CHAPTER 9

BIOLOGICAL MONITORING RESEARCH

In the mid-1960s, I became convinced that, if human society had “real time” information about the condition of the planet’s biospheric life support system, it would take immediate corrective action when the health and condition of these systems were threatened. I defined the term *biological monitoring* as surveillance undertaken to ensure that previously established quality control conditions were being met. To get the information rapidly, computer-interfaced systems were used. Of course, the system has been vastly improved over the years, but it represented a significant improvement over the methodology used at that time. However, human society only minimally recognized both its dependence upon the biospheric life support system and its ethical obligation to other life forms. Over four decades later, this condition still persists.

I toured many industrial plants while doing field surveys and collecting industrial waste effluent for toxicity tests. Most industrial quality control systems were impressive. When any entity pushed a part of the system beyond acceptable boundaries, sensors detected the deviation from normal limits; alarms went off, and corrective action was taken immediately. I wondered if a comparable, rapid information system could be designed for environmental quality with near real-time feedback of information and a concomitant means of either shunting the unacceptable waste to a holding pond (instead of discharging it into a river), recycling it for additional treatment, or, in the ultimate emergency, shutting down production until the problem was corrected. Such a system would require direct computer interfacing (or what passed for computers in the 1960s) and a whole set of early warning parameters that could immediately signal the appearance of a deleterious level of toxicity in the waste stream before it reached the river. The Academy of Natural Sciences Philadelphia (ANSP) did not have staff with the technical competence I required for this undertaking. However, when I left ANSP in 1966 for the University of Kansas, I had to rethink my entire research program: the field team research approach was definitely out; aquatic toxicity testing could continue, but should I do this type of research?

I decided to launch an entirely new rapid biological information system to operate as a quality control unit. Early attempts are described in some of my publications from the 1960s (Cairns 1966, 1967). In my search to find help with the technical aspects of a computer interfaced system, I had the good fortune to encounter H. W. (Tony) Shirer, a Professor of Electrical Engineering at the University of Kansas who also happened to have a medical degree. About the same time, I acquired my first PhD candidate, William T. (Tom) Waller, who was extremely enthusiastic about rapid, biological information systems. Our first apparatus (the electronic components were built almost entirely by Tony Shirer and the equipment to test fishes was built predominantly by Tom Waller) was from a design that I developed and was funded by a water resources research grant obtained in a national competition through the University of Kansas Water Resources Research Center. The first publication on this apparatus appeared in 1968 (Shirer et al. 1968). I also acquired my first MS candidate, Richard E. (Rip) Sparks; however, the space was insufficient in the tiny research “closet” allocated to me by the Zoology Department of the University of Kansas for more than one student. Although Sparks had finished his MS thesis on aquatic toxicity testing when I left Kansas, he and Waller both came with me to Virginia Polytechnic Institute and State University (VA Tech) to work on rapid, biological monitoring systems.

Fortunately, Alan Heath, then a young assistant professor at VA Tech, was measuring electrical signals from fish heart and opercular muscles for his physiological research. We quickly added this methodology to our research base, using equipment initially borrowed from Heath. The basic idea was not new—the King's wine taster and the canary in the coal mine are well known examples of early warning systems. The objective was to detect deleterious concentrations of chemicals before they left the factory and entered the stream since pollutants are generally most easily treated in their most concentrated form. Water quality frequently has pronounced effects on the expression of toxicity. Here was an opportunity to assure that the assimilative capacity (nonharmful loading) of the stream or river was not exceeded. Instead of analyzing complex waste components individually, their biological effects could be measured in the aggregate. Of course, discovering the particular cause of the problem still required chemical analyses. Furthermore, knowing the precise concentration of each individual chemical in an effluent did not provide a reliable estimate of the combined effect. The investigation worked quite well for short-term episodic events (e.g., spills), but not for chronic, long-term toxicity problems. The cause of the warning signal was usually immediately apparent, but sometimes I had to visit the purchasing department of the industry to check for any new chemicals that had been acquired. Often, a new chemical was being used that was not a part of the production process (e.g., a new cleaning agent) and was not on the list of chemicals for which regulatory compliance analyses were required.

As has often been the case throughout my career, large foundations did not generally fund this area of research. However, the Federal Water Quality Administration (the forerunner of USEPA) did. Preliminary papers on this research were published in 1970 (Cairns et al. 1970a,b). By the time the apparatus was ready to be field tested, its size had been reduced due to miniaturization of computers. The Manufacturing Chemists Association (MCA, now the Chemical Manufacturers Association) not only sponsored the trials, but also found a nearby industry (Celanese Corporation) for the actual work. Later, even more extensive trials were carried out at the Radford Army Ammunition Plant (RAAP), which was nearer the VA Tech campus. At the latter site, the entire apparatus was housed in a mobile trailer. A postdoctoral fellow (David Gruber), later an adjunct faculty member, spent many years entirely on the RAAP project. Both MCA and RAAP agreed at the outset to unrestricted publication of the results—what an advantage to find a sponsor willing to forgo censorship before publication! Fortunately, many organizations now realize that the promise of unrestricted publication vastly increases credibility, despite some evidence that public relations personnel regard such publications as unfavorable.

The graduate students involved in this extended research, listed in order of graduation, were: 1971 – Richard E. Sparks, PhD; William T. Waller, PhD; 1973 – Eric Morgan, PhD; 1975 – Anthony F. Maciorowski, PhD; I. Prather, MS; W. B. Wrenn, PhD; 1977 – William van der Schalie, PhD; 1979 – Kenneth S. Lubinski, PhD; 1984 – Thomas R. Doane, PhD; and 1985 – S. I. Hartwell, PhD. Postdoctoral fellows were David Gruber, Kenneth W. Thompson, and Gary F. Westlake. Their contributions were essential to the completion of this complex research.

Industrial effluents have a way of co-mingling in receiving waters, and the cumulative impact often differs significantly from individual effects. In addition, a community of indigenous organisms could be used as sensors, and the analysis could be automated so that results could be quickly compared with the single species "in-plant" monitoring system. Diatoms were selected as the indigenous organisms because Patrick's diatometers, which were colonized by diatoms, had a two-decade history of being effective in a variety of conditions.

After a number of false starts, both within and outside the university, Silverio P. Almeida, an optical physicist on campus, agreed to work with biologists to address this problem. Naturally, large foundations rejected the grant proposals as not on their priority list or as too visionary, unworkable, etc. Again, the MCA came through with a small sum of money that enabled the construction and testing of a small working model. We then approached the National Science Foundation, Research Applied to National Needs Program and got multi-year funding. The sum seemed large to me as a biologist, but to a physicist, it was barely adequate. I enjoyed working with Almeida and the people he selected to participate in the project. I found the system intimidating and felt very insecure until Almeida ventured the opinion that diatoms were very complicated. We were each strangers in an alien discipline, but eventually, everyone functioned as a cohesive group.

Publishing this research was as great a challenge as obtaining extramural funding. Eventually, the first manuscripts were published; within a few years, we even published in one or two journals that had rejected the pioneering manuscripts. I still have warm feelings for the *Transactions of the Kansas Academy of Sciences* and *Archiv für Microbiologie* for having the courage to publish the first manuscripts (Almeida et al. 1972, 1978; Cairns et al. 1972). Later publications include Cairns et al. (1976, 1982) and Case et al. (1978).

None of the monitoring systems from our laboratory were widely used, probably because automated environmental quality control was still not a high priority item in industrial settings. Still, all the systems were sufficiently tested elsewhere to demonstrate their utility. I remain confident that the years spent on an automated monitoring system provided evidence that system-level, automated, environmental quality control is possible and that, in the future, society will realize the benefits of monitoring the health of the biospheric life support system. However, until humankind recognizes its dependence upon the planet's biospheric life support system and its ethical responsibility for other life forms, the likelihood of extensive use of any monitoring system that might markedly change the behavior of human society is unlikely.

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