

NN31545.0823

A bird's-eye view of soil pollution research
in the U. S. A.

dr. F. A. M. de Haan

BIBLIOTHEEK
STARINGGEBOUW

Nota's van het Instituut zijn in principe interne communicatiemiddelen, dus geen officiële publikaties.

Hun inhoud varieert sterk en kan zowel betrekking hebben op een eenvoudige weergave van cijferreeksen, als op een concluderende discussie van onderzoeksresultaten. In de meeste gevallen zullen de conclusies echter van voorlopige aard zijn omdat het onderzoek nog niet is afgesloten.

Bepaalde nota's komen niet voor verspreiding buiten het Instituut in aanmerking.

11/11/74

Contents

	<u>Page</u>
1. Introduction.....	1
2. Experiments on Pollution Induced by Different Manure Application Rates (Cornell University).....	3
3. Soil Pollution Research at the Agricultural Research Center, Beltsville.....	7
4. Sewage Sludge Utilization Studies at Urbana.....	12
5. On Site Waste Water Disposal Research at the University of Wisconsin.....	18
6. Research at Robert S. Kerr Water Research Center, Ada, on Waste Water Treatment by Overland Flow.....	22
7. Research on Groundwater Renovation at the Flushing Meadows Project, Phoenix.....	29
8. Research on Modeling the Runoff Impact on Surface Water Quality at the Southeast Environmental Research Laboratory, Athens.....	33
9. Studies on Waste Water Renovation and Conservation at Penn. State University.....	38
10. Miscellaneous.....	42
11. Itinerary.....	43

REPORT TO THE NETHERLANDS AMERICA COMMISSION

FOR EDUCATIONAL EXCHANGE

dr. ir. F.A.M. de Haan

1. Introduction

The author is in charge of the educational and research program on Soil Pollution at the Agricultural State University, Wageningen, The Netherlands. This educational program forms part of the Environmental Studies Program at that University, which enables students to take majors in Water Quality Control (including waste water treatment), Air Pollution and Soil Pollution. The first two mentioned majors were started a number of years ago whereas the program in Soil Pollution is of more recent date. During these courses students are becoming familiar with all aspects of soil pollution in the more narrow sense on the one hand, and with the possibilities for proper use of land and soil as a contributing factor to the solution of a number of environmental problems at the other. In this respect recycling procedures of plant nutrient elements from waste materials as well as correct handling of waste disposal systems involving soils constitute major items.

The research program is concentrated on the behavior of elements or compounds in the soil system that should be looked upon as possible deteriorating factors for sound environmental conditions. Or as possible hazards with respect to water or plant composition when used in human or animal consumption. Thus the major compounds under study are phosphorus and nitrogen in view of eutrophication, heavy metals (interactions with soil compounds as well as uptake by plants) and oil (especially decomposi-

tion in the soil following an oil spill).

Both with respect to the educational and the research program it was felt of utmost importance to be abreast of the latest developments in this field of study in research institutions abroad. The opportunity offered by the Netherlands America Commission for Education Exchange to visit a number of such institutes in the United States of America was gratefully accepted.

The scholarship consisted of a two month visiting tour to eight research institutes active in the field of soil pollution aspects and a one month stay with the Agronomy Department, Cornell University, Ithaca, New York. This report is restricted to the first two months.

The last month was spent on the writing of a chapter entitled "Soil Pollution Phenomena" for a text on Soil Chemistry, edited by G. H. Bolt. To be published by Elseviers Publishing Company. This work has been performed in very close cooperation with prof. dr. P. J. Zwerman, Cornell University, who is the co-author of the above mentioned chapter and who acted as a counterpart during the reporters stay in the U.S.A. Text of this chapter is available now in first draft only. A copy will be sent to NACEE as the second part of this report when finished.

This part of the report focuses attention on the most important subject matters and experiences as gathered during the visiting tour. At the end some attention is being paid to miscellaneous affairs like interviews, seminars, etc.

2. Experiments on Pollution Induced by Different Manure Application Rates

(Department of Agronomy, Cornell University, Ithaca, New York)

Cornell University owns an experimental farm with a total surface area of about 200 hectares. This farm is located about halfway between the villages of Poplar Ridge and Aurora in Cayuga County, New York, at a distance of about 45 kilometers from Ithaca. The soil can be considered as a light clayey soil with a clay content of about 25 per cent. The soil is comparable to the "zavel" soils of Friesland and Groningen in the Netherlands and has a very high slaking sensitivity in common with these zavel-soils. Topography, however, is strongly different. The land is situated under slope with an overall percentage of roughly 4%, sloping toward Cayuga Lake.

Thus following heavy rainfall, which causes a deterioration of soil crumbs and consequently a decrease of water intake rate, these soils are subjected to surface runoff and macro-erosion rather than surface ponding of the water and micro-erosion as would occur at comparable weather conditions in the Netherlands. This situation offers an extremely favorable opportunity for a study on the possible damage that can be induced on the environment when large amounts of manure are applied to the soil. Experimental plots that have been installed in 1956 to measure surface runoff under varied conditions of soil management have been used for this purpose during the last three years.

It has recently been realized that accelerated soil erosion may contribute considerably to water pollution. The measuring device at the experi-

mental farm allows a collection of surface runoff water as well as drainage water. A comparison between the composition of both types of water provides an insight on the influence of the interaction with the soil system on the removal of different water components. Till now this experimental field, consisting of 24 plots with a surface area of 0.8 acres each, was used for runoff measurements following different climatic events.

Small interceptor ditches prevent the surface water to move from one plot to another, whereas across the slope runoff ditches have been installed up and down slope. Flow volumes of runoff water are measured by means of H-flumes. Passing the H-flume a so-called Coshocton wheel collects roughly 1% subsamples, which can be further divided by a splitter arrangement. In this manner an integrated water sample over a certain time period is collected, parts of which are subjected to laboratory analyses.

Each experimental plot contains one tile drain, installed through the middle of the plot, perpendicular to the slope. The tile enters a concrete tank containing a measuring device for continuous registration of the tile discharge and for the collection of an integrated sample of drainage water. All measurement installations are protected against freezing by means of a heating lamp.

Variables studied until now include

- 1) different application rates of dairy manure, viz. 35, 100 and 200 tons per hectare.

The first mentioned application rate can be considered as normal from a point of view of plant nutrition, whereas the 200 tons application constitutes a heavy overdose.

- 2) different treatments of soil management, viz. poor management, involving removal of all plant residues at harvest; such a treatment can be obtained at continuous corn growing when harvesting for silage. Good management, involving the build-in in the soil of all plant residues; such a treatment can be gained (except for the ear) by corn harvesting for grain.

These two soil management treatments date from 16 years ago, when the experimental plots were merely used for runoff measurements. As is well-known, continuous reincorporation of plant residues into the soil may considerably improve soil structure stability, thus preventing or diminishing surface runoff.

- 3) time of manure application, viz.

Winter spreading on snow or frozen soil

Spring plow down (i.e. manure is immediately plowed down after spread).

Summer topdress (i.e. manure is applied during summer on top of growing corn).

Runoff measurements and subsequent analysis of water samples were run at three different climatic events in 1972. The first event constitutes the melt of winter snow, corresponding to a water load of 33.0 mm. Hurricane Agnes occurring on June 21 and 22, 1972, caused a very high precipitation of about 175 mm. As the third event an intense August storm accompanied by almost 65 mm of rain was taken.

Results may be summarized by means of a retention efficiency of different nutrients applied. This has been done for the two soil management treatments, averaged over application rates, as presented in the following table:

Table 1. Retention Efficiency for Nitrogen and Phosphorus, Expressed as Percentage of Nutrients Applied (data from Zwerman, et. al.)

Event	Soil Management	Nitrogen	Phosphorus
Winter	Good	97.7	98.0
Snow melt	Poor	94.6	94.1
Hurricane Agnes	Good	98.7	99.2
	Poor	97.7	96.5
Intense August Storm	Good	99.8	99.7
	Poor	99.8	99.6

As is obvious from these data, degree of retention is very high for all treatments. The intense August storm caused the lowest nutrient runoff which must undoubtedly be attributed to the rainfall interception by the plant cover. If runoff takes place at an appreciable rate, the soil management treatment is clearly reflected into the amount of runoff water and consequently in the amount of nutrients removed.

Experiments like the above are indispensable to increase the insight in waste disposal - environmental quality interrelations. This is the more so because (and this is fairly comparable to the situation in the Netherlands) economic considerations force dairymen to enlarge their live-

stock at maintenance or decrease of the available land surface area for manure spreading.

3. Soil Pollution Research at the Agricultural Research Center

Beltsville, Maryland

The A.R.C. participates in a large number of environmental studies. This summary will be limited to several aspects of research programs which are directly related to soil pollution phenomena, viz. contamination of soils with heavy metals and pesticide behavior in soil systems.

I. Heavy Metal Contamination of Soils

During the last decade the interest in the fate of heavy metals in the soil as part of human environment has considerably been increased. This must mainly be attributed to the combination of a growing demand for land for waste disposal purposes and the progressing awareness of possible hazards induced by heavy metals when present in soil.

There are a number of reasons explaining the fact that especially agricultural research provides such an important contribution in the development of techniques and programs to study the effect of heavy metals. One of these is that heavy metal containing wastes are increasingly disposed of on land which is kept in normal agricultural use for crop production. This activity causes an incorporation of these waste materials into the soil matrix with all the consequences of such incorporation. One of these consequences is that the heavy metals can possibly be taken up by plants depending on characteristics of the soil as well as of the specific heavy metal. Thus a direct influence may be established

on the composition of plants that are grown on these sites, and possibly being used for animal or human consumption. Also the transport of heavy metals in the soil system is of major importance with respect to their environmental impact, because the factors that adjust this transport process eventually also regulate the composition of the contacting ground or surface water.

Until now the heavy metal research at Beltsville was mainly confined to the resulting influence on plant composition and the direct impact on animals and human beings. Several metals are being studied more specifically with respect to their chemical behavior in soils.

The heavy metal sources that are being considered are manifold with as the most important ones: sewage sludges, traffic emissions along roadsides and industrial emissions at specific sites, e.g. in the vicinity of smelters. Sludge from a sewage water treatment plant in Washington, D.C. is composted on practical scale, applying wood chips for the regulation of moisture content and as an easily accessible carbon source. This composting plant is operated in close cooperation between A.R.C. and the Maryland Environmental Service and offers the opportunity for the application in experimental plots of sewage sludge which has been treated according to practical standards. Application rates amount to 40, 80, 116 and 240 metric tons of dry sludge per hectare, respectively. Effects on yield and uptake by a number of crops are the main research targets in these experiments. Crops are chosen either on their relative contribution

to the common diet or for their indicatory properties. Specific uptake studies are conducted in pot experiments in glass houses, employing the same or comparable heavy metal sources. One of the main goals of these studies is to arrive at practical and safe advices on application rates of sewage sludges in agriculture as a function of sludge composition on the one hand and soil properties and land use on the other.

A thorough study on the occurrence of heavy metals in the vicinity of a zinc smelter near Galena, Kansas, provided an insight in the distribution pattern of such metals as induced by emissions from the smelter. Distribution was studied as a function of distance to the smelter and as a function of soil depth. Uncontaminated soil samples were collected underneath houses which had been constructed before the smelter started its activities. They thus serve as indicators for the soil metal content prior to the emissions from smelter stacks or the occurrence of tailing dusts. In addition to soil analyses, also the analysis results of plants, occurring as natural vegetation or as commercial crops, again sampled as a function of distance to the smelter and as a function of the prevailing main wind direction, show the smelter influence, even indicating the actual presence of an environmental hazard under the prevailing conditions. Careful evaluation of such data allows an estimation on the Pb and Cd intake in these high exposure areas as compared to areas of low exposure. An example of this comparison is presented in Table 2.

Table 2. Increase in dietary intake of Pb and Cd from milk, vegetables and meat under conditions of high exposure (Galena) relative to those of low exposure. (Data by J. V. Lagerwerff)

Diet Components and %	Low Exposure mg/yr	Factor ^{1/}	High Exposure mg/yr
<u>Lead: Average low exposure intake: 120 mg/yr</u>			
Dairy products, 8	10	2.9	29
Vegetables, 22	26	1.8	47
Meat, 32	<u>38</u>	2.2	<u>61</u> ^{2/}
Total	74		137
			Increase: 63
<u>Cadmium average low exposure intake: 32 mg/yr</u>			
Dairy products, 10	3.2	1.0	3.2
Vegetables, 10	3.2	4.8	15.4
Meat, 30	<u>9.6</u>	(2.2)	<u>15.4</u> ^{2/}
Total	16		34
			Increase: 18

^{1/} This factor compares the content in the Galena area as compared to the Washington, D.C. area.

^{2/} Assuming that 50% of the meat is store-bought, i.e. from a low exposure area.

These data thus show that persons living in an area of high exposure ingest Pb and Cd at rates more than 50% above those associated with normal dietary intake. This is also confirmed by the analysis of samples of human blood and hair.

II. Some Aspects of Pesticides Behavior in Soil

Research on pesticides behavior in soils constitutes a very broad field because of the many specific interactions between pesticides and soil components. Moreover, the situation is considerably complicated by the occurrence of decomposition reactions as a single or combined result of merely chemical and biological processes.

The method for studying uptake and concentration of pesticides in components of a model ecosystem, as has been developed at Beltsville in the study of alkyl arsenicals, has also an important educational perspective. This method allows in a short time period a good demonstration on the simulation of relative pesticide concentrations in such ecosystems that e.g. contain algae, daphnia and fish on an aquarium volumetric scale. Specific soil influences may be introduced by application of different soils in these ecosystems. Radioactive tracing of the pesticide enables a fast and useful allocation of the compounds introduced.

Both for research and educational purposes good use can be made of the semiquantitative method to depict the displacement of pesticides in soils by applying the thin-layer chromatography. A certain degree of quantification can be facilitated by using again radioactive compounds and autoradiographic techniques.

In runoff experiments on practical scale it was found that the total runoff of aldrin and dieldrin never exceeded about 0.1% of the on values. However, measurement of the aerial flux rates from soil to the

air indicated that a considerable part may be lost by volatilization. These aerial losses could greatly be diminished by particular land management measures like disking and mixing. Also for heptachlore it was monitored that during several days after application up to 50% of application may be lost to the air. Volatilization has the important feature of diurnal fluctuation with energy input on the soil. This can have important consequences with respect to advisable times of application and may possibly contribute to a partial explanation of the many fairy-tale like results of pesticide applications at different times and climatic conditions.

A prime difficulty in the evaluation of experimental data is caused by the variability of sampling results. This is of special importance in studies on the disappearance of pesticides from the soil system either by leaching or by volatilization or by decomposition.

4. Sewage Sludge Utilization Studies at Urbana, Illinois

At the Department of Agronomy, University of Illinois, Champaign-Urbana, Illinois, considerable attention is being paid a.o. to the utilization of digested sewage sludge in agriculture. Experimental design can in a first approach roughly be divided in lysimeter experiments in which the fate and behavior of a number of components present in the sludge are being followed, and in large scale practical applications of sewage sludge in the reclamation of strip mined areas.

The sludge is supplied by the Metropolitan Sanitary District of Chicago, which nowadays has to face as one of its main problems the disposal of about 1,000 tons on dry basis of sewage sludge that are produced

each day. Until about 6 years ago the total sludge load was treated in 4 ways, namely: heat drying (almost 50%), wet air oxidation (about 15%), heated digestion (about 20%) and Imhoff tanks (about 15%). It was felt that the disposal systems used until that time became less acceptable for a number of reasons; besides by economic considerations these were also set forward by an increasing concern for the inherent water and air pollution.

In the evaluation of the possibilities for land disposal of such sludges a number of questions arise which are attempted to be answered by experimental work as will be summarized here. Such questions refer predominantly to application rates and the resulting consequences for plant and crop composition or groundwater pollution.

The application rate that should be advised highly depends on the final goal that is to be gained. If the sewage sludge is applied for chemical fertilization purposes only it is evident that the rate of application should be adjusted to the fertility requirements with respect to one of the three major plant nutritional elements: nitrogen, phosphorus or potassium. In that case maximum fertilizer utilization can usually be obtained by adjusting rates of application to nitrogen requirements. Phosphorus and potassium needs can then be met by means of additional fertilizer supply. This way of adjustment is the more of importance because considerable nitrogen leaching as $\text{NO}_3\text{-N}$ may occur if application would be adjusted on either phosphorus or potassium.

If not so much the chemical properties of the soil but more specifically the physical crop growing conditions are intended to be improved by means of sewage sludge disposal, a completely different

situation has to be visualized. Such a situation arises e.g. in case of the reclamation of strip mined areas by sewage sludge utilization. Assuming that this could be an acceptable and possibly even a favorable approach, an evident opportunity for killing two birds with one stone would be opened, as for U.S.A. conditions a large percentage of population for a number of states lives within economical sludge pumping distance to land that has previously been used for strip mining.

A general idea about the Chicago sewage sludge composition is presented in the following table for two sewage water treatment plants.

Table 3. Composition of anaerobically digested sewage sludges from MSD of Chicago, Calumet and Stickney treatment plants. Samples obtained during 1971 (Calumet late in year). (Data of Hinesly et. al.)

Element	Means (Wet Weight)	
	Calumet	Stickney
Cd ppm	3.0	14.0
Mn "	8.0	18.0
Ni "	3.0	15.0
Zn "	83.0	223.0
Cu "	16.0	67.0
Cr "	26.0	194.0
Fe "	726.0	2100.0
Pb "	16.0	75.0
Hg "	0.063	0.275
Na "	98.0	131.0
P "	757.0	1141.0
Ca "	963.0	1289.0
Mg "	180.0	484.0
K "	195.0	390.0
N %	0.09	0.156
% Solid	2.05	4.36
% Volatile	58.0	48.0

Solid contents of these digested sludges amount to about 3-5%. Thus if the rate of application would be around 500 mm adequate supply of major nutrient elements would be warranted since such application corresponds to a fertilizer supply of roughly 220-239 kg N/ha as NH_4 ; 280-500 kg/ha of P and 45-90 kg/ha of K. A considerable part of the phosphorus is bound to organic matter, whereas in addition to the NH_4 -N supply about an equal amount of N is added as organic N.

As is being reasoned in a first report on this subject matter, it would not seem likely that heavy metals would considerably displace in soil under such conditions. Moreover, control of heavy metal fate seems easier after land disposal than when partly disposed of in water bodies or in the air. Such a control, as well as with respect to plant uptake as to movement to deeper soil layers can relatively easily be achieved and could in a first approach be limited to the elements with the highest hazard potentials. Moreover, a number of management measures both of chemical or physical nature, can be applied to regulate the metals mobility.

In Fulton County, Illinois, at a distance of about 300 km from Chicago, large strip mined areas are reclaimed now with Chicago sewage sludge. In such reclamation activities the sludge is primarily used, at least in the beginning, as a soil conditioner. As the result of an increased organic matter content an amelioration of porosity and water holding capacity as well as an increase of ion exchange and soil

structure stability is gained. To arrive at a desirable organic matter content in these soils of about 4-5% in the top layer in a reasonable time period of about 4 years, the application rate was at the beginning suggested as about 450 metric tons of dry sludge per ha per year. This would be about 2 to 2.5 times as much as the 500 mm mentioned before to meet fertilization requirements. It was expected at that time that the nitrogen fixation capacity of the mined soils would be sufficiently high, as compared to normal agricultural land to prevent nitrate from leaching. It turned out, however, that according to Illinois standards for nitrogen contents in groundwater the yearly application rate had to be diminished to about 160 metric tons of dry sludge per ha.

This is about the same value as was applied as a maximum application rate in the lysimeter experiments. In order to present a general idea about the increase of plant available elements at 4 applications relative to the maximum value, Table 4 is given.

Table 4. Contents of chemical elements extractable by 0.1 N HCl in soil samples collected in April 1971 from corn plots at two depths after a total of 65.4 cm or 167.8 dry tons per hectare of digested sludge was applied on the maximum-treated plots. (Data of Hinesly et. al.)

Sludge Appl. Rate	0-to 15.2-cm depth												
	P**	K	Ca	Mg	Fe	Mn	Na**	Cr**	Cu**	Pb**	Ni**	Zn**	Cd**
0	16	16	1200	400	499	304	14	0.94	3.9	6.6	2.3	13	0.22
1/4 Max	51	224	2100	536	536	306	24	3.3	8.4	11.0	3.5	41	1.50
1/2 Max	148	229	1200	413	792	428	27	11.0	19.0	17.0	5.3	98	3.80
Max	376	268	1500	410	775	402	32	19.0	32.0	30.0	7.0	181	7.00
<u>30.5-to 45.7-cm depth</u>													
0	15	283	1600	1300	741	45	18	0.64	3.5	2.0	2.6	7.8	0.61
1/4 Max	25	258	1500	1200	671	63	27	0.82	4.9	2.7	3.6	12	0.68
1/2 Max	27	272	1600	1200	706	57	38	1.30	5.9	4.2	3.6	16	0.82
Max	49	247	1600	1200	791	61	52	1.60	6.4	5.3	3.6	18	0.88

* Treatment effects significant at 5% level

** Treatment effects significant at 1% level

As may be concluded from these figures digested sludge applications did increase the mobility of P, Na, Cr, Cu, Pb, Ni, Zn and Cd in the upper 15 cm soil layer. Also in the layer of 30-45 cm increased mobilities of Na, Cr, Cu, Zn and Cd are found, whereas at somewhat lower significance also for Mn and Pb.

5. On Site Waste Water Disposal Research at the University of Wisconsin

One of the research projects at the Department of Soil Science, University of Wisconsin, Madison, Wisconsin, related to a protection of desirable environmental conditions has its major concern on the impact of domestic waste water disposal on human environment. The research in this field has a multidisciplinary approach; not only soil science aspects are being considered but also sanitary engineering aspects e.g. with respect to different pretreatments of the waste water prior to the disposal. Prime attention is also being paid on health aspects as e.g. distribution of disease bacteria and viruses. This summary is confined to soil aspects only.

The importance of the problem for the State of Wisconsin may be reflected by the following figures: of the total number of inhabitants of about 3.5-4 millions the domestic waste water of roughly one-third is being disposed of by means of septic tank systems. Moreover, Wisconsin has important recreational areas where summer inhabitation in cottages and trailers may cause a large temporary waste burden. As a consequence of the location of such more temporary residences areas of high recreational or natural value can be affected considerably. The main reason for the

use of septic tanks as against sewer systems is the low population density and hence the inacceptably high costs per capita for the installation and maintenance of sewer systems and waste water treatment plants.

The working of a septic tank system seems very simple at first sight. All domestic waste water, which is mainly generated by toilet flushing, bathing, kitchen activities, and laundry is being collected in a tank which is usually sized as several cubic meters. In this tank an anaerobic microbial digestion causes a partial decomposition of the freshly added waste water solids and a transformation to more stable sludge compounds; about 40% of all solids is thus reduced. During this decomposition methane and carbon dioxide gases are formed, which are vented from the tank by the house vent system. The remaining solids have to be pumped out once every two, three or four years.

Once the septic tank has been filled up to the overflow outlet, each addition of fresh waste water causes an equal discharge of septic tank effluent into the second part of the system: the soil absorption field. Usually this field consists of a number of gravel filled benches with a depth of about 50-60 cm. The effluent is distributed in this field by means of perforated pipes. When working properly the effluent is subjected to a final treatment in the soil system underlying the adsorption field and reaches in purified form groundwater and/or surface water.

For such proper working, however, a number of requirements has to be met which can roughly be summarized as: removal of oxygen demand,

nitrogen and phosphorus and of disease bacteria and viruses. The degree of removal is indicated for practical purposes in guidelines as provided by the Environmental Protection Agency and by health officers. It is self-evident that specific soil properties are the main factors in determining the possibilities for meeting discharge requirements (at least if such requirements are not out of reality). Thus the suitability for septic tank installations and hence for house building in unsewered areas may be related to soil characteristics. In a special State Health Code adopted in 1969 suitability was thus related to: the water permeability of the soil, the thickness of the soil layer in between the absorption field and the groundwater table or creviced bedrock, the percentage of surface slope and the physical geographical situation of the site (e.g. floodplains are considered as unsuitable). For reasons of legislation unsuitability is being expressed nowadays as "degrees of limitations for suitability."

As may result from the above soil properties that are responsible for the septic tank effluent treatment may be divided in physical, chemical and microbiological properties. As is always the situation in soils, these do not operate independently but influence each other to a high degree. Thus one of the prime physical properties is the soil permeability and infiltration rate. This has an important bearing on the residence time of the effluent in the soil and consequently on the time available for chemical and microbial reactions to take place. Limits must be established for the minimum value of this residence time and as a matter of fact the above mentioned unsuitability of creviced bedrock is based on not

meeting such minimum requirements.

On the other hand, too low infiltration rates will lead to surface ponding of the effluent. Besides unacceptable odor formation, this also causes anaerobic conditions in the soil, thus preventing the aerobic microorganisms from decreasing the oxygen demand of the water. In the meantime such conditions will preferentially cause denitrification resulting in the removal of previously formed nitrates as gaseous nitrogen. As usually in disposal systems involving soils, a number of interests to obtain specific goals are contradictory to each other. The situation becomes even more complicated when it is being realized that the soil properties do not remain constant but are continuously changing with the age of the disposal system.

This is not only true for chemical characteristics like composition of adsorption sites with certain ions, but also for physical properties. Soil permeability in absorption fields of septic tanks may decrease gradually upon aging of the system due to clogging of the soil pores. This clogging mechanism, its results and possible measures for its prevention are under study now in soil column experiments using undisturbed soil cores.

Considerable attention is also being paid on the interpretation and transferability of soil survey and mapping criteria in the evaluation of soils on their suitability for on site waste water disposal. One of the prime questions in this respect is related to the variability in soil physical properties within the same soil mapping units. The previously mentioned suitability criteria as developed in the State Health Code are more empirical than scientific in nature. As a result soils indicated

according to these criteria as "non-problem" soil may under specific conditions offer many problems. On the other hand, the criteria used in the evaluation of the depth of the groundwater table have usually been based on easily accessible observations like e.g. visible phenomena in a soil profile. It seems at least questionable whether the occurrence of muddles can be applied for a correct determination of water saturated conditions.

Why not help nature, when soil property requirements are not met under natural circumstances? This is the main idea underlying the development of mound systems for disposal of septic tank effluents. In this case one looks for optimal criteria for sizes of the disposal bed, both with respect to extent and height. Naturally also the quality of available soil materials are taken into account. The whole has to be practicable at reasonable cost; the septic tank system being a one-family system costs do form an important factor with respect to practical applicability. Results obtained so far are encouraging.

6. Research at Robert S. Kerr Water Research Center, Ada, Oklahoma,
on Waste Water Treatment by Overland Flow

One of the fields of research at the above Center focuses attention on the aspects of land disposal of processing waste water. Although the water treatment is the prime and major objective in this case, constituents of the waste water are in the mean time used as plant nutrient elements for grass grown on the disposal fields. Consequently the treatment may, at least in part, also be characterized as a utilization or

recycling procedure.

At the Texas plant of Campbell Soup Company, Paris, Texas, treatment of cannery waste water has been taken care of by spray irrigation followed by overland flow ever since the plant became operational in 1964. At that time the total surface area of the treatment system covered around 400 acres; in several expansions since that period the system was extended to its present acreage of roughly 900 acres, of which several hundreds are in final preparation to water disposal now.

As the infiltration rate of the soil is low (less than about 2 mm per day) and the land is mostly under slope considerable runoff occurs as soon as the precipitation intensity, either naturally originating or induced by sprinkling irrigation, exceeds the infiltration rate. This combination of soil properties and poor land management during a period of several decades prior to the present soil use are responsible for the poor state in which the land prevailed when bought in 1960 by Campbell Soup Company. The soil was then covered with brush and small trees and intersected by numerous erosion gullies. Thus special reclamation measures were required to make the land suitable for its new service: treatment of waste water by overland flow.

Such measures initially consist of tree removal and clearing of the land, followed by a first land leveling with heavy earth-moving equipment in order to fill the erosion gullies. Following this rough adaptation the slopes are smoothed with land planes and terraces are built at spacings of roughly 60-100 meters depending on local circumstances. At the same time an underground distribution system is installed consisting of force

mains with automatic valve take offs. These mains are replaced upslope of the terraces with in between spacing of roughly 40-50 meters. In the beginning the surface distribution system consisted of aluminum pipes which were laid across the slope in manual labor, and sprinklers which were installed on these pipes. In later extensions this has been replaced by subsurface plastic pipes on which the sprinklers are permanently installed. Initially the slopes were seeded with grass and installation of terraces was performed once the grass had developed a good and complete cover. In present reclamation measures terracing is being performed prior to grass seeding.

The waste water itself is being produced within the cannery plant at two main sources. The first type of waste water originates from the cooking area, contains grease and is forced to pass a gravity grease separation. Following this treatment the water joins the second waste stream which originates from the vegetable washing area. Large pieces of solids are being removed by passing water through screens. Both grease and solids are separately collected and utilized in soap and animal feed production, respectively, by contracted buyers. The pre-treated waste water is finally pumped at high pressure from the waste treatment building to the disposal fields. Disposal activities are entirely automated. Application regimes differ slightly depending on climatic conditions; during the warm months of summer the daily application schedule constitutes 8 hours on and 16 hours off, changing in cooler periods to 6 hours on and 18 hours off. The longer off-periods in summer allow sufficient dry conditions for grass harvesting; the change

in application schedule in summer allows application of the same amount of water on $3/4$ of the surface area; thus alternately $1/4$ of surface area is left to dry for harvesting. The grass is used for pelleting and has a protein content comparable to a good alfalfa crop. The grass seeded is a mixture of Reed Canary grass, Red Top grass, Tall Fescue and perennial Rayegrass. On irrigated spots Reed Canary suppresses the other types and produces a crop which is equally and possibly even preferentially being consumed as hay by cattle in comparison to several other test hays.

Water balance measurements indicated that of the total amount of waste water applied about 60% flows over the land surface downslope the terrace; at the end of the terrace the water is collected against the small earth wall and is being discharged as surface water by a discharge system of small gullies and ditches. About 10 to 30 percent of the amount applied is lost by evapotranspiration and the remaining portion percolates down through the soil system.

About $1/4$ to $1/3$ of each terrace surface area is directly subjected to sprinkling irrigation; the remainder of the area is required to obtain sufficient retention time of the water for proper treatment during overland flow. This residence time is also strongly dependent on the slope of the land; in the Campbell system these slopes range from about 1% to 8%. Slopes of roughly 2-6% are considered optimal for overland flow treatment. Application intensity, expressed over the total area, should not exceed 2.5 mm per hour, again in order to obtain sufficient residence time.

Application of waste water is three times as high as mean natural precipitation, namely 3380 mm as against 1140 mm, again expressed per total surface area. In view of the above figures, the irrigation intensity underneath the nozzles during the time of application is about 10 times higher.

Despite the very high application rates an efficient waste water treatment may be obtained as is indicated by the following data: BOD is decreased from 600-900 ppm to somewhere around 9 ppm in the terrace runoff, with about half of the number of measurements being around 6; this corresponds to a BOD removal of 99 percent. Nitrogen removal amounts to almost 90 percent, namely from about 18 ppm total N to roughly 2 ppm. Removal of phosphates was initially rather poor, viz 40 percent; phosphate removal could be increased to almost 90 percent temporarily by introducing longer rest periods between applications. Under practical conditions, however, phosphate removal still remains the poorest. These extremely high removal values are the combined result of mechanical, chemical and especially microbiological screening of the water while passing the grass-covered terrace. The whole undertaking may be characterized as a successful waste treatment procedure in which a number of goals are being served simultaneously like efficient waste water treatment at acceptable costs and conversion of useless, idle land in productive and erosion protected crop land areas.

Results of this practical waste water treatment system were and still are so good, that Robert S. Kerr Water Research Center presently studies the possibilities of overland flow systems in the treatment of

municipal waste water. To this purpose a number of experimental plots have been installed, which are situated such that as well raw municipal waste water as primary and secondary effluents may be used in overland flow experiments. An impression of the results that may be arrived at in this way can be obtained by a comparison of the composition of the raw sewage water, as given in Table 5, with the composition of the runoff of different plots, presented in Table 6.

Table 5. Raw Sewage Characteristics for the 18-Month Study Period

Parameter	Concentration, mg/l	
	Mean	Range
Total Solids	1120	650-1660
Suspended Solids	160	52-420
Biochemical Oxygen Demand	150	84-273
Total Nitrogen ^a	23.6	10.7-36.8
Kjeldahl Nitrogen	22.8	8.3-36.8
Chemical Oxygen Demand	314	130-620
Total Organic Carbon	89	21-198
Total Phosphorus	10.0	4.8-15.0

^a Includes 0.8 mg/l of nitrite plus nitrate nitrogen.

Table 6. Quality of Plot Runoff for November 1971 Through April 1972

Parameter	Mean Concentration, mg/l		
	7.4 cm/wk. plot	8.6 cm/wk. plot	9.8 cm/wk. plot
Total Solids	700	685	730
Suspended Solids	12	8	9
Biochemical Oxygen Demand	12	11	8
Total Nitrogen	5.4	7.2	6.8
Kjeldahl Nitrogen	2.4	3.6	2.9
Nitrate Nitrogen	2.8	3.4	3.7
Chemical Oxygen Demand	53	48	46
Total Organic Carbon	22	14	15
Total Phosphorus	4.4	5.4	5.1

(Data by R. E. Thomas)

It is seen that the quality of the runoff water is considerably better than the effluents of normal secondary treatment plants. An additional advantage is that no sludge problem has to be faced, although further research is required to predict long term effects. A natural prerequisite for overland flow systems, of course, is sloping land.

7. Research on Groundwater Renovation at Flushing Meadows Project

Phoenix, Arizona

In 1967 a study was started at the United States Water Conservation Laboratory, Phoenix, on the possibilities of renovation of the effluent of sewage water treatment plants following secondary treatment of the sewage water. The main purposes for reuse of the water are for unrestricted irrigation, for recreation, and also for specific industrial use. The renovation procedure consists of passing the secondary effluent through the soil in such a way that the standards for the above uses are met when the groundwater is reached.

In a joint venture between the U.S. Water Conservation Laboratory, the City of Phoenix and the Salt River Project, a pilot plant was installed, known as the Flushing Meadows, in which the renovation can be studied on a practical scale. The pilot project is situated in the Salt River bed downstream of one of the sewage water treatment plants of Phoenix, located at 91 Avenue. Thus the effluent may directly be pumped from the creek in the Salt River bed on which the treatment plant is discharging.

The soil involved consists in the topsoil (to about 0.9 m) of fine loamy sand, overlying coarse sand and gravel layers to a depth of about 2.5 meters. Then a clay layer is found, forming the lower boundary of the aquifer. In the pilot plant six basins, sized about 6 x 210 meters, were installed which allow to study the treatment results of different application managements. A number of observation wells were installed in between different basins and on several distances from the basins. At

the point where the effluent is taken from the creek, a constant head structure for regulation of the application was installed. From this structure the water is brought by a supply pipe to the inlet points of the different basins. An overflow device at the lower end of the basin allows maintenance of constant water depth. The amount of water infiltrated into the soil is found from the differences in flume-measurements at the inflow and the outflow points.

The infiltration rates of this soil are very high. The maximum water loading may be obtained by applying alternatively flooding periods and drying periods, on a schedule of 20 days flooding alternated with 10 days drying in the summer and 20 days drying in the winter. Following this application schedule, the annual infiltration amounts to roughly 100 m of water, which is extremely high in comparison to other existing water disposal systems on soils. Due to settlement of solids the infiltration rate may gradually decrease during a flooding period. The drying period, however, takes care of a drying and cracking of the sludge that has been deposited on the bottom of the basin, thus completely restoring the infiltration rates of the basin. Cleaning of the basin from the sludge may be delayed for several years if the suspended solids content of the secondary effluent applied does not exceed about 20 mg/l.

Results obtained with respect to the quality improvement of the water are very good. The fact that the groundwater of the Salt River bed is salt, whereas the salt content of the secondary effluent amounts to only one half of the groundwater content allows conclusions about the origin of water samples taken from the sampling wells. The BOD of the effluent

applied to the basins is in the range of 10-20 mg/l. Corresponding values of the groundwater are 0-1 mg/l, and usually less than 0.5 ppm. This means that the biodegradable carbon is practically completely removed. Total organic carbon (TOC) measurements, however, indicate that a small amount of some types of organic carbon still occur in the renovated water, since TOC values range from about 10 to 30 mg/l.

Fecal coliform bacteria removal is also very high. The fecal coliform density in the secondary effluent amounts to $10^5 - 10^6$ ml, whereas this value is decreased to 0-100 in the well water. Fecal coliform removal is predominantly obtained in the upper 60-90 cm of the soil. In the well situated at a distance of 90 m from the basins no coliform bacteria have ever been found, indicating that the lateral transport of the water to reach this well suffices for a complete removal of all coliforms.

Phosphate removal is relatively poor, namely somewhere around 50 percent. Phosphate concentrations in the secondary effluent itself considerably decreased since the start of the pilot project, viz. from about 30 ppm PO_4 to about 20 ppm. This must presumably be attributed to the increased use of detergents which are low in phosphates. Iron and aluminum compounds do not occur in the soil at detectable degree. This means that removal of phosphate will predominantly occur by precipitation as either calcium phosphates or fluorophosphates, or by surface adsorption on calcium carbonate particles. Other phosphate adsorption sites do not occur in this specific soil profile. The mechanism of phosphate removal will be one of the research topics in the Flushing Meadows project in the near future.

Considerable attention has been paid to the reduction of nitrogen, both with respect to the quantification and to the mechanism of the removal. These studies were performed on the basins in the pilot project as well as in laboratory experiments involving the use of long soil columns (2.5 meters). These studies considerably attributed to the understanding of the successive reactions involved in the nitrogen removal and led to the adjustment of the water application management in such a manner that the highest possible removal values can be obtained. A brief summary of this adjustment procedure may read as follows. Following the application of secondary effluent it may be calculated from the cation exchange capacity of the soil, from the presence of other cations competing for adsorption and from preference constants to what depth ammonium ions will occur in the soil. These ions must be subjected to nitrification in the succeeding drying period, and for this purpose required oxygen must intrude the soil by diffusion. The depth of the prevailing ammonium may thus be the first rate-limiting step to obtain complete nitrification of all ammonium applied. The final stage in the nitrogen removal, which is of key-position, is given by the denitrification, which result in a transformation of nitrate into gaseous N_2 , which will leave the system by volatilization. Thus the conditions for denitrification have to be met, preferably in the most favorable way. Such conditions are: presence of denitrifying microorganisms, anaerobic conditions, and presence of a carbon source for energy supply. The first condition is usually met in soils without problems. Anaerobic conditions may be obtained by the next flooding, following the drying period used

for nitrification. This, however, may induce favorable conditions for nitrate leaching, which should be prevented both for health aspects as for prevention of eutrophication. Nitrate is, due to its anionic character, extremely easily displaceable in soils. This phenomenon may be registered by the very sharp increase of nitrate concentrations in the groundwater following the renewed flooding with secondary effluent; nitrate break-through exposes itself as a sharp peak. It is a challenge for the present research in this project to adjust the first infiltration after drying and the addition of required C-sources in such a way that all nitrate has been denitrified, when the soil water reaches the groundwater level, or a point where the water is being extracted again from the soil for renewed use. Present nitrogen removal amounts to roughly 30 percent as an overall value, starting with an average nitrogen concentration of about 35 ppm in the secondary effluent. After passing of the nitrate peak, however, removal amounts to about 90 percent, indicating that it is indeed of prime importance to diminish and remove the nitrate concentration peak in the leaching water.

8. Research on Modeling the Runoff Impact
on Surface Water Quality at the Southeast Environmental Research
Laboratory, Athens, Georgia

The Agro-Environmental Systems Branch of the above laboratory directs its combined efforts on the prediction of the contribution by runoff from agricultural land to the deterioration of water quality in natural waste water bodies. The general approach that is being applied is based on the

use of mathematical models rather than on a trial and error method. In the last case a large number of specific sites would have to be studied in all possible variations of characteristics and parameters involved, like e.g. type of pollutant, soil properties, climatic conditions and agricultural practices as crop rotation and soil management. It is felt that such an approach, although leading to information on short-term for the specific site under the conditions studied, would require an almost endless experimentation due to the limited applicability of the experimental results.

The modeling approach will hopefully lead to an understanding of all processes and mechanisms involved, and the proper combination of these factors in such a manner that predictions of great general applicability may be performed with respect to expectable and most probable contributions by runoff. Although it is realized that subsurface transport may also contribute to the increase of pollutant concentrations in surface water, major attention is focused on runoff during the first stage of the research project. The preliminary work has especially been directed to the behavior of a number of pesticides. Presently also nutrients like nitrogen and phosphorus are taken into consideration.

It has long been realized that non-point sources of pollution are extremely hard to quantify, whereas they may have at the meantime considerable impact on the environment, especially following a number of climatic events. As such the occurrence of snow melt over a frozen topsoil layer, or precipitation events of high intensities and exceeding the

infiltration rate of the soil, may be indicated. Both will result in surface runoff, not only of the excess water but also of soil particles, depending on soil properties and specific circumstances involved.

Thus at first sight it would seem obvious to take the Universal Soil Loss Equation, as developed by researchers in soil erosion and soil conservation, as a point of departure in the mathematical model. This equation, however, turns out to be not useful in this respect because it expresses the loss of sediments as weight per unit surface area per year. Taking this equation as point of departure would thus limit the prediction model to yearly contributions, whereas information is required on contributions of specific events. Moreover, the prediction would be limited to the transport of compounds attached to the displaced soil particles whereas no account would be made for pollutants displaced in dissolved state in the accompanying runoff water.

In order to avoid the above limitations a dynamic model was preferred in which the pollutant behavior is described as well during the runoff event as during the in between periods. Such a model then must account for the transport in adsorbed and dissolved state as a function of external factors, whereas it also must have the possibility, either by incorporation or by superimposition, to describe, in a mathematical form the factors which influence the behavior of the pollutant on or in the soil system. In summary the model thus consists of a basic part which describes the transport processes, whereas a large number of submodels are introduced for the description of the intrinsic behavior of the pollutant under consideration.

Also the source of the pollutant must be considered. When e.g. manure or artificial fertilizer is involved the erodibility and consequently displaceability will greatly depend on the application procedure. Mixing of these materials through the topsoil layer will decrease their transportability, whereas surface application induces increased possibility for surface runoff. This same holds for pesticides which may be applied to the soil in a number of different ways, depending on their objective or specific properties.

These considerations point to an extremely important practical aspect of this research on predictive modeling: it may well be possible to arrive in this way at a number of practical guidelines for the application procedure of compounds to soil, in order to prevent runoff as much as possible. Such guidelines should not necessarily be confined to practical farming, but may be extended to the production procedure of certain compounds like fertilizers and pesticides, in order to introduce properties which minimize their mobility.

For the basic transport models, the models as developed at the Stanford University, Palo Alto, California, are used both with respect to the hydrologic watershed model as to the sediment transport model.

A large number of attenuation factors must be considered, especially when studying pesticide behavior. Also with respect to other compounds, however, several of these must be taken into account, e.g. when studying carbon sources. A brief listing of such attenuation factors reads as follows: microbial degradation, chemical and photochemical degradation volatilization and uptake by plants or organisms. Leaching with downward

moving soil water is an attenuation factor which may be accounted for by the submodel for vertical transport.

The interactions of the compounds of interest with soil constituents, like adsorption on organic matter or clay particles or precipitation as solid phases, constitute another field of required information. These types of possible interactions usually lend themselves for research in experiments on laboratory scale.

In cooperation with the Department of Agriculture, experimental station at Watkinsville, Ga., (Southern Piedmont Conservation Research Center) a start was made several years ago in the collection of experimental data on microscale watersheds. This data collecting has now been expanded to pilot project watersheds ranging from 3-7 acres each. Such data are required in the control of the predictions that are arrived at when using the model.

It may be hoped that the above approach may be useful for direct utilization of the tremendous basic information that is already available in soil science, as well with respect to erosion and hydrology as to chemical and microbial interactions in soil. What is badly needed now is a proper combination of this isolated information. Research as described here may well lead to such combinations, thus providing enlarged insight in the complex processes of nature as well as practical guidelines to improve the environmental quality.

9. Studies on Waste Water Renovation and Conservation
at Penn State University

The Department of Agronomy of Penn State University, University Park, Pennsylvania, has the oldest research program on waste water renovation by disposal on land in the U.S.A. After a period of preliminary research on soil and groundwater characteristics for the involved site and preparations for installment of pipelines, pumping plant and a sprinkling irrigation system, the first effluent of a secondary sewage water treatment plant was applied here to the soil on May 16, 1963.

This approach of land use in effluent treatment was stimulated by the observed degradation of Spring Creek near State College, which resulted from the enrichment as induced by the discharge of nutrients in the effluent of the sewage treatment plant.

The principal objectives of this specific project were recorded as:

- "1. To determine to what extent the biological complex of forest, crops and soil is capable of preparing sewage effluent for recharge and reuse.
2. To determine criteria for selecting non-aqueous sites for safe disposal of sewage effluent.
3. To develop and apply to the data gathered under objectives 1 and 2 a system analysis procedure for the determination of minimum net costs for land disposal systems in terms of municipal sewer service charges."

The above enumeration indicates that all main questions related to land use for waste disposal were already recognized at that time.

The terrestrial disposal sites consist of two different areas, namely an agronomic and forestry area with a total acreage of about 40 and a gamelands area with an acreage of about 20 acres. The first mentioned sites are located on so-called Hublersburg clay loam, whereas the gamelands area consist of Morrison sandy loam. The whole disposal area is underlain by a thick sequence of carbonate bedrocks. This formed a particular concern in the disposal considerations since the groundwater supplies may consequently be specifically susceptible to contamination if the pollutants would still be present in the soil moisture when reaching the groundwater.

Application management is mainly based on a rate of two inches of effluent per week; for specific research purposes various small experimental areas are subjected to one, four or six inches per week. The application is obtained by a solid-set sprinkling irrigation system; such a permanent arrangement is preferred, especially when forest areas are involved, because the presence of trees would greatly impede the movement of the pipes. The on-surface part of the pipeline system has been installed in such a manner that frost damage may be prevented by rapid draining of the system during freezing weather.

The waste water used (after secondary treatment) originates from The Pennsylvania State University and from the Borough of State College. It has the advantage, from a research point of view, to be relatively constant in composition.

Treatment results, as well with respect to soil water and groundwater composition as to changes in the soil composition, are measured on a great

number of monitoring wells and sample collecting spots, Overall results may be summarized in the following way:

Application of this effluent to cropland areas at the rates of one to two inches per week results in a 60-100% recharge of the totally applied amount of waste water in the form of potable water; at the above rates a good yield of most agricultural crops can be guaranteed.

For forest areas, the same percentages of recharge were found at a weekly rate of one inch, whereas at the meantime an improved diameter growth of the trees was measured. At higher application rates (two inches) growth responses were found to be different depending on soil properties and vegetative cover type. Under all conditions covered in the pilot plants nitrate-nitrogen levels in the groundwater remained below the U.S.P.H.S. value of 10 mg $\text{NO}_3\text{-N}$ per liter for drinking water, except for the red pine area at complete absence of ground vegetation.

When growing normal agricultural crops, crop removal may cause a phosphorus removal equivalent to 20-80% of the total amount applied, whereas in this way 40-100% of totally applied nitrogen may be removed. Transport of phosphorus in the soil profile after a 7-year application period was limited to the upper 30 cm in the clay loam and to the upper 60 cm in the sandy loam. At a depth of about 1 meter no difference in phosphorus concentration in the soil moisture was found between control plots and waste water disposal areas.

The main changes in chemical composition of the soils involved are:

- increase in extractable phosphorus in the top soil layer;
- increase in exchangeable sodium to about 1.5 meters;
- increase in exchangeable magnesium to the same depth.

A small increase in exchangeable manganese, and a relatively large increase in chloride as extracted by ammonium-nitrate.

Special attention is given now to the possibilities of using the same application system for disposal of the generated sewage sludge. This can be done by diluting the digested sludge with the treatment effluent. Safe operation of the sprinkling system as far as application is concerned may be maintained at a dilution of a factor 10. When feasible this could considerably decrease total cost of sewage water treatment. Effects of heavy metals present in the sludge on groundwater composition, soil and plant composition are presently under study.

10. Miscellaneous

The items described in the foregoing sections are necessarily a sample only of all research work in the field of environmental studies that is being conducted at the host institutions. A good overall impression about the way of approach in this research, the goals scored and the difficulties met, was obtained in the numerous discussions and interviews that were held during the authors stay.

The author presented seminars, varying in number from one to four, at each visited institute on several soil pollution problems in The Netherlands. The titles of these seminars were:

- 1: Phosphate removal by soil from domestic waste water.
- 2: Utilization of potato starch processing waste water.
- 3: Interactions of anions with soil colloids.
- 4: Heavy metal pollution of specific Dutch soils.

The author wants to express his sincere thanks to all persons who contributed in making this visit the invaluable experience it has been.

11. Itinerary

- May 3 - May 10: Department of Agronomy, Cornell University, Ithaca, New York.
- May 11 - May 17: Agricultural Environmental Quality Institute, Agricultural Research Center, Beltsville, Maryland.
- May 18 - May 24: Department of Agronomy, University of Illinois, Champaign-Urbana, Illinois.
- May 25 - May 31: Department of Soil Science, University of Wisconsin, Madison, Wisconsin.
- June 1 - June 7: Robert S. Kerr Water Research Center, Ada, Oklahoma
- June 8 - June 14: United States Water Conservation Laboratory, Phoenix, Arizona.
- June 15- June 21: Southeast Environmental Research Laboratory, Athens, Georgia
- June 22- June 28: Department of Agronomy, Penn. State University, University Park, Pennsylvania.
- June 29-August 1: Department of Agronomy, Cornell University, Ithaca, New York.