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Fumio Matsumura – Accomplishments at the University of California, Davis, and in the Sierra Nevada Mountains

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ABSTRACT

Fumio Matsumura joined the University of California, Davis, faculty in 1987 where he served as founding director of the Center for Environmental Health Sciences, associate director of the U.C. Toxic Substances Research and Teaching Program, and chair of the Department of Environmental Toxicology. He was an active affiliate with the NIEHS-funded Superfund Basic Research Program and the NIH Comprehensive Cancer Center. He was in many instances a primary driver or otherwise involved in most activities related to environmental toxicology at Davis, including the education of students in environmental biochemistry and ecotoxicology. A significant part of his broad research program was focused on the long range transport of chemicals such as toxaphene, PCBs and related contaminants used or released in California to the Sierra Nevada mountains, downwind of the urban and agricultural regions of the state. He hypothesized that these chemical residues adversely affected fish and wildlife, and particularly the declining populations of amphibians in Sierra Nevada streams and lakes. Fumio and his students and colleagues found residues of toxaphene and PCBs at higher elevations, an apparent result of atmospheric drift and deposition in the mountains. Fumio and his wife Teruko had personal interests in, and a love of the mountains, as avid skiers, hikers, and outdoor enthusiasts.

1. Introduction – early acquaintances

I first became personally acquainted with Fumio Matsumura through the IR-4 (Interregional Project 4) project, designed to obtain field and residue data to support the registration of pesticides on minor crops (i.e. in situations where the growers need the chemicals but there is too limited use expected for the manufacturer or registrant to fund the required studies on the minor uses). The program encompasses field researchers and laboratory chemists located primarily at Land Grant institutions or in the USDA Agricultural Research Service (ARS). Fumio and I belonged to the IR-4 Technical Committee, he representing the North Central Region, including his home institution at Michigan State University, and I representing the Western Region, including California and the University of California, Davis. Both of us oversaw IR-4 “Leader Laboratories” for conducting residue analysis, to obtain data to support registration and tolerance petitions to EPA and other appropriate agency authorities.

In 1985, the Technical Committee (TC) included the Leader Lab directors Fumio; Willis Wheeler – South; John Bourke – Northeast; Paul Schwartz – ARS; and me. These five TC representatives recommended resource allocations to the Leader Labs, and with IR-4 Regional Coordinators and IR-4 Headquarters personnel at Rutgers University, the location(s) where the field work and residue analyses should be conducted, including recommendations on budgets.

The TC met together frequently and, at least once each year, in person at the campus of a Leader Lab director. In 1985 Fumio hosted the TC at Michigan State University, but it was much more than a simple business meeting. He had arranged an entire symposium on pesticide chemistry and biochemistry, covering various aspects of pesticide analysis, environmental fate, and toxicology. TC members, faculty and students from the host institution, and other invited experts participated. Fumio and Teruko hosted the TC members at their home for dinner in East Lansing, providing an opportunity for us all to become better acquainted. Fumio and I discussed skiing – a mutual passion – and the relative merits of skiing in California vs Michigan. Fumio knew much more about skiing in California and the West than I expected, from his past as an accomplished skier in Alberta while a graduate student, and an earlier trip he had taken to Squaw Valley with Canadian Ski Team members. He was clearly most interested in hearing more about California, and the

Abbreviations: ARS, Agricultural Research Service; CEHS, Center for Environmental Health Sciences at UC Davis; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; EPA, U.S. Environmental Protection Agency; IR-4, Interregional Project 4; NIH, National Institutes of Health; NIEHS, National Institute of Environmental Health Sciences; PCB, polychlorinated biphenyls; UC Davis, University of California, Davis; UCTSRTP, University of California Toxic Substances Research & Teaching Program; USDA, U.S. Department of Agriculture.

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possibility came up of relocating his research program to the University of California, Davis. Fumio already had many professional contacts at Davis – Don Crosby and Wendell Kilgore in the Department of Environmental Toxicology, and Bob Washino and Bruce Hammock in the Department of Entomology. As a result we arranged a seminar visit for Fumio to UC Davis so he could become more familiar with our current programs. Bob Washino, then Chair of Entomology, and I suggested that the new campus program – UC Toxic Substances Research and Teaching Program – might be a good fit with Fumio's interests. We approached UCTSRTP Director Jerry Last, Dean of the Graduate School and Research, A.G. (Gerry) Marr, and the Dean of the College of Agricultural and Environmental Sciences, Charles E. Hess. It turned out that there was a possibility for Fumio to join (plus another expert, Hanspieter Witsche) as Associate Directors of UCTSRTP and members of academic departments – Environmental Toxicology and Entomology, in Fumio's case.

Fumio was eager for the visit, in part to give a seminar to faculty at Davis and in part to ski the Sierras. After his seminar, Fumio set off for a few days of skiing in a rental car, staying at our shared cabin in Incline Village, Nevada, overlooking Lake Tahoe. I had planned to join him, but teaching delayed my departure, so Fumio was on his own in the cabin the night of his arrival. The next morning he called and explained excitedly that he could not get out of the front door, and his rental car was buried. A 5 ft snowfall overnight blocked the door and buried his car and the road. I told him where he could find a few food items, and that the snow plows would be by later in the day, so Fumio settled in to enjoy the winter snow and eventually ski the nearby areas.

2. Beginnings in Davis

A few days later it was clear that Fumio was hooked on joining our program – the snow was the clincher! Fumio went on to establish, from scratch, an excellent program of research and teaching in biochemical toxicology focusing on pesticides. It was a good fit given the large agricultural production and heavy use of pesticides in California. Fumio was especially interested in the usage of organochlorine compounds over the years, including toxaphene – a mixture of more than 175 individual chlorinated camphenes and bornanes applied principally to cotton and tomatoes in California – which he studied earlier in his career [1,2]. Like many of us in Environmental Toxicology, he was intrigued by the question "Where does it all go?" in reference to the millions of pounds applied in the U.S. Estimates of balance in the 1970s and 1980s could account for 1–10% at most of what was applied. For toxaphene, which largely resists chemical/photochemical degradation, and is not appreciably soluble in water, the evidence suggested that most of it entered the air, but where it went after that was anyone's guess. Since the wind patterns in California were mostly from west and the Pacific Ocean, to east and the Sierra Nevada Mountains, it appeared that toxaphene, and many of the other chemicals applied to agriculture in the Central Valley, could migrate to the Sierras and potentially undergo deposition to the fragile ecosystems of granitic streams, forests, and lakes.

There was limited experimental evidence in support of this west to east migration of airborne pesticides, including their intrusion into the Sierras. Cory et al. had found DDT and DDE residues in the Sierras presumably originating in part from heavy uses of DDT in the San Joaquin Valley in the 1940s–1960s [3]. Zabik and Seiber analyzed for chlorpyrifos, diazinon, and parathion, and their oxons, at three elevations in the southern Sierra's in the general vicinity of Kings Canyon National Park in rain and snow water and air [4]. These organophosphorus insecticides were all widely used in the San Joaquin Valley during the late winter dormant spray season on a variety of orchard crops grown in the valley floor. The findings supported that atmospheric transport of pesticides applied in the valley to the Sierra Nevada Mountains was occurring, and the levels in air decreased as distance increased from valley floor to higher elevation mountains. Rainwater concentrations showed the same general trend, but the concentrations in rainwater did not fall off so abruptly with sampling elevation as for air samples. It appeared that both wet and dry deposition processes were at work in attenuating the airborne residues as they moved further into the mountains.

2.1. Sierra Nevada Research

Fumio and his students launched a research program sampling trout and amphibians for organochlorine residues in the Sierras (Fig. 1). His team found residues of PCB, toxaphene, DDT and DDE [6]. For frogs particularly, many species of which found in the Sierras are listed as threatened or endangered, Fumio's team concluded that the potential detrimental interaction of cold and contaminant exposure, as occurs during winters in the higher elevations of the Sierras, warranted further study.

They also studied the distribution of PCBs and chlorinated pesticides, including toxaphene and chlordane, in trout [7]. These studies showed that residues in high-altitude mountains could provide important information on the long-range transport and distribution of persistent pollutants like these.

In another study, Fumio and colleagues, now including Dr. Gary Fellers of the U.S. Geological Survey [5,8–10], advanced the potential for PCB and toxaphene bioaccumulation in Sierra Nevada amphibians. They found a linear regression of PCB and toxaphene residues versus elevation, and that tadpole samples from sites in east-facing drainage basins showed significant differences in residue levels, suggesting a rain-shadow effect in the atmospheric transport of contaminants to the Sierra Nevada.

Fumio's work well complemented our studies. For toxaphene, capillary column gas chromatography was used to demonstrate the stability of toxaphene on cotton leaf surfaces, and its dissipation by volatilization, favoring the early loss of the more volatile components, and stability of the less volatile ones [11]. It was clear from this study and others that post-application volatilization was a major source of toxaphene to the air, and to the environment. We also obtained indirect evidence, by analyzing water and fish from Lake Tahoe and a higher altitude, more isolated lake, Lake Marlette, that PCBs and DDE entered these systems from deposition and long range transport, rather than from more local sources [12]. Another piece of the puzzle was addressed for organophosphate residues in air, the more stable of which also can enter the Sierra Nevada ecosystem as a result of transport from the use areas in the Central Valley and deposition. In this study, deposition of residues to pine tree needle surfaces was a significant step on the way eastward into the Sierra higher elevations [13]. Fellers et al. [14] added considerable information on several types of pesticides found as residues in amphibian habitats in the Sierra mountains and other areas of eastern California. Sparling and Fellers [15] studied the toxicity of chlorpyrifos and endosulfan to species of frogs that inhabit the Sierras, adding to the evidence that pesticides are harmful at low concentration levels to amphibians living in areas remote from known uses that might lead to airborne transfer and deposition to habitat of these amphibian species. Datta et al. analyzed for organochlorine residues in fish and tadpoles from the Kaweah River basin flowing from the high Sierras to the San Joaquin Valley Floor [16]. McConnell et al. (1998) studied the wet deposition of current use pesticides in the Sierra Nevada mountains [17], confirming the existence of both wet and dry deposition pathways for pesticides entering the Sierra mountains resulting from airborne transport from application sites far away.

None of the groups studying amphibian decline, including Fumio's and ours, was able to establish a definitive link between PCB and/or pesticide exposures and detrimental effects to amphibian populations in the Sierras, although the cumulative evidence is