECISION

Element	Concentration		Deviation (%)	NAA Precision (%)
	Maximum (ppm)	Minimum (ppm)		
Mn	12.6	9.6	27.0	7.8
Na	210	170	40.0	10.0
Sb	13.2	9.4	33.6	8.3
Sm	0.7	0.05	173	8.9
Sc	1.7	1.1	42.9	7.2
Ta	30	20	40.0	6.5

ORNL-DWG. 69-5168

Figure 1. Correlation between Z and Mn in tape.

CORRELATION Zn-Mn