

PROPOSAL TO MONSANTO COMPANY

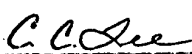
TITLE: The Degradation of Polychlorinated Biphenyls by Fungi and Anaerobic Bacteria

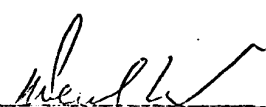
PRINCIPAL INVESTIGATOR: Dr. Chun C. Lee (SSN 521-52-6704)

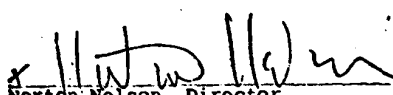
INSTITUTION: New York University Medical Center
Institute of Environmental Medicine
Laboratory for Environmental Studies
550 First Avenue
New York, New York 10016

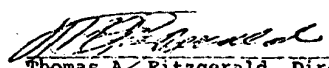
DURATION OF PROPOSED WORK: June 1, 1979 through May 31, 1982

TOTAL AMOUNT REQUESTED: \$154,931


Chun C. Lee
Research Assistant Professor
Institute of Environmental
Medicine
New York University Medical
Center
Tuxedo, New York 10987


Merril Eisenbud
Associate Director
Institute of Environmental
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New York University Medical
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Tuxedo, New York 10987


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Institute of Environmental
Medicine
New York University Medical
Center
550 First Avenue
New York, New York 10016


Thomas A. Fitzgerald, Director
Office of Grants Administration
and Institutional Studies
550 First Avenue
New York, New York 10016

OBJECTIVES

This research will seek to isolate and cultivate fungi and anaerobic bacteria from a variety of aquatic environments, which are able to grow in the presence of polychlorinated biphenyls and degrade the polychlorinated biphenyls. After such cultures have been established, the rate and mode of polychlorinated biphenyl degradation by these cultures will be examined, both in vitro and in situ.

INTRODUCTION

This study is proposed to investigate the role of fungi and anaerobic bacteria in polychlorinated biphenyl (PCB) degradation. Because of their low solubility in water, high specific gravity, and high adsorbability, PCBs in aquatic environments tend to accumulate in reducing or anaerobic sediments of lakes, rivers, estuaries and coastal zones (1,4,9).

Evidence available to date indicates that microbial degradation may be a mechanism by which PCBs are eliminated from the environment (1,5,7,8,10,11,13). PCB resistant or degrading bacteria have been found to be ubiquitously distributed in the natural environment (11).

Thus far, degradation studies have centered on aerobic bacterial activity, and are not applicable, directly, to PCBs found in reducing or anaerobic sediments. Little information is available on the role of fungi.

SPECIFIC AIMS

1. To isolate and cultivate fungi and anaerobic bacteria from a variety of freshwater, estuarine and marine environments which are able to grow in the presence of PCBs (Aroclor 1016 and Aroclor 1254) and to investigate their ability to degrade the PCBs. Initially, this will be done with mixed cultures; studies will be done with pure cultures as they are purified.
2. To determine the rate and mode of PCB degradation by the fungi and by the anaerobic bacteria in vitro; first with PCBs serving as the sole carbon source, and second with PCBs amended with alternate carbon sources and alternate inorganic energy sources.
3. To determine the rate and mode of PCB degradation by the fungi and by the anaerobic bacteria in situ: natural deposits (with or without added PCBs) will subsequently be inoculated ^{in the laboratory} with a specific fungal or anaerobic bacterial culture, and the change in PCB content examined after incubation over pre-determined time intervals.

Fungi and anaerobic bacteria will be added to sterilized sediments and non-sterilized sediments ^{laboratory experiments designed} ~~in order to investi-~~gate the ability of the inoculated organisms to degrade PCBs under as natural conditions as possible.

METHODS

1. Procedures for Specific Aim 1: Sediments for the isolation of fungi and anaerobic bacteria will be collected from

representative sites in freshwater, estuarine and marine environments. These samples will be collected by the principal investigator or by requests of colleagues at other institutions. Physical and chemical aspects of the environment at the time of sampling (e.g., salinity, depth, pH, Eh, water temperature) will be recorded when possible. Immediately upon collection, the sediment will be transferred to duplicate sets of glass bottles which will be almost filled with filtered water and sealed with serum caps. One set will be gassed with nitrogen to maintain or to establish reducing conditions necessary for anaerobes; the other will be maintained aerobic for fungal isolation. Both sets of samples will be used for subsequent isolation of PCB degraders by enrichment culture.

Enrichment cultures for anaerobic bacteria will be set up by adding 1-2 g of sediment to a 250 ml flask containing 100 ml of an organic medium (thioglycollate medium) made with distilled water or water of appropriate salinity and pH for estuarine and marine samples. Techniques for anaerobic cultures as described by Bryant (2) will be strictly followed. Cultures will be incubated for three days to two weeks at 26°C; intermittently, culture flasks will be shaken by hand. Isolation will be carried out in a second flask which contains 100 ml of a mineral salt solution adjusted to the desired salinity: $(\text{NH}_4)_2\text{SO}_4$, 1 g; KH_2PO_4 , 0.2 g; K_2HPO_4 , 1.6 g; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.2 g; NaCl , 01. g; $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 0.01 g; $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, 0.02 g (pH 7.5) containing 0.05% of the appropriate PCB. Following standard anaerobic techniques, 1 ml of the enrich-

ment culture will be transferred to this second medium and incubated as before until substantial growth is observed. Such cultures will be maintained in duplicate or triplicate. One series will be incubated in the light and one in the dark to enable the growth of phototrophic bacteria as well as strict chemotrophs and heterotrophs.

Enrichment cultures for fungi will be started in Sabouraud dextrose agar (Difco) made to the desired salinity and incubated under aerobic conditions. After initial growth, 1 ml of the enrichment culture will be transferred to the PCB-mineral salts medium (described above) but amended with 1 ml of a trace elements solution per liter. The trace elements solution contains 0.1 g H_3BO_3 , 0.05 g each of $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$, $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, $\text{ZnSO}_4 \cdot 7 \text{H}_2\text{O}$, Na_2MoO_4 , and $\text{CoCl}_2 \cdot 6 \text{H}_2\text{O}$ per liter.

After incubation for predetermined time intervals (4 days to 1 month), aliquots of the incubated samples will be examined by high performance liquid chromatographic techniques, or they will be transferred to separatory funnels and extracted with hexane for gas chromatographic analysis. Gas chromatograms will be run with 1-5 μl aliquots of the hexane extracts. Initially, only the disappearance of certain PCB homologs from the mixed culture systems will be measured. If the PCBs disappear or decrease in quantity, degradation products will be looked for, perhaps using thin-layer chromatographic techniques and with ^{14}C -labelled PCBs. Mixed cultures will be purified by plating onto mineral salts agar plates containing 0.05% PCBs; degradation studies will be conducted with the resultant pure cultures.

2. Procedures for Specific Aim 2: Once the respective microbial systems capable of growth on PCBs are obtained, the kinetics of PCB degradation will be followed by analyzing the PCBs in the growth medium at different time intervals. The cells will be harvested by centrifugation and washed twice with 0.5 M phosphate buffer (pH 7.0). The washed cells will be injected into culture tubes containing the mineral salts medium and PCB. The procedures employed will be similar to those described by Halvorson et al. (6), who used resting suspensions of bacteria harvested from a sewage lagoon to examine the degradation of mixtures of pesticides. Comparisons will be made of gas chromatograms of PCBs before and after incubation with test organisms and with non-inoculated PCB controls over the pre-determined time interval. Metabolites and residual PCBs will be characterized by the use of column and thin-layer chromatographic techniques of Stalling and Huckins (12), and Furukawa and Matsumura (5).

3. Procedures for Specific Aim 3: In situ studies will be conducted with natural sediments whose PCB content will have been determined previously. Sediments will be autoclaved to kill indigenous microbial flora. Depending on the test organisms to be used in the test (fungi or anaerobic bacteria), the test conditions of the sediment will either be made anaerobic or left aerobic. The specific organism for the PCB degradation experiments will be inoculated into the sediments, and the rest of the experiment will be run as in Procedure for Specific Aim 2 to determine PCB degradation. A second variation of the

in situ study involves the inoculation of the test isolates into non-sterilized sediment of known PCB content along with all of its indigenous flora and fauna; this is designed to test the ability of the isolated PCB degraders to function and compete with other organisms under natural conditions. PCB degradation will be assessed as per Procedure for Specific Aim 2.

4. The research tasks will be performed in the following sequence, assuming a beginning date of June 1, 1979:

June 1, 1979 - May 31, 1980: Specific Aim 1.

June 1, 1980 - May 31, 1981: Specific Aim 2.

June 1, 1981 - May 31, 1982: Specific Aim 3.

LITERATURE REFERENCES

1. Ahmed, M. and D.D. Focht. (1973). "Degradation of polychlorinated biphenyls by two species of Achromobacter," Can. J. Microbiol. 19: 47.
2. Bryant, M.P. (1972). "Commentary on the Hungate technique for culture of anaerobic bacteria," Amer. J. Clin. Nutrition 25: 1324.
3. Duke, T.W., J.I. Lowe, and A.I. Wilson. (1970). "PCB (Aroclor 1254) in the water, sediment, and biota in Escambia Bay, Florida," Bull. Environ. Contamin. Toxicol. 5: 171.
4. Fulk, R., D. Gruber, and R. Wullschlegel. (1976). "Laboratory study of the release of pesticide and PCB materials to the water column during dredging and disposal operations," Final Rept. of U.S. Army Engineer Contract No. DACW39-74-CO142.
5. Furukawa, K. and F. Matsumura. (1976). "Microbial metabolism of polychlorinated biphenyl components by Alkaligenes sp.," J. Agri. Food Chem. 24: 251.
6. Halvorson, H., M. Ishaque, J. Solomon, and O.W. Grussendorf. (1971). "A biodegradability test for insecticides," Can. J. Microbiol. 17: 585.
7. Kaiser, K. and P. Wong. (1974). "Bacterial degradation of polychlorinated biphenyls. Identification of some metabolic products from Aroclor 1242," Bull. Environ. Contamin. Toxicol. 11: 291.
8. Liu, D. (1976). "PCB degradation," Mar. Pollut. Bull. 7: 83.
9. Munson, T.O., H.D. Palmer, and S.M. Forns. (1976). "Transport of chlorinated hydrocarbons in the Upper Chesapeake Bay," Nat'l Conf. on Polychlorinated Biphenyls, Chicago, Ill., p. 218.
10. Sayler, G.S., M. Shon and R.R. Colwell. (1977). "Growth of an estuarine Pseudomonas sp. on polychlorinated biphenyl," J. Microbial Ecol. 3: 241.
11. Sayler, G.S., R. Thomas and R.R. Colwell. (1978). "Polychlorinated biphenyl (PCB) degrading bacteria and PCB in estuarine and marine environments," Estuarine and Coastal Marine Science 6: 553.

12. Stalling, D. and J. Huckins. (1973). "Reverse phase thin layer chromatography of some Aroclors, Halowaxes, and pesticides," J.A.O.A.C. 56: 367.
13. Wong, P. and K. Kaiser. (1975). "Bacterial degradation of polychlorinated biphenyls II. Rate studies," Bull. Environ. Contamin. and Toxicol. 13: 249.

FACILITIES AVAILABLE

The proposed research will be carried out using the facilities of the analytical chemistry and aquatic ecology sections of the Laboratory for Environmental Studies. The proposed research will be carried out in the culture and analytical facilities at the A.J. Lanza Laboratory, Tuxedo, New York, and at the Hudson River field station maintained by the Medical Center at Buchanan, N.Y. NYU boats equipped for collection of samples and certain field analytical procedures are berthed at Stony Point, N.Y. and operate throughout the open-water months. Dock facilities are available at the Buchanan wet-lab, but only on a temporary basis.

Equipment available for this project includes apparatus for:

Extraction/concentration of organics

Freeze-dry techniques

Scintillation spectrometry (low level - beta)

Gel electrophoresis

Thin-layer chromatography

Gas-liquid chromatography

Respiration studies

Water quality analysis

Autoradiography

Culture facilities and equipment for aerobic and anaerobic microorganisms

Culture of aquatic organisms

Maintenance of aquatic organisms

Computer data analysis

PRINCIPAL INVESTIGATOR ASSURANCE

The undersigned agrees to accept responsibility for the scientific and technical conduct of the research project and for provision of required progress reports if a contract is awarded as a result of this application.

5/18/79
Date

C. C. Lee
Principal Investigator

PROPOSED BUDGET

DEGRADATION OF POLYCHLORINATED BIPHENYLS BY FUNGI AND ANAEROBIC BACTERIA

		<u>Year</u>					
		<u>1979-80</u>		<u>1980-1981</u>		<u>1981-82</u>	
1. Personnel							
<u>Name</u>	<u>Title</u>	<u>% Time</u>	<u>Salary</u>	<u>% Time</u>	<u>Salary</u>	<u>% Time</u>	<u>Salary</u>
C.C. Lee	Prin. Invest.	20	4,592	20	4,821	20	5,159
Theo. J. Kneip	Tech. Advisor	10	N.C.	10	N.C.	10	N.C.
J.M. O'Connor	Tech. Advisor	10	N.C.	10	N.C.	10	N.C.
Research Technician		100	12,500	100	13,125	100	14,044
Laboratory Aide		50	5,071	50	5,325	50	5,698
Clerical Assistance		10	1,200	10	1,260	10	1,348
Total			\$23,363		\$24,531		\$26,249
Fringe benefits			4,731		5,029		5,447
Overhead			12,559		12,879		13,780
Total salaries/benefits			\$40,653		\$42,439		\$45,476
2. Equipment							
a. High performance liquid chromatograph (partial)			\$12,000		-		-
b. Shaker table			500		-		-
c. Incubator			-		600		-
d. Spectrophotometer			-		1,150		-
Totals			\$12,500		\$1,750		-

	<u>1979-80</u>	<u>1980-81</u>	<u>1981-82</u>
3. Supplies			
a. Glassware	\$500	\$500	-
b. Chemicals	500	500	\$300
c. Gases (N ₂ , CO ₂)	200	200	200
d. Chromatographic equipment (gases, columns, etc.)	600	600	400
	\$1,800	\$1,800	\$900
4. Miscellaneous Expenses			
a. Travel to scientific meeting	\$500	\$500	\$500
b. Personal travel (collection, etc.)	500	200	100
c. Publication costs	-	300	300
d. Other costs (Xerox, inter-library loan, service, etc.)	500	500	300
	\$1,500	\$1,500	\$1,200
Totals			
1. Salaries	\$40,653	\$42,439	\$45,476
2. Equipment	12,500	1,750	-
3. Supplies	1,800	1,800	900
4. Miscellaneous	1,500	1,500	1,200
Total amount requested	\$56,453	\$47,489	\$47,576

CURRICULUM VITAE

May 1979

Chun Chi Lee
(Formerly Known as King Mon Tsue)

Date and Place of Birth: August 31, 1939 - Hong Kong

Marital Status: Married, Two children

Residence: R.D. #2, Felter Hill Rd.
Monroe, New York 10950

Professional Address: New York University Medical Center
Institute of Environmental Medicine
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Telephone: (212) 679-3200, Ext. 5276

Title: Research Assistant Professor
Laboratory for Environmental Studies

Education: 1962 - B.S. in Zoology
Colorado State University

1969 - Doctor of Philosophy in
Marine Science
University of Miami (Florida)

Dissertation Title: The decomposition of organic matter
in some shallow water calcareous
sediments of Little Black Water
Sound, Florida Bay

Positions Held: New York University Medical Center
Department of Environmental Medicine
1975 - Present

Course Offering: Aquatic and Estuarine Microbiology
(Department of Environmental
Medicine and Department of
Biology)

University of Miami (Florida)
Rosenstiel School of Marine and
Atmospheric Science, 1969-1975

Research Scientist, Functional
Biology 1969 - 1973

Research Assistant Professor
Biology and Living Resources
1973 - 1975

Positions Held:

University of Miami (Florida)
Institute of Marine Science
1962 - 1969

NDEA Fellow, Marine Biology
1962 - 1965

Graduate Assistant
1965 - 1967

Senior Field Biologist
McMurdo Sound, Antarctica
1967 - 1968

Senior Field Biologist
First International Weddell Sea
Oceanographic Expedition
1968 - 1969

Colorado State University
Department of Botany and Plant Pathology
1958 - 1962

Research Assistant, 1958 - 1962

Professional Societies:

American Association for the
Advancement of Science

American Society of Limnology
and Oceanography

Research Interests:

Microbiology
Algal and Protozoan Physiology and
Ecology
Biochemistry of Organic Matter in
Aquatic Sediments

Awards and Grants:

Achievement Award in Biological Science
Colorado State University, 1962

National Defense and Educational Act
Predoctoral Fellowship, 1962 - 1965

National Science Foundation Grant
University of Miami, \$44,000
1973 - 1975

National Science Foundation Grant
New York University Medical Center,
\$3,900
1976

PUBLICATIONS

C. C. LEE

1. Meyers, S. P., W. A. Feder and King Tsue. Nutritional relationships among certain filamentous fungi and a marine nematode. Science, 141, 520-522 (1963).
2. Meyers, S. P., W. A. Feder and King Tsue. Studies of relationships among nematodes and filamentous fungi in the marine environment. Dev. Indus. Microbiol., 5, 354-364 (1964).
3. Altman, J. and King Tsue. Changes in plant growth with chemicals used as soil fumigants. Plant Disease Reporter, 49, 600-602 (1965).
4. Bunt, J. S. and C. C. Lee. Observations within and beneath antarctic sea ice in McMurdo Sound and the Weddell Sea. Methods and Data. IMAS Special Publ., Univ. of Miami, 69-1 (1969).
5. Bunt, J. S. and C. C. Lee. Seasonal primary production within and beneath antarctic sea ice. J. Mar. Res., 28(3), 304-320 (1970).
6. Bunt, J. S., K. E. Cooksey, M. Heeb, C. C. Lee and B. F. Taylor. Algal nitrogen fixation in the marine subtropics: Assay by acetylene reduction. Nature, 227, 1163 (1970).
7. Corcoran, E. F. and C. C. Lee. The distribution of chlorinated hydrocarbon pesticides in the Mississippi River Delta and the adjacent Gulf of Mexico. Joint Southeast and Southwest ACS Meeting, New Orleans (Abst.). Dec. 2-4, 1970. p. 88.
8. Taylor, D. L. and C. C. Lee. A new Cryptomonad from Antarctica: Cryptomonas cryophila sp. Nov. Archiv fur Mikrobiol., 75, 269-280 (1971).
9. Bunt, J. S., C. C. Lee and E. L. Lee. Primary productivity and related data from tropical and subtropical marine sediments. Mar. Biol., 16, 28-36 (1972).
10. Bunt, J. S. and C. C. Lee. Data on the composition and dark survival of four marine microalgae. Limnology and Oceanogr., 17, 458-461 (1972).
11. Fenchel, T. and C. C. Lee. Studies on ciliates associated with sea ice from Antarctica. I. The nature of the fauna. Archiv fur Protistenk., 114, 231-236 (1972).
12. Lee, C. C. and T. Fenchel. Studies on ciliates associated with sea ice from Antarctica. II. Temperature responses and tolerances in comparison with ciliates from temperate and tropical habitats. Archiv fur Protistenk., 114, 237-244 (1972).

PUBLICATIONS CONT'D.

13. Bunt, J. S., C. C. Lee and M. A. Heeb. The site off Freeport intended for Hydro-Lab. Hydro Lab J., 1:3-6 (1972).
14. Bunt, J. S., C. C. Lee. An exploratory study of benthic primary production. Hydro Lab J., 1:7-10 (1972).
15. Taylor, B. F., C. C. Lee and J. S. Bunt. Nitrogen-fixation associated with the blue-green alga, Trichodesmium, as measured by the acetylene-reduction technique. Archiv fur Mikrobiologie, 88:205-212 (1973).
16. Lee, C.C., E. L. Lee and J. S. Bunt. Distribution of biomass in a coral reef transect. In: Results of the Tektite Program, coral reef invertebrates and plants (Sylvia Earle and Robert Lavenberg, editors), Natural History Museum, Los Angeles County, Science Bull., 20:69-75 (1975).
17. Steinhausler, F., S. Schaffer, N. Cohen, C. C. Lee, J. M. O'Connor and McDonald E. Wrenn. Effect of high LET radiation on intracellular ATP content of prokaryotic and eukaryotic algae. Radiation Research Society, 26th Meeting, Toronto, Canada (Abst.). May 14-18, 1978, pp. 591-592.
18. O'Connor, J. M., C. C. Lee and M. Eisenbud. Environmental Health. MESA New York Bight Atlas Monograph 32. (In press).
- ✓ 19. Lee, C. C., R. Califano and R. Sansur. The degradation of polychlorinated biphenyls (Aroclor 1254) by anaerobic bacteria and fungi from the Hudson River. Atlantic Estuarine Research Society, 61st Annual Meeting, Rehoboth, Del. April 26-28, 1979.

CURRICULUM VITAE

Theodore J. Kneip

April, 1979

Date and Place of Birth: December 20, 1926; St. Paul, Minnesota

Marital Status: Married, Six children

Residence: 20 Stonefield Road
Glen Rock, New Jersey 07452

Professional Address: New York University Medical Center
Institute of Environmental Medicine
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Telephone: (212) 679-3200, Ext. 5232

Title: Research Professor,
Deputy Director
Laboratory for Environmental Studies

Education: 1950 - Bachelor of Chemistry (with distinction)
University of Minnesota
1952 - Master of Science
University of Illinois
1954 - Doctor of Philosophy
University of Illinois

Positions Held: New York University Medical Center
Department of Environmental Medicine
1967 - present

- Senior Research Scientist
1967-1975
- Adjunct Associate Professor
1969-1971
- Adjunct Professor
1971-1975
- Research Professor
1975 - present
- Acting Director,
Laboratory for Environmental Studies
1968-1970
- Deputy Director,
Laboratory for Environmental Studies
1970 - present

Course Offerings:
(Department of Environmental Medicine) Analytical Chemistry of
Environmental Contaminants

Positions Held:
(continued) Mallinckrodt Chemical Works
St. Louis, Missouri
1954-1966

Research Chemist - Uranium Division
1957-1959

Group Leader, Uranium Division
1957-1959

Asst. Manager, Analytical Laboratory
Uranium Division
1961-1963

Manager, Laboratory Products Research
1963-1966

Honor Societies: Phi Lambda Upsilon, 1950
Sigma Xi, 1954

Professional Societies: American Chemical Society
American Association for the
Advancement of Science
American Industrial Hygiene Association
American Conference of Governmental
Industrial Hygienists
The New York Academy of Sciences
Vice Chair - Environmental Sciences Section
1976
Chair - Environmental Sciences Section
1977-1978
Elected Fellow - 1977 MQNS 012641

Committees:
Chairman of Subcommittee #6 - Metals I
Intersociety Committee on Manual of Methods
for Ambient Air Sampling and Analysis
1971-1977; Member 1971-present
Member of International Meeting on Effects
and Dose-Response Relationships of Toxic
Metals, Tokyo, November 18-23, 1974.
Organized by: The Subcommittee on Toxicology
of Metals of the Permanent Commission and
International Association on Occupational
Health.

Committees:
(continued)

Member of American Society for Testing and Materials Committee D-22: Methods of Sampling and Analysis of Atmospheres, Subcommittees D-22.04, 1973-present. D-22.09, 1975-present.

New York State Governor's ad hoc committee on PCB's, 1975.

Secretariat, International Standards Organization/Technical Committee 146 (Air Quality)/Working Group 3 - Nitrogen Compounds, 1975-1976.

Secretariat, International Standards Organization/Technical Committee 2 - Workplace Atmospheres, 1976-present.

Consulting:

Various corporate organizations including Consolidated Edison, RSR Corporation, Equitable Environmental Health.

United States Department of Commerce, National Oceanic and Atmospheric Administration, Marine Ecosystems Analysis Project, New York Bight Contaminants Panel.

Cornell University, New York State College of Agriculture and Life Sciences and New York State College of Human Ecology, Cooperative Extension, New York City Urban Gardening Program.

List of Published Works:

1. Laitinen, H. A. and T. J. Kneip. "Polarographic and Coulometric Study of p-Dimethylaminobenzene," Journal of the American Chemical Society, 78:736-740 (1956).
2. King, P., E. Bretz and T. J. Kneip. "Determination of Iodine in Mineral Premixes," Analytical Chemistry, 34:565-567 (1962).
3. Kneip, T. J., T. H. Beasley, P. King and W. K. Dean. "Programmed Temperature Gas Chromatography with Dual Electron Capture Detector for Pesticide Residue Analysis," Analytical Chemistry, 39:1510-1512 (1967).
4. Cohen, N. and T. J. Kneip. "A Method for the Analysis of ^{210}Pb in Urine of Uranium Miners," Journal Health Physics, 17:125-130 (1969).
5. Strehlow, C. D. and T. J. Kneip. "The Distribution of Lead and Zinc in the Human Skeleton," Journal American Industrial Hygiene Association, 30:372-378 (1969).
6. Kneip, T. J., G. P. Howells and M. E. Wrenn. "Trace Metals, Radionuclides and Pesticides in the Hudson River," Symposium on Hudson River Ecology, October 1969, Proceedings of the Symposium, New York State Department of Environmental Conservation, Albany, New York.
7. Furtado, V. C., T. J. Kneip and M. Eisenbud. "Measurement of Low Levels of ^{131}I in Reactor Atmospheres," Nuclear Applications and Technology, 9:268-273 (1970).
8. Kneip, T. J., M. Eisenbud, C. D. Strehlow and P. C. Freudenthal. "Airborne Particulates in New York City," Journal Air Pollution Control Association, 20:144-149 (1970).
9. Howells, G. P., T. J. Kneip and M. Eisenbud. "Water Quality in Industrial Areas: Profile of a River," Environmental Science and Technology, 4:26-35 (1970).
10. Kneip, T. J. "Atomic Absorption Spectrophotometry," AIHA Conference on Advances in Instrumental Method of Analyses, Environmental Trace Substances Center, University of Missouri, Columbia, Missouri (May, 1970).

11. Laurer, G. R., T. J. Kneip, R. E. Albert and P. S. Kent. "In Situ Determination of Lead on Painted Surfaces for the Prevention of Childhood Lead Poisoning," Proceedings of the Third Symposium on Low Energy X- and Gamma Ray Sources and Applications, Boston, Gordon and Breach Science Publishers, New York, pp. 289-301 (1971).
12. Lentsch, J. W., M. E. Wrenn, T. J. Kneip and M. Eisenbud. "Manmade Radionuclides in the Hudson River Estuary," Proc. 5th Annual Midyear Topical Symposium, Health Physics Society, Idaho Falls, Idaho, p. 499 (1970).
13. Howells, G. P., M. Eisenbud and T. J. Kneip. "Ecology of the Estuary of the Lower Hudson River," Proc. FAO Tech. Conf. on Marine Pollution and its Effects on Living Resources and Fishing, Publ. FIR:MP/70/E-20, Food and Agriculture Organization of the United Nations, New York (1970).
14. Kneip, T. J. "Concentration Factors, Environmental Complexity and the Analytical Chemist," American Chemical Society, Analytical Division--National Bureau of Standards Summer Symposium: Key to Progress in National Problem Areas, Washington, D. C. June 1971, Proceedings of the Symposium
15. Kneip, T. J., G. P. Howells and M. E. Wrenn. "Trace Elements, Radionuclides and Pesticide Residues in the Hudson River," Proc. FAO Tech. Conf. on Marine Pollution and its Effects on Living Resources and Fishing, Publ. FIR:MP/70/E-20, Food and Agriculture Organization of the United Nations, New York (1970).
16. Laurer, G. R., T. J. Kneip, R. E. Albert and P. S. Kent. "X-ray Fluorescence: Detection of Lead in Wall Paint," Science, 172: 466-468 (1971).
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CURRICULUM VITAE

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PERSONAL

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EDUCATION

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AWARDS

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AFFILIATIONS

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Respiratory physiology of fishes
Reproductive physiology of fishes
Chemical-biological interrelationships in ecology
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TEACHING
INTERESTS

Physiological ecology
General physiology
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Pollution biology
Ichthyology

PUBLICATIONS

O'Connor, J.M. 1969. The effects of melatonin on *in vitro* ovulation of frog ovarian oocytes. *Amer. Zool.* 9:549.

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