FINAL REPORT

of the

SEWAGE SLUDGE MANAGEMENT COMMISSION

January, 1983

Prepared by
Research Division
Maryland Department of Legislative Reference
90 State Circle
Annapolis, Maryland 21401

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HOUSE OF DELEGATES

ANNAPOLIS, MARYLAND 21401-1991

January 10, 1983

TORREY C. BROWN, M.D.
39TH LEGISLATIVE DISTRICT
BALTIMORE CITY
CHAIRMAN
ENVIRONMENTAL MATTERS COMMITTEE
841-3536

HOME ADDRESS:
3941 CANTERBURY ROAD
BALTIMORE, MARYLAND 21218

Honorable Harry Hughes
Governor
State House
Annapolis, Maryland 21401

Dear Governor Hughes:

The Sewage Sludge Management Commission held its final meeting on December 29, 1982. Two model pieces of legislation were drafted:

(1) "The Maryland Sewage Sludge Resource Recovery Act", and

(2) "The Sewage Sludge Management Advisory Commission".

The first bill establishes the technical, managerial, and legal framework for the management of sludge as a resource in Maryland. The second bill calls for the establishment of an on-going commission to advise DHMH, state and local agencies, and citizens on the proper management and utilization of sewage sludge state-wide.

With respect to this second bill, the Commission indicated that it wishes to be re-constituted in its present form and membership. Additionally, the Commission is also requesting that it be allowed to meet on an ad hoc basis until its formal establishment on July 1, 1983.

The Commission final report, which includes the proposed legislation, outlines of regulation and administration of a Maryland Sludge Management Program and Fund, and representative technical materials from its hearings, is in preparation. Staff informs me that these should be enroute to you by the close of this week.

I want to express my appreciation to you for the support and interest you have given this Commission and me as Chairman.

Best wishes.

Sincerely,

Torrey C. Brown, M.D.

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IV. APPENDICES: REPRESENTATIVE* MATERIALS FROM COMMISSION WORKBOOKS

*Complete copies of workbooks, including meeting minutes, are on file in the Research Division of the Department of Legislative Reference.

I. INTRODUCTION

A. Commission Charge

The Sewage Sludge Management Commission was created by the Governor pursuant to Joint Resolution 25 (H.J.R. 64) of the 1982 Session. Its charge was:

"To study sewage sludge utilization and disposal options and environmental impacts of these options in Maryland."

B. Members of the Commission were:

The Hon. Torrey C. Brown, Chairman	House of Delegates Speaker's Appointee
Clinton R. Albrecht Chief, Engineering Services Department of Natural Resources	Secretary of Natural Resources Appointee
Hugh E. Binks, D.V.M. Deputy Secretary of Agriculture	Secretary of Agriculture Appointee
Robert T. Brown	Watermen's Association Representative
Lucien M. Brush, Jr., Ph.D.	Johns Hopkins University Environmental Engineering Department Representative
Penny S. Davis Chief of the Office of Technical Services Department of Economic and Community Development	Secretary, Department of Economic and Community Development Appointee
The Hon. Dennis C. Donaldson	House of Delegates, Speaker's Appointee
The Hon. Arthur Dorman	Maryland Senate, President of Senate's Appointee
Turner A. Duncan	Sewage Sludge Utilization Industry Representative
Max Eisenberg, Ph.D. Director, Science and Health Advisory Group Department of Health and Mental Hygiene	Secretary of Health and Mental Hygiene Appointee

Laurence S. Fogelson Chief of Natural Resources Department of State Planning	Secretary of State Planning Appointee
James E. Gutman	State Water Quality Committee Representative
The Hon. David B. Hartlove, Jr. Prince George's County Councilman	Maryland Association of Counties Representative
Marjorie Hill	Private Citizen
The Hon. Francis X. Kelly	Maryland Senate, President of Senate's Appointee
Douglas A. MacFarlane	Sewage Sludge Utilization Industry Representative
Robert S. McGarry, General Manager WSSC	Sewage Sludge Generators Representative
Wayne McGinnis	Maryland Farming Representative
James R. Miller, Ph.D.	University of Maryland, Agronomy Department Representative
The Hon. Clayton Mitchell, Jr.	House of Delegates, Speaker's Appointee
Steven P. Quarles, Esq.	Private Citizen
Mary M. Rosso	Private Citizen
The Hon. Norman R. Stone, Jr.	Maryland Senate, President of Senate's Appointee
Hugh B. Trimble, III	Private Citizen
Jerold D. Wingeart	Maryland Municipal League Representative
Rufus Chaney, Ph.D.	U.S.D.A. Consultant
Myron H. Miller, Ph.D.	Staff
Robert H. Forste, Ph.D.	Staff
Joseph Bernstein	Staff Counsel
Priscilla K. Sanger	Staff

C. Synopsis of Hearings

The Commission's seven meetings included a site visit and a day-long work session. In the course of five hearings, the Commission received testimony representing a wide range of interests, including:

(1) Agronomists (State, Federal, Regional and Academic);

(2) Citizens Groups;

(3) City, County and Regional Sludge Generators (Wastewater Plant Operators);

(4) Commercial Sewage Sludge Applicators;

(5) Environmental Groups;

(6) Farmers;

(7) Land Use Planners:

(8) Maryland Department of Health;

(9) Other State's Sludge Program Managers;

(10) Other Management Technical Processes (Composting, Incineration);

(11) Watermen; and

(12) Water Quality Planners.

Testimony was augmented by written materials compiled by the staff.

Consideration focused primarily on landspreading of sludges from sewage treatment plants. The rationale for this was twofold:

(1) Alternate methods for sludge handling, such as incineration, composting and landfilling, were believed to be already adequately addressed by law and regulation and these techniques are familiar to regulators and practitioners;

(2) Traditional sewage sludge options have become prohibitively expensive, and questionable on environmental grounds.

Conversely, escalation in the costs of traditional (petroleum-based) fertilizers has heightened agricultural interest in alternative fertilizers/conditioners such as treated sewage sludge.

Pertinent aspects of sludge landspreading considered by the Commission included:

I. Sludge Landspreading Practice

A. Contaminant Concentrations

1. Limits for Farmlands
2. Definition of Farmland
3. Tie-in with Pretreatment
4. Includes Septage?

B. Heavy Metal Loading Rates

1. Whose Tech. Guidelines?
   i) For metals
   ii) For N, P/Cropping
2. Via Regs. or Legislation
3. Treatment
   i) Heat
   ii) Lime
   iii) Composting
   iv) Digestion
4. Soil pH
5. Cation Exchange Capacity
6. Topo- & Hydrographical
   i) Grade
   ii) Water Tables
   iii) Percolation Rates
   iv) Water courses

C. Monitoring

1. Methods/Frequencies
2. Lab. Qualification
3. State Facilities

D. Hearings (Site-Specific)

1. Mandatory/Discretionary?
2. Batched?
3. Advertising/Lead-Times
4. Standing (Judicial)

E. Related Topics

1. Time-of-year Application
2. On-site Storage
3. Property Set-Backs
4. Storm Run-Off Courses
5. Potable Aquifer Avoidance
6. Haul Routes
7. Spreading Gear Approval
8. Hauling Gear Approval
9. Applicator Qualification
10. Spill Cleanup (Hauler)
11. Odor
12. Permit Durations
13. Contamination Avoidance
    i) Forage
    ii) Vegetables

II. Management of Sewage Sludge

A. Advisory Commission

1. Make-Up
2. Appointing Authority
3. Charge

B. Other Advisory Bodies

1. U. of Md.
2. Md. Dept. of Agriculture
3. DNR
4. State Planning

C. Oversight/Pre-emption

1. Md. Dept. of Ag.
2. Soil Conserv. Districts
3. Local Zoning/Ordinances

D. Recordance

1. By DHMH
2. Property Records?

E. Liaison

1. Water/Wastewater Regional Plans
2. MES
3. Adjoining States

F. Planning (Generators/Treaters)

1. Regional vs. Local
2. Public Participation
3. Planning Horizons
4. Costs/Benefits of Alternatives
5. Advertising of Hearings
6. Criteria for Decisions
7. Application Lead-Times

G. Education/Outreach

1. Of generators
2. Of applicators
3. Field Research

H. Contingency Actions

1. Emergency Response
2. Stop-Work Powers
3. Penalties

III. Financial Issues

A. Public Costs

1. Fee amount
2. Method of Levy
3. Equity Issues

B. Risk Coverage

1. Bonding (Performance)
2. Liability
   i) Type/Term
   ii) Availability

II. COMMISSION FINDINGS AND RECOMMENDATIONS

The Commission's main findings and recommendations are listed below. They form the basis for two proposed bills: "The Maryland Sewage Sludge Resource Recovery Act", and "The Sewage Sludge Management Advisory Commission", which are provided in section III of this report. Commission suggestions and concerns have also been factored into "Procedural Aspects of Sludge Utilization on Land" and "Proposed Sludge Management Program". These latter, prepared by DHMH, also appear in this report's third section. The Commission regards these documents as providing a framework for an orderly, reliable, responsive and cost-effective sludge management program.

Findings and recommendations of the Commission are here grouped by category. The order of appearance in the listing is not intended to indicate priorities.

A. Overview

(1) Properly landspread sewage sludge can be an inexpensive source of fertilizer and an effective water retention conditioner. Improperly landspread sludge can be a source of public apprehension, a nuisance and an environmental or health problem. Instances of proper and improper sludge landspreading have occurred in the State.

(2) The multiplicity of technical factors and institutional considerations tend to complicate the governance of sludge landspreading. For instance, several metals occurring in sewage sludge can, if applied in excess, reduce the productivity of farmlands. Hence sludge composition and annual spreading rates as well as spreading uniformity must be controlled. Soil pH and cation exchange capacity determine, in part, how much cumulative metal loading is non-detrimental. If sludge is spread at rates whereby added nitrogen exceeds the annual uptake by crops, then there is potential for seepage into groundwaters (depending on soil percolation rates and water table heights.) Heavy sludge applications or applications to areas subject to runoff (depending on grade, cover, erosion control) can cause degredation of surface waters. Nuisance avoidance involves adequate treatment of sludges, proper design of hauling and spreading equipment, set-backs from traffic arteries and populated tracts, choice of haul routes, attention to weather conditions and mishap response planning.

(3) Each method of dealing with sewage sludge has particular risks and benefits. No method is risk free and no single method will be optimal for all situations. Each sewage treatment plant should retain the flexibility to use the mix of management options (e.g., landspreading, composting, incineration, landfilling) it deems most appropriate. A statewide sludge management program will assist sludge generators in assessing their options on a long range and continuing basis. This is important because the comparative costs and availabilities of alternative management options shift with time, but the amount of sludge will increase as wastewater treatment plants further improve the quality of their effluents.

(4) The Commission recommended that, other things being equal, the State should encourage sludge management methods which yield a useful end product (such as crop fertilization). The Commission explicitly opposed ocean dumping of sludge: this option was deemed undesirable because of its potential impact on the marine environment and because mishaps enroute might pollute the State's tidal waters.

(5) Sound regulations are necessary but not sufficient for ready and reliable sludge management on a continuing basis. Planning, training, adequate staffing and a well-defined, predictable process are also needed -- to avoid a "crisis management" approach or uneven enforcement. In small, relatively densely populated states such as Maryland, there tends to be less margin for managerial lapses than in large, predominently agricultural, states.

(6) Sludge can be managed, but it cannot be "disposed of" in the sense that the elements comprising it persist. Incineration, for example, results in emissions which may affect air quality and leaves an ash residue rich in heavy metals that must be contained.

(7) The Commission strongly advised wastewater treatment plants to continue monitoring their input streams for heavy metal contributors and to work expeditiously with industries to effect pretreatment for removal of heavy metals.

B. Technical

(1) Professional agronomists agree on what metal concentrations render sewage sludge unsuitable for spreading on agricultural lands (please see Appendices).

(2) Professional agronomists agree that it is good form and environmental practice to landspread sludge at annual rates for which available nitrogen loadings do not exceed the (particular) crop's nitrogen uptake.

(3) There is expert consensus that in the day-to-day management of sewage sludge landspreading, issues involving public health will be much less frequent than issues related to the long term productivity of farmlands. That is, as long as sewage sludge is not used on market vegetable crops or on lands not immediately grazed by livestock, risks from pathogen ingestion or vectoring appear to be nil. With application at rates which satisfy crop nitrogen requirements and proper spreading practices, pollution of water supplies should not be troublesome. Occasionally organic chemicals do get into sewage sludges, but to date this has been a transient, isolated problem and treatment plant managers have diverted their sludge flows accordingly. Adverse metal uptakes by livestock (from sludge-grown forage) or by people (from vegetables grown at least 3 years after sludge application as per existing State regulation) is safeguarded against (even if over-spreading has occurred in the past) because most plants die before their tissues can accumulate harmful metal concentrations.

(4) There is considerable disagreement between agronomy experts regarding what cumulative loading rates, per metal, reduce farmland productivity. Federal agencies (USDA, FDA, EPA) do have a consistent set of metal loading guidelines, but some state, university and regional agronomy groups differ substantially amongst each other (please see appended tables). Some of these discordances have been ascribed to differences in soil types and crops tested, but all the sources of disagreement have not been identified.

(5) Land used for tobacco production was characterized as a special case because of that crop's potential for metal uptake, and concern about how metals in tobacco could affect smokers. The majority of agronomists heard from recommended blanket prohibition against spreading sludge on tobacco lands since even the perception of questions about crop quality might deter foreign buyers.

(6) Capabilities of the State Chemist should be employed to help with the analyses of sewage sludge, and sludged soils. Private laboratories should also be given qualification procedures whereby they can also perform such work.

C. Regulatory and Institutional

(1) It is recommended that the Maryland Department of Agriculture be given approval authority over farmland sewage sludge spreading regulations promulgated by the Department of Health and Mental Hygiene.

(2) The public should have ample and early access to administrative hearings. It is recommended that this include licensing hearings where sludge generator's five year plans are considered. In addition to generator licensing, public hearings should be held for permits for marginal land sludge sites and for permanent sites designed primarily for receiving sewage sludge (e.g., composting facilities, "sludge farms") Hearings on such permanent sites should be held prior to construction. All public hearings should be well advertised in newspapers. Routine sewage sludge applications to farmlands were seen as not warranting site-specific hearings.

(3) In licensing and permitting procedures, the Department of Health and Mental Hygiene should give consideration to local zoning ordinances.

(4) Landowner's written approval should be one condition for permitting of sewage sludge spreading on land.

(5) All applications of sewage sludge in Maryland should be recorded in an accessible and permanent way. As a minimum, The Department of Health and Mental Hygiene should keep such records (including the composition of sludges used: Assays should also be available to landowners prior to applications).

(6) Permits for sludge application should contain clear provisions whereby the Department of Health and Mental Hygiene can revoke the permit and stop work in short order if ongoing work is being done improperly.

(7) Based on the State's experience with air quality, hazardous wastes, and other comprehensive management programs, framing and refining of sewage sludge management regulations and practice would benefit from creation of a Sewage Sludge Management Advisory Commission. This is envisioned as advising DHMH primarily but also assisting localities (upon request) in overcoming start-up problems.

(8) Recognizing that firm scheduling is required if farmers are to meet planting schedules, the Commission expressed hope that permit processing time would not be so long as to impede landspreading as a management option in Maryland.

D. Financial and Remedial

(1) To support sewage sludge management, fees should be charged to both sewage sludge generators and to land applicators. Licensing fees for generators should be on a per ton basis (of sludge generated) and assessed annually so as to provide a predictable income stream for management. Applicators should pay fees on a schedule which reflects the site specific costs of administration/inspection/monitoring. These fees, and any fines or penalties levied on the improper utilization of sewage sludge, will be paid into a newly-created State Sewage Sludge Utilization Fund for program management.

(2) Sewage sludge applicators should post performance bonds and carry liability insurance or equivalent security.

(3) The DHMH should develop on ongoing response capability for remedying mishaps in sludge utilization that pose threats to the public health or the environment.

(4) Owners of property adjacent to a sludge application site should be granted standing in judicially contested proceedings, even if damage cannot be concretely documented.

(5) The DHMH is empowered to issue corrective orders, pursue administrative and civil procedures, and levy penalties for violations of the Sewage Sludge Resource Recovery Act. The Act also stipulates civil and criminal fines and imprisonment for violations of DHMH rules, regulations, orders and permits.

BILL NO. 1

MARYLAND SEWAGE SLUDGE RESOURCE RECOVERY ACT

Preamble

WHEREAS, The Sewage Sludge Management Commission was established under Joint Resolution 25 (H.J.R. 64) of the 1982 Session of the General Assembly and accomplished its purpose by conducting numerous meetings and discussions concerning the proper utilization and management of sewage sludge, including hearing from numerous concerned and involved witnesses. From these meetings and discussions, including a site visit to a sewage sludge injection site in Bowie, Maryland, the Commission proposes the following Act; and

WHEREAS, Contamination of sewage sludge renders it unsafe and difficult to manage, and it is the intent of the Sewage Sludge Management Commission that: (1) municipal sewage treatment plants must meet the requirements contained in the federal pretreatment regulations to produce clean and safe recyclable products; and (2) the Commission is opposed to the practice of ocean dumping of sewage sludge; and

WHEREAS, Application of treated sewage sludge to farmland has proven to be a valuable source of agricultural fertilizer and can be cost effective, but these applications must be designed, executed, and monitored to avoid nuisances to localities and possible adverse impact on farmland productivity; and

WHEREAS, Other states, including Virginia and Ohio, have developed programs that insure that management of sewage sludge can be carried out in a way to benefit sewage sludge generators and users at a minimum of inconvenience and disruption to people; and

WHEREAS, The United Stated Department of Agriculture, the United States Environmental Protection Agency, and schools of public health and agronomy in many states have studied the impact of sewage sludge and have found to date no detrimental effects when sewage sludge is utilized in a proper manner; and

WHEREAS, Adequate regulations, guidelines, testing, and personnel are desirable to reduce the possibilities of poor management practices for sewage sludge, which can be a public nuisance and also have long-term adverse impacts on soil and air quality and purity of ground waters and surface waters; and

WHEREAS, An orderly and systematic regional approach is necessary to manage sewage sludge as a statewide concern; and

WHEREAS, The approach of this State towards the management of sewage sludge should be flexible and leave the options open for future developments since: (1) sewage sludge which is properly managed is a resource that should be utilized in a manner consistent with health and environmental protection; and (2) the goal is to manage the generation and use of sewage sludge to maximize its use as a resource; and

WHEREAS, It is desirable to develop a consistent method to assess the risks, comparative costs, and benefits of other methods of sewage sludge management; and

WHEREAS, Selecting between alternative management methods of sewage sludge has long-term fiscal, health, land use, and environmental impacts on this State and its citizens; and

WHEREAS, The State should take an active role in research, testing, public education, uniformity of rules and regulations, and long-term planning concerning the generation and management of sewage sludge; and

WHEREAS, A centralized, efficient sewage sludge management program is needed, and the State will have to manage long-term methods of sewage sludge management that are efficient, environmentally safe, and cost effective; and

WHEREAS, Sewage sludge is produced in an unrelenting and continuing large scale way in this State, and to protect the public health and water quality, the State now must manage the problems associated with the generation and utilization of sewage sludge; and

WHEREAS, In order to match these needs to deal with sewage sludge, the State shall pursue a management program that is rigorous, comprehensive, and readily available; now, therefore,

SECTION 1. BE IT ENACTED BY THE GENERAL ASSEMBLY OF MARYLAND That the Laws of Maryland read as follows:

Article - Health - Environmental

1-101.

(a) In this article the following words have the meanings indicated.

(f) "Person" means an individual, receiver, trustee, guardian, personal representative, fiduciary, or representative of any kind and any partnership, firm, association, corporation, or other entity.

9-210.

/(b)(1) An individual or corporation for commercial purposes and a municipality, county, district, or institution may not engage in collection, handling, burning, storage, or transportation of sewage sludge without a permit from the Secretary.

(2) The Secretary shall adopt appropriate rules and regulations relating to permissible uses and methods of collection, handling, burning, storage and transportation of sewage sludge./

SUBTITLE 14. MARYLAND SEWAGE SLUDGE RESOURCE RECOVERY ACT

9-1401.

(A) IN THIS SUBTITLE THE FOLLOWING WORDS HAVE THE MEANINGS INDICATED.

(B) "GENERATOR'S LICENSE" MEANS A LICENSE ISSUED BY THE DEPARTMENT FOR A SEWAGE SLUDGE GENERATOR.

(C) "PERSON" INCLUDES THE FEDERAL GOVERNMENT, THIS STATE, ANY COUNTY, MUNICIPAL CORPORATION, OR OTHER POLITICAL SUBDIVISION OF THIS STATE OR ANY OTHER STATE OR ANY OF THEIR UNITS.

(D) "SEWAGE SLUDGE" MEANS THE ACCUMULATED SEMILIQUID SUSPENSION OF SETTLED SOLIDS OR DRIED RESIDUE OF THESE SOLIDS THAT IS DEPOSITED FROM SEWAGE IN WASTEWATER TREATMENT PLANT TANKS OR BASINS.

(E) (1) "SEWAGE SLUDGE GENERATOR" MEANS ANY PERSON WHO OWNS OR OPERATES A FACILITY THAT RECEIVES OR PROCESSES WASTE WATER AND PRODUCES OR OTHERWISE GENERATES SEWAGE SLUDGE IN THIS STATE.

(2) "SEWAGE SLUDGE GENERATOR",IN ADDITION, INCLUDES:

(I) THE WASHINGTON SUBURBAN SANITARY COMMISSION; AND

(II) THE MARYLAND ENVIRONMENTAL SERVICE.

(F) "SEWAGE SLUDGE UTILIZATION" MEANS THE COLLECTION, HANDLING, BURNING, STORAGE, TREATMENT, LAND APPLICATION, OR TRANSPORTATION OF SEWAGE SLUDGE.

(G) "SEWAGE SLUDGE UTILIZATION PERMIT" MEANS A PERMIT ISSUED BY THE DEPARTMENT TO A SEWAGE SLUDGE OPERATOR FOR THE COLLECTION, HANDLING, BURNING, STORAGE, LAND APPLICATION, TREATMENT, OR TRANSPORTATION OF SEWAGE SLUDGE.

(H)(1) "SEWAGE SLUDGE UTILIZER" MEANS ANY PERSON WHO COLLECTS, HANDLES, BURNS, STORES, APPLIES TO LAND, TREATS, OR TRANSPORTS SEWAGE SLUDGE IN THIS STATE.

(2) "SEWAGE SLUDGE UTILIZER", IN ADDITION, INCLUDES:

(I) THE WASHINGTON SUBURBAN SANITARY COMMISSION; AND

(II) THE MARYLAND ENVIRONMENTAL SERVICE.

9-1402.

THE PURPOSE OF THIS SUBTITLE IS TO INITIATE A COMPREHENSIVE, EFFICIENT, AND WORKABLE PROGRAM FOR THE REGULATION AND MANAGEMENT OF THE GENERATION AND UTILIZATION OF SEWAGE SLUDGE IN THIS STATE.

9-1403.

(A) THE DEPARTMENT SHALL ADOPT RULES AND REGULATIONS TO CARRY OUT THE PROVISIONS OF THIS SUBTITLE. THE STATE DEPARTMENT OF AGRICULTURE ALSO MUST APPROVE THESE RULES AND REGULATIONS.

(B) IN ADOPTING ANY RULE OR REGULATION, THE SECRETARY SHALL CONSIDER AMONG OTHER THINGS:

(1) ALTERNATIVE UTILIZATION METHODS, INCLUDING LAND APPLICATION;

(2) PATHOGEN CONTROL;

(3) METHODS FOR CALCULATING LOADING RATES FOR LAND APPLICATION;

(4) CROPS TO BE GROWN ON LAND ON WHICH SEWAGE SLUDGE MAY BE UTILIZED;

(5) THE NATURE OF ANY SURROUNDING OR UNDERLYING BODIES OF WATER;

(6) THE CHARACTER OF AN AFFECTED SPECIFIC AREA OR OF NEARBY EXISTING OR PLANNED LAND USES AND TRANSPORT ROUTES AND THEIR PROXIMITY TO ANY SENSITIVE AREA, INCLUDING FLOOD PLAINS, WETLANDS, AND AREAS OF CRITICAL STATE CONCERN;

(7) THE DEFINITIONS OF AT LEAST:

(I) SLUDGE THAT IS UNSUITABLE FOR APPLICATION TO AGRICULTURAL LAND;

(II) AGRICULTURAL LAND; AND

(III) MARGINAL LAND;

(8) ACCEPTABLE LOADING RATES, INCLUDING NITROGEN AND HEAVY METALS;

(9) SPECIAL REQUIREMENTS OF LAND USED FOR TOBACCO PRODUCTION;

(10) ADVERTISING REQUIREMENTS FOR PUBLIC HEARINGS; AND

(11) PERFORMANCE BONDING, LIABILITY INSURANCE, OR OTHER SECURITIES.

(C) THE DEPARTMENT SHALL PUBLISH NOTICE AND OFFER AN OPPORTUNITY TO HOLD A PUBLIC HEARING:

(1) FOR A GENERATOR'S LICENSE;

(2) FOR ANY APPLICATION TO SPREAD SEWAGE SLUDGE ON MARGINAL LAND; AND

(3) BEFORE CONSTRUCTION OF ANY PERMANENT FACILITY THAT IS DESIGNED PRIMARILY TO RECEIVE SEWAGE SLUDGE.

(D) THE SECRETARY SHALL ADOPT A RULE OR REGULATION TO ESTABLISH A MECHANISM FOR DETERMINING A GENERATOR'S LICENSE FEE AND A UTILIZER'S PERMIT FEE, WHICH INCLUDES PUBLIC INPUT INTO THE DEVELOPMENT OF FEE SCHEDULES.

9-1404.

(A) THERE IS A STATE SEWAGE SLUDGE UTILIZATION FUND.

(B) ALL GENERATOR LICENSE FEES, UTILIZER PERMIT FEES, AND FUNDS COLLECTED BY THE DEPARTMENT UNDER THIS SUBTITLE, INCLUDING ANY CIVIL OR ADMINISTRATIVE PENALTY OR ANY FINE IMPOSED BY A COURT UNDER THE PROVISIONS OF THIS SUBTITLE, SHALL BE PAID INTO THE STATE SEWAGE SLUDGE UTILIZATION FUND.

(C) THE DEPARTMENT SHALL USE THE STATE SEWAGE SLUDGE UTILIZATION FUND FOR:

(1) EMERGENCY REMOVAL OF SEWAGE SLUDGE OR MITIGATION OF THE EFFECT OF ANY SEWAGE SLUDGE UTILIZATION THAT THE DEPARTMENT DETERMINES:

(I) ENDANGERS THE PUBLIC HEALTH, SAFETY, OR WELFARE; OR

(II) ENDANGERS OR DAMAGES NATURAL RESOURCES; AND

(2) ACTIVITIES THAT ARE RELATED TO IDENTIFYING, MONITORING, AND REGULATING THE PROPER UTILIZATION OF SEWAGE SLUDGE, INCLUDING PROGRAM DEVELOPMENT OF THESE ACTIVITIES.

(D) ALL EXPENDITURES FROM THE STATE SEWAGE SLUDGE UTILIZATION FUND MADE BY THE DEPARTMENT UNDER SUBSECTION (C)(1) OF THIS SECTION SHALL BE REIMBURSED TO THE DEPARTMENT FOR THE STATE SEWAGE UTILIZATION FUND BY A SEWAGE SLUDGE UTILIZER WHO:

(1) ENDANGERS THE PUBLIC HEALTH, SAFETY, OR WELFARE; OR

(2) ENDANGERS OR DAMAGES NATURAL RESOURCES.

(E) IN ADDITION TO ANY OTHER LEGAL ACTION AUTHORIZED BY THIS SUBTITLE, THE ATTORNEY GENERAL MAY BRING AN ACTION TO RECOVER COSTS FROM ANY PERSON WHO FAILS TO MAKE A REIMBURSEMENT AS REQUIRED UNDER SUBSECTION (D) OF THIS SECTION.

9-1405.

A PERSON MAY NOT GENERATE OR ENGAGE IN SEWAGE SLUDGE UTILIZATION IN THIS STATE EXCEPT IN ACCORDANCE WITH THE PROVISIONS OF THIS SUBTITLE.

9-1406.

(A) A PERSON SHALL HOLD A SEWAGE SLUDGE GENERATOR'S LICENSE BEFORE THE PERSON MAY PRODUCE OR OTHERWISE GENERATE SEWAGE SLUDGE IN THIS STATE.

(B) TO APPLY FOR A SEWAGE SLUDGE GENERATOR'S LICENSE, AN APPLICANT SHALL SUBMIT AN APPLICATION TO THE DEPARTMENT ON THE FORM THAT THE DEPARTMENT REQUIRES.

(C) AS A CONDITION OF THE ISSUANCE OR RENEWAL OF A SEWAGE SLUDGE GENERATOR'S LICENSE, THE DEPARTMENT SHALL REQUIRE AN APPLICANT:

(1) TO SUBMIT TO THE DEPARTMENT A PLAN FOR SEWAGE SLUDGE UTILIZATION FOR THE TIME PERIOD THE DEPARTMENT REQUIRES; AND

(2) TO PAY THE FEE ASSESSED UNDER §9-1407 OF THIS SECTION.

(D) UNLESS IT IS RENEWED FOR ANOTHER TERM, A SEWAGE SLUDGE GENERATOR'S LICENSE EXPIRES FIVE YEARS AFTER ISSUANCE OR RENEWAL.

(E) IF AN APPLICANT COMPLIES WITH ALL OF THE PROVISIONS OF THIS SUBTITLE, THE DEPARTMENT MAY RENEW A GENERATOR'S LICENSE.

(F)(1) BEFORE THE DEPARTMENT ISSUES OR RENEWS A GENERATOR'S LICENSE, THE DEPARTMENT SHALL GIVE NOTICE OF THE APPLICATION AND PROVIDE OPPORTUNITY FOR A PUBLIC HEARING ON THE PLAN FOR SEWAGE SLUDGE UTILIZATION IN THE COUNTY IN WHICH THE SEWAGE SLUDGE IS PRODUCED OR OTHERWISE GENERATED.

(2) FOR SEWAGE SLUDGE PROCESSED BY THE WASHINGTON SUBURBAN SANITARY COMMISSION, HEARINGS SHALL BE HELD IN BOTH PRINCE GEORGE'S COUNTY AND MONTGOMERY COUNTY.

(3) THE DEPARTMENT MAY HOLD ADDITIONAL HEARINGS ON A PLAN FOR SEWAGE SLUDGE UTILIZATION AT ANY TIME OR LOCATION THAT THE DEPARTMENT DETERMINES.

(G)(1) ON JULY 1, 1983, A SEWAGE SLUDGE GENERATOR'S LICENSE THAT IS EFFECTIVE FOR A PERIOD OF 2 YEARS SHALL AUTOMATICALLY BE ISSUED TO A SEWAGE SLUDGE GENERATOR WHO QUALIFIES AND OPERATES AS A SEWAGE SLUDGE GENERATOR.

(2) THE SEWAGE SLUDGE GENERATOR WHO IS LICENSED UNDER THIS SUBSECTION SHALL PAY A FEE AND SUBMIT A SEWAGE SLUDGE MANAGEMENT PLAN TO THE DEPARTMENT ACCORDING TO THE RULES AND REGULATIONS ADOPTED BY THE DEPARTMENT.

9-1407.

THE DEPARTMENT SHALL SET AN ANNUAL GENERATOR FEE FOR EACH SEWAGE SLUDGE GENERATOR, TAKING INTO ACCOUNT:

(A) THE AMOUNT OF SEWAGE SLUDGE PRODUCED OR OTHERWISE GENERATED BY THE SEWAGE SLUDGE GENERATOR;

(B) THE METHOD OF UTILIZATION;

(C) THE ANTICIPATED COSTS OF MONITORING AND REGULATING THE UTILIZATION SITES;

(D) THE ANTICIPATED NEEDS OF THE PROGRAM; AND

(E) THE POTENTIAL HAZARD TO THE PUBLIC HEALTH, SAFETY, OR WELFARE OR TO THE ENVIRONMENT.

9-1408.

(A) A PERSON SHALL HOLD A SEWAGE SLUDGE UTILIZATION PERMIT BEFORE THE PERSON MAY UTILIZE SEWAGE SLUDGE IN THIS STATE.

(B) A SEPARATE SEWAGE SLUDGE UTILIZATION PERMIT IS REQUIRED FOR EACH SITE WHERE THE SEWAGE SLUDGE UTILIZER UTILIZES SEWAGE SLUDGE.

(C) TO APPLY FOR A SEWAGE SLUDGE UTILIZATION PERMIT, AN APPLICANT SHALL SUBMIT AN APPLICATION TO THE DEPARTMENT ON A FORM THAT THE DEPARTMENT REQUIRES,

(D) AS A PREREQUISITE TO THE ISSUANCE OF A SEWAGE SLUDGE UTILIZATION PERMIT, THE DEPARTMENT SHALL REQUIRE AN APPLICANT:

(1) TO FILE WITH THE DEPARTMENT ACCEPTABLE EVIDENCE OF A BOND OR OTHER SECURITY THAT THE DEPARTMENT REQUIRES UNDER SUBSECTION (G) OF THIS SECTION;

(2) TO OBTAIN THE WRITTEN CONSENT OF THE LANDOWNER WHERE THE SEWAGE SLUDGE WILL BE APPLIED; AND

(3) TO AGREE TO PERMIT ACCESS TO THE SEWAGE SLUDGE UTILIZATION SITE FOR THE PURPOSES OF ANY INSPECTION PERMITTED UNDER THIS SUBTITLE.

(E)(1) UNLESS IT IS RENEWED FOR ANOTHER TERM, A SEWAGE SLUDGE UTILIZATION PERMIT EXPIRES ON THE EXPIRATION DATE THE DEPARTMENT SPECIFIES AT ISSUANCE OR RENEWAL.

(2) THE DEPARTMENT MAY RENEW A SEWAGE SLUDGE UTILIZATION PERMIT IF THE PERMIT HOLDER:

(I) IS IN COMPLIANCE WITH ALL APPROPRIATE RULES AND REGULATIONS OF THE DEPARTMENT; AND

(II) SUBMITS TO THE DEPARTMENT A RENEWAL APPLICATION ON THE FORM THAT THE DEPARTMENT REQUIRES.

(F) THE DEPARTMENT SHALL DENY AN APPLICATION FOR A SEWAGE SLUDGE UTILIZATION PERMIT IF THE DEPARTMENT FINDS THAT THE SEWAGE SLUDGE UTILIZER CANNOT UTILIZE SEWAGE SLUDGE WITHOUT IMPOSING AN UNDUE RISK TO THE ENVIRONMENT OR THE PUBLIC HEALTH, SAFETY, OR WELFARE.

(G) AS A REQUIREMENT FOR KEEPING THE SEWAGE SLUDGE UTILIZATION PERMIT, THE SEWAGE SLUDGE UTILIZER SHALL:

(1) MAINTAIN A BOND OR OTHER SECURITY THAT THE DEPARTMENT CONSIDERS SUFFICIENT TO COVER ANY COST THAT GUARANTEES THE FULFILLMENT OF ANY REQUIREMENT RELATED TO THE SEWAGE SLUDGE UTILIZATION PERMIT; AND

(2) COMPLY WITH ANY OTHER REQUIREMENT THAT THE DEPARTMENT SETS.

(H) IN ISSUING OR RENEWING A SEWAGE SLUDGE UTILIZATION PERMIT, THE DEPARTMENT SHALL CONSIDER LOCAL ZONING REQUIREMENTS.

9-1409.

THE DEPARTMENT SHALL MAINTAIN A PERMANENT PUBLIC RECORD OF ALL SEWAGE SLUDGE UTILIZATION PERMITS ISSUED UNDER THIS SUBTITLE.

9-1410.

(A) TO ENFORCE THIS SUBTITLE, A REPRESENTATIVE OF THE SECRETARY, AT ANY REASONABLE TIME, MAY ENTER AND INSPECT ANY SITE WHERE SEWAGE SLUDGE IS UTILIZED.

(B) A SEWAGE SLUDGE UTILIZER MAY NOT:

(1) REFUSE TO GRANT ACCESS TO ANY REPRESENTATIVE OF THE SECRETARY WHO REQUESTS TO ENTER A SEWAGE SLUDGE UTILIZATION SITE UNDER THIS SUBTITLE; OR

(2) INTERFERE WITH ANY INSPECTION UNDER THIS SUBTITLE.

(C)(1) THE HEALTH OFFICER FOR ANY COUNTY MAY INSPECT AND INVESTIGATE A SITE WHERE A SEWAGE SLUDGE UTILIZER UTILIZES SEWAGE SLUDGE.

(2) BEFORE MAKING AN INSPECTION UNDER THIS SECTION, THE HEALTH OFFICER SHALL NOTIFY THE DEPARTMENT OF THE PLANNED INSPECTION.

(3) ON THE NEXT BUSINESS DAY AFTER AN INSPECTION, THE HEALTH OFFICER SHALL REPORT, IN WRITING, TO THE DEPARTMENT:

(I) THE NAME OF THE DEPARTMENT OFFICIAL WHO WAS NOTIFIED BEFORE THE INSPECTION;

(II) THE TIME AND PLACE OF THE INSPECTION;

(III) A SUMMARY AND FINDINGS OF THE INSPECTION; AND

(IV) RECOMMENDATIONS FOR ENFORCEMENT AND OTHER RECOMMENDATIONS.

9-1411.

IN ACCORDANCE WITH THE ADMINISTRATIVE PROCEDURE ACT, THE DEPARTMENT MAY SUSPEND, REVOKE, OR MODIFY A GENERATOR'S LICENSE OR A SEWAGE SLUDGE UTILIZATION PERMIT IF THE DEPARTMENT FINDS THAT:

(A) FALSE OR INACCURATE INFORMATION WAS CONTAINED IN THE APPLICATION;

(B) THERE IS OR HAS BEEN A VIOLATION OF THIS SUBTITLE OR ANY RULE, REGULATION, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE;

(C) SUBSTANTIAL DEVIATIONS FROM PLANS, SPECIFICATIONS, OR REQUIREMENTS HAS OCCURRED;

(D) ANY REPRESENTATIVE OF THE DEPARTMENT HAS BEEN REFUSED ENTRY TO THE PREMISES FOR THE PURPOSE OF INSPECTING TO INSURE COMPLIANCE WITH THE CONDITIONS OF THE SEWAGE SLUDGE UTILIZATION PERMIT; OR

(E) ANY OTHER GOOD CAUSE EXISTS FOR SUSPENDING, REVOKING, OR MODIFYING THE LICENSE OR PERMIT.

9-1412.

ANY PERSON WHO OWNS LAND THAT ADJOINS PROPERTY FOR WHICH AN APPLICATION TO APPLY SLUDGE HAS BEEN FILED OR FOR WHICH A PERMIT HAS BEEN GRANTED HAS STANDING AS A MATTER OF RIGHT AND WITHOUT THE NECESSITY OF SHOWING ANY SPECIAL DAMAGE:

(1) TO SUE THE STATE, APPLICANT, OR PERMITTEE IN LAW OR EQUITY TO REQUIRE COMPLIANCE WITH THE PROVISIONS OF THIS SUBTITLE AND WITH THE PROVISIONS OF ANY PERMIT ISSUED UNDER THIS SUBTITLE;

(2) TO INTERVENE IN ANY COURT PROCEEDING, WHETHER LEGAL OR EQUITABLE, THAT RELATES TO A PERMIT ISSUED UNDER OR TO A REQUIREMENT OF THIS SUBTITLE; AND

(3) TO HAVE STANDING AS AN AGGRIEVED PARTY UNDER THE ADMINISTRATIVE PROCEDURE ACT IN A CONTESTED CASE THAT INVOLVES ANY PERMIT ISSUED UNDER OR ANY MATTER RELATING TO THIS SUBTITLE.

9-1413.

BY RULE, REGULATION, ORDER, PERMIT, OR OTHERWISE, THE DEPARTMENT MAY REQUIRE THE HOLDER OF A SEWAGE SLUDGE GENERATOR'S LICENSE OR A SEWAGE SLUDGE UTILIZATION PERMIT TO:

(A) KEEP RECORDS;

(B) MAKE REPORTS;

(C) INSTALL, CALIBRATE, USE, AND MAINTAIN MONITORING EQUIPMENT OR METHODS, INCLUDING BIOLOGICAL MONITORING METHODS WHERE APPROPRIATE;

(D) OBTAIN SAMPLES IN ACCORDANCE WITH THE METHODS, AT THE LOCATION, AT THE INTERVALS, AND IN THE MANNER THE DEPARTMENT REQUIRES; AND

(E) PROVIDE TO THE DEPARTMENT ANY INFORMATION THAT THE DEPARTMENT REASONABLY REQUIRES.

9-1414.

(A) THE DEPARTMENT SHALL ISSUE A WRITTEN COMPLAINT IF THE DEPARTMENT HAS REASONABLE GROUNDS TO BELIEVE THAT THE PERSON TO WHOM THE COMPLAINT IS DIRECTED HAS VIOLATED:

(1) ANY PROVISION OF THIS SUBTITLE;

(2) ANY RULE OR REGULATION ADOPTED UNDER THIS SUBTITLE; OR

(3) ANY ORDER OR PERMIT ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE.

(B) A COMPLAINT ISSUED UNDER THIS SECTION SHALL:

(1) SPECIFY THE PROVISION THAT ALLEGEDLY HAS BEEN VIOLATED; AND

(2) STATE THE ALLEGED FACTS THAT CONSTITUTE THE VIOLATION.

9-1415.

(A) AFTER OR CONCURRENTLY WITH SERVICE OF A COMPLAINT UNDER THIS SUBTITLE, THE DEPARTMENT MAY:

(1) ISSUE AN ORDER THAT REQUIRES THE PERSON TO WHOM THE ORDER IS DIRECTED TO TAKE CORRECTIVE ACTION WITHIN A TIME SET IN THE ORDER;

(2) SEND A WRITTEN NOTICE THAT REQUIRES THE PERSON TO WHOM THE NOTICE IS DIRECTED TO FILE A WRITTEN REPORT ABOUT THE ALLEGED VIOLATION; OR

(3) SEND A WRITTEN NOTICE THAT REQUIRES THE PERSON TO WHOM THE NOTICE IS DIRECTED TO:

(I) APPEAR AT A HEARING BEFORE THE DEPARTMENT AT A TIME AND PLACE THE DEPARTMENT SETS TO ANSWER THE CHARGES IN THE COMPLAINT; OR

(II) FILE A WRITTEN REPORT AND ALSO APPEAR AT A HEARING BEFORE THE DEPARTMENT AT A TIME AND PLACE THE DEPARTMENT SETS TO ANSWER THE CHARGES IN THE COMPLAINT.

(B) ANY ORDER ISSUED UNDER THIS SECTION IS EFFECTIVE IMMEDIATELY, ACCORDING TO ITS TERMS, WHEN THE ORDER IS SERVED.

(C) ANY COMPLAINT, ORDER, NOTICE, OR OTHER INSTRUMENT ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE MAY BE SERVED ON THE PERSON TO WHOM IT IS DIRECTED:

(1) PERSONALLY;

(2) BY PUBLICATION; OR

(3) BY REGISTERED MAIL TO THE PERSON'S LAST KNOWN ADDRESS AS SHOWN ON THE DEPARTMENT'S RECORDS.

(D) IF SERVICE IS MADE BY REGISTERED MAIL, THE PERSON WHO MAILS THE DOCUMENT SHALL FILE WITH THE DEPARTMENT VERIFIED PROOF OF THE MAILING.

(E) ANY NOTICE THAT REQUIRES FILING OF A REPORT OR ATTENDANCE AT A HEARING OR BOTH SHALL BE SERVED AT LEAST 10 DAYS BEFORE THE EARLIER OF:

(1) THE TIME SET FOR THE HEARING, IF ANY; OR

(2) THE TIME SET FOR FILING OF THE REPORT, IF ANY.

9-1416.

(A) THE DEPARTMENT SHALL GIVE NOTICE AND HOLD ANY HEARING UNDER THIS SUBTITLE IN ACCORDANCE WITH THE ADMINISTRATIVE PROCEDURE ACT.

(B)(1) WITHIN 10 DAYS AFTER BEING SERVED WITH AN ORDER UNDER §9-1415 (A)(1) OF THIS SUBTITLE, THE PERSON SERVED MAY REQUEST IN WRITING A HEARING BEFORE THE DEPARTMENT.

(2) IF A REQUEST FOR A HEARING IS MADE UNDER THIS SUBSECTION, THE DEPARTMENT SHALL:

(I) HOLD THE HEARING WITHIN 10 DAYS AFTER RECEIVING THE REQUEST; AND

(II) RENDER A DECISION WITHIN 10 DAYS AFTER THE HEARING.

(C) WITHIN 10 DAYS AFTER BEING SERVED WITH A NOTICE UNDER §9-1415 (A)(2) OF THIS SUBTITLE, THE PERSON SERVED MAY REQUEST IN WRITING A HEARING BEFORE THE DEPARTMENT.

(D) THE DEPARTMENT MAY MAKE A VERBATIM RECORD OF THE PROCEEDINGS OF ANY HEARING HELD UNDER THIS SUBTITLE.

(E)(1) IN CONNECTION WITH ANY HEARING UNDER THIS SUBTITLE, THE DEPARTMENT MAY:

(I) ISSUE A SUBPOENA TO ANY PERSON OR FOR THE PRODUCTION OF EVIDENCE; AND

(II) ORDER A WITNESS TO GIVE EVIDENCE.

(2) A SUBPOENAED WITNESS SHALL RECEIVE THE SAME FEES AND MILEAGE REIMBURSEMENT AS IF THE HEARING WERE PART OF A CIVIL ACTION.

(3) IF A PERSON FAILS TO COMPLY WITH A SUBPOENA OR ORDER ISSUED UNDER THIS SUBSECTION, ON PETITION OF THE DEPARTMENT, A CIRCUIT COURT MAY ORDER THE PERSON TO COMPEL:

(I) OBEDIENCE TO THE DEPARTMENT'S ORDER OR SUBPOENA;

(II) TESTIMONY; OR

(III) THE PRODUCTION OF EVIDENCE.

(4) THE CIRCUIT COURT MAY PUNISH UNDER ITS CONTEMPT POWERS ANY FAILURE TO OBEY THE CIRCUIT COURT'S ORDER ISSUED UNDER THIS SECTION.

9-1417.

(A)(1) UNLESS THE PERSON SERVED WITH AN ORDER UNDER §9-1415 (A)(1) OF THIS SUBTITLE MAKES TIMELY REQUEST FOR A HEARING, THE ORDER IS A FINAL ORDER.

(2) IF THE PERSON SERVED WITH AN ORDER UNDER §9-1415 (A)(1) OF THIS SUBTITLE MAKES A TIMELY REQUEST FOR A HEARING, THE ORDER BECOMES A FINAL CORRECTIVE ORDER WHEN THE DEPARTMENT RENDERS ITS DECISION FOLLOWING THE HEARING.

(B)(1) IF THE DEPARTMENT ISSUES A NOTICE UNDER §9-1415 (A)(2) OR (3) OF THIS SUBTITLE, THE DEPARTMENT MAY NOT ISSUE AN ORDER THAT REQUIRES CORRECTIVE ACTION BY THE PERSON TO WHOM THE NOTICE IS DIRECTED UNTIL AFTER THE LATER OF:

(I) THE TIME SET FOR THE HEARING, IF ANY; OR

(II) THE TIME SET FOR FILING OF THE REPORT, IF ANY.

(2) IF THE DEPARTMENT FINDS THAT A VIOLATION OF THIS SUBTITLE HAS OCCURRED AFTER THE TIME IS PASSED WITHIN WHICH THE DEPARTMENT MAY NOT ISSUE A CORRECTIVE ORDER, THE DEPARTMENT SHALL ISSUE AN ORDER THAT REQUIRES CORRECTION OF THE VIOLATION WITHIN A TIME SET IN THE ORDER.

(3) ANY ORDER ISSUED UNDER THIS SUBSECTION IS A FINAL CORRECTIVE ORDER, AND THE PERSON TO WHOM THE ORDER IS DIRECTED IS NOT ENTITLED TO A HEARING BEFORE THE DEPARTMENT AS A RESULT OF THE ORDER.

(C) THE DEPARTMENT SHALL:

(1) TAKE ACTION TO SECURE COMPLIANCE WITH ANY FINAL CORRECTIVE ORDER; AND

(2) IF THE TERMS OF THE FINAL CORRECTIVE ORDER ARE VIOLATED OR IF A VIOLATION IS NOT CORRECTED WITHIN THE TIME SET IN THE ORDER, SUE TO CORRECT THE VIOLATION.

(D) THIS SECTION DOES NOT PREVENT THE DEPARTMENT OR THE ATTORNEY GENERAL FROM TAKING ACTION AGAINST A VIOLATOR BEFORE THE EXPIRATION OF THE TIME LIMITATIONS OR SCHEDULES IN THE ORDER.

9-1418.

(A) THE DEPARTMENT MAY BRING AN ACTION FOR AN INJUNCTION AGAINST ANY PERSON WHO VIOLATES ANY PROVISION OF THIS SUBTITLE OR ANY RULE, REGULATIONS, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE.

(B) IN ANY ACTION FOR AN INJUNCTION UNDER THIS SECTION, ANY FINDING OF THE DEPARTMENT AFTER A HEARING IS PRIMA FACIE EVIDENCE OF EACH FACT THE DEPARTMENT DETERMINES.

(C) ON A SHOWING THAT ANY PERSON IS VIOLATING OR IS ABOUT TO VIOLATE THIS SUBTITLE OR ANY RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE, THE COURT SHALL GRANT AN INJUNCTION WITHOUT REQUIRING A SHOWING OF A LACK OF AN ADEQUATE REMEDY AT LAW.

(D) IF AN EMERGENCY ARISES FROM IMMINENT DANGER TO THE PUBLIC HEALTH, SAFETY, OR WELFARE OR TO THE ENVIRONMENT, THE DEPARTMENT MAY SUE FOR AN IMMEDIATE INJUNCTION TO STOP ANY POLLUTION OR OTHER ACTIVITY THAT IS CAUSING THE DANGER.

9-1419.

(A) ANY PERSON AGGRIEVED BY A FINAL DECISION OF THE DEPARTMENT IN CONNECTION WITH AN ORDER OR PERMIT ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE:

(1) MAY NOT APPEAL TO THE BOARD OF REVIEW; BUT

(2) MAY TAKE A DIRECT JUDICIAL APPEAL.

(B) THE APPEAL SHALL BE MADE AS PROVIDED FOR JUDICIAL REVIEW OF FINAL DECISIONS IN THE ADMINISTRATIVE PROCEDURE ACT.

9-1420.

(A)(1) IN ADDITION TO BEING SUBJECT TO AN INJUNCTIVE ACTION UNDER THIS SUBTITLE, A PERSON WHO VIOLATES ANY PROVISION OF THIS SUBTITLE OR OF ANY RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE IS LIABLE FOR A CIVIL PENALTY NOT EXCEEDING $10,000, TO BE COLLECTED IN A CIVIL ACTION BROUGHT BY THE DEPARTMENT.

(2) EACH DAY A VIOLATION OCCURS IS A SEPARATE VIOLATION UNDER THIS SUBSECTION.

(B)(1) IN ADDITION TO ANY OTHER REMEDIES AVAILABLE AT LAW OR IN EQUITY AND AFTER A HEARING AT WHICH A VIOLATION IS FOUND TO EXIST, THE DEPARTMENT MAY IMPOSE A CIVIL PENALTY FOR VIOLATION OF ANY PROVISION OF THIS SUBTITLE OR ANY RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE.

(2) THE CIVIL PENALTY IMPOSED UNDER THIS SUBSECTION SHALL BE:

(I) UP TO $500 FOR EACH DAY OF VIOLATION, BUT NOT EXCEEDING $10,000 TOTAL; AND

(II) ASSESSED WITH CONSIDERATION GIVEN TO:

1. THE WILLFULNESS OF THE VIOLATION;

2. THE DAMAGE TO, INJURY TO, OR INTERFERENCE WITH THE PUBLIC HEALTH, SAFETY, OR WELFARE OR TO THE ENVIRONMENT OF THIS STATE; AND

3. OTHER RELEVANT FACTORS.

(3) ANY CIVIL PENALTY IMPOSED UNDER THIS SUBSECTION IS PAYABLE TO THIS STATE AND COLLECTIBLE IN ANY MANNER PROVIDED AT LAW FOR THE COLLECTION OF DEBTS.

(4) IF ANY PERSON WHO IS LIABLE FOR A CIVIL PENALTY IMPOSED UNDER THIS SUBSECTION FAILS TO PAY THE CIVIL PENALTY AFTER DEMAND, THE AMOUNT, TOGETHER WITH INTEREST AND ANY COSTS THAT MAY ACCRUE, SHALL BE:

(I) A LIEN IN FAVOR OF THIS STATE ON ANY REAL OR PERSONAL PROPERTY OF THE PERSON; AND

(II) RECORDED IN THE OFFICE OF THE CLERK OF COURT FOR THE COUNTY IN WHICH THE PROPERTY IS LOCATED.

(5) ANY PENALTY COLLECTED UNDER THIS SECTION SHALL BE PLACED IN A SPECIAL FUND TO BE USED FOR PURPOSES OF THIS SUBTITLE.

9-1421.

(A)(1) A PERSON WHO VIOLATES ANY PROVISION OF OR FAILS TO PERFORM ANY DUTY IMPOSED BY A RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE IS GUILTY OF A MISDEMEANOR AND ON CONVICTION IS SUBJECT TO:

(I) FOR A FIRST OFFENSE, A FINE NOT EXCEEDING $25,000 OR IMPRISONMENT NOT EXCEEDING 1 YEAR OR BOTH; OR

(II) IF THE CONVICTION IS FOR A VIOLATION COMMITTED AFTER A FIRST CONVICTION OF THE PERSON UNDER THIS SUBSECTION, A FINE NOT EXCEEDING $50,000 FOR EACH DAY OF VIOLATION OR IMPRISONMENT NOT EXCEEDING 2 YEARS OR BOTH.

(2) IN ADDITION TO ANY CRIMINAL PENALTIES IMPOSED ON A PERSON CONVICTED UNDER THIS SUBSECTION, THE PERSON MAY BE ENJOINED FROM CONTINUING THE VIOLATION.

(3) EACH DAY ON WHICH A VIOLATION OCCURS IS A SEPARATE VIOLATION UNDER THIS SUBSECTION.

(B) A PERSON IS GUILTY OF A MISDEMEANOR AND ON CONVICTION IS SUBJECT TO A FINE NOT EXCEEDING $10,000 OR IMPRISONMENT NOT EXCEEDING 6 MONTHS OR BOTH IF THE PERSON:

(1) KNOWINGLY MAKES ANY FALSE STATEMENT, REPRESENTATION, OR CERTIFICATION IN ANY APPLICATION, RECORD, REPORT, PLAN, OR OTHER DOCUMENT FILED OR REQUIRED TO BE MAINTAINED UNDER THIS SUBTITLE OR ANY RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE; OR

(2) FALSIFIES, TAMPERS WITH, OR KNOWINGLY RENDERS INACCURATE ANY MONITORING DEVICE OR METHOD REQUIRED TO BE MAINTAINED UNDER THIS SUBTITLE OR ANY RULE, REGULATION, ORDER, OR PERMIT ADOPTED OR ISSUED BY THE DEPARTMENT UNDER THIS SUBTITLE.

(C) ANY PENALTY COLLECTED UNDER THIS SECTION SHALL BE PLACED IN A SPECIAL FUND TO BE USED FOR THE PURPOSES OF THIS SUBTITLE.

9-1422.

THE ATTORNEY GENERAL SHALL TAKE CHARGE OF, PROSECUTE, AND DEFEND ON BEHALF OF THIS STATE EVERY CASE ARISING UNDER THE PROVISIONS OF THIS SUBTITLE, INCLUDING THE RECOVERY OF ANY PENALTY.

SECTION 2. AND BE IT FURTHER ENACTED, That within 90 days of the effective date of this Act, the Department of Health and Mental Hygiene shall adopt rules and regulations to implement a timetable for this Act, and the program shall be fully implemented no later than July 1, 1984.

SECTION 3. AND BE IT FURTHER ENACTED, That this Act shall take effect July 1, 1983.

SEWAGE SLUDGE MANAGEMENT ADVISORY COMMISSION

Preamble

WHEREAS, The Sewage Sludge Management Commission was established under Joint Resolution 25 (H.J.R. 64) of the 1982 Session of the General Assembly and accomplished its purpose by conducting numerous meetings and discussions concerning the proper utilization and management of sewage sludge, including hearing from numerous concerned and involved witnesses. From these meetings and discussions, including a site visit to a sewage sludge injection site in Bowie, Maryland, the Commission proposes the following Act; and

WHEREAS, Contamination of sewage renders it unsafe and difficult to manage, and it is the intent of the Sewage Sludge Management Commission that: (1) municipal sewage treatment plants must meet the requirements contained in the federal pretreatment regulations to produce clean and safe recyclable products; and (2) the Commission is opposed to the practice of ocean dumping of sewage sludge; and

WHEREAS, Application of treated sewage sludge to farmland has proven to be a valuable source of agricultural fertilizer and can be cost effective, but these applications must be designed, executed, and monitored to avoid nuisances to localities and possible adverse impact on farmland productivity; and

WHEREAS, Other states, including Virginia and Ohio, have developed programs that insure that management of sewage sludge can be carried out in a way to benefit sewage sludge generators and users at a minimum of inconvenience and disruption to people; and

WHEREAS, The United States Department of Agriculture, the United States Environmental Protection Agency, and schools of public health and agronomy in many states have studied the impact of sewage sludge and have found to date no detrimental effects when sewage sludge is utilized in a proper manner; and

WHEREAS, Adequate regulations, guidelines, testing, and personnel are desirable to reduce the possibilities of poor management practices for sewage sludge, which can be a public nuisance and also have long-term adverse impacts on soil and air quality and purity of ground waters and surface waters; and

WHEREAS, An orderly and systematic regional approach is necessary to manage sewage sludge as a statewide concern; and

WHEREAS, The approach of this State towards the management of sewage sludge should be flexible and leave the options open for future development since: (1) sewage sludge which is properly managed is a resource that should be utilized in a manner consistent with health and environmental protection; and (2) the goal is to manage the generation and use of sewage sludge to maximize its use as a resource; and

WHEREAS, It is desirable to develop a consistent method to assess the risks, comparative costs, and benefits of other methods of sewage sludge management; and

WHEREAS, Selecting between alternate management methods of sewage sludge has long-term fiscal, health, land use, and environmental impacts on this State and its citizens; and

WHEREAS, The State should take an active role in research, testing, public education, uniformity of rules and regulations, and long-term planning concerning the generation and management of sewage sludge; and

WHEREAS, A centralized, efficient sewage sludge management program is needed, and the State will have to manage long-term methods of sewage sludge management that are efficient, environmentally safe, and cost effective; and

WHEREAS, Sewage sludge is produced in an unrelenting and continuing large scale way in this State, and to protect the public health and water quality, the State now must manage the problems associated with the generation and utilization of sewage sludge; and

WHEREAS, In order to match these needs to deal with sewage sludge, the State shall pursue a management program that is rigouous, comprehensive, and readily available; now, therefore,

SECTION 1. BE IT ENACTED BY THE GENERAL ASSEMBLY OF MARYLAND That the Laws of Maryland read as follows:

SUBTITLE 14. SEWAGE SLUDGE MANAGEMENT ADVISORY COMMISSION.

9-1401. IN THE SUBTITLE, "COMMISSION" MEANS THE SEWAGE SLUDGE MANAGEMENT ADVISORY COMMISSION.

9-1402. THERE IS A SEWAGE SLUDGE MANAGEMENT ADVISORY COMMISSION.

9-1403.

(A)(1) THE COMMISSION CONSISTS OF 26 MEMBERS.

(2) OF THE 26 COMMISSION MEMBERS:

(I) 3 SHALL BE MEMBERS OF THE HOUSE OF DELEGATES;

(II) 3 SHALL BE MEMBERS OF THE SENATE OF MARYLAND;

(III) 1 SHALL REPRESENT THE DEPARTMENT OF HEALTH AND MENTAL HYGIENE;

(IV) 2 SHALL REPRESENT THE DEPARTMENT OF NATURAL RESOURCES, ONLY 1 OF WHOM SHALL REPRESENT THE MARYLAND ENVIRONMENTAL SERVICE;

(V) 1 SHALL REPRESENT THE DEPARTMENT OF STATE PLANNING;

(VI) 1 SHALL REPRESENT THE DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT;

(VII) 1 SHALL REPRESENT THE STATE DEPARTMENT OF AGRICULTURE;

(VIII) 1 SHALL REPRESENT THE MARYLAND ASSOCIATION OF COUNTIES;

(IX) 1 SHALL REPRESENT THE MARYLAND MUNICIPAL LEAGUE;

(X) 1 SHALL REPRESENT THE AGRONOMY DEPARTMENT OF THE UNIVERSITY OF MARYLAND;

(XI) 1 SHALL REPRESENT THE ENVIRONMENTAL ENGINEERING DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY;

(XII) 1 SHALL REPRESENT THE STATE WATER QUALITY ADVISORY COUNCIL;

(XIII) 1 SHALL REPRESENT THE FARMING COMMUNITY IN THIS STATE;

(XIV) 1 SHALL REPRESENT SEWAGE SLUDGE GENERATORS IN THIS STATE;

(XV) 1 SHALL REPRESENT THE SEWAGE SLUDGE DISPOSAL INDUSTRY IN THIS STATE;

(XVI) 1 SHALL REPRESENT THE SEWAGE SLUDGE UTILIZATION INDUSTRY IN THIS STATE;

(XVII) 1 SHALL REPRESENT THE MARYLAND WATERMEN'S ASSOCIATION; AND

(XVIII) 4 SHALL BE PRIVATE CITIZENS WHO RESIDE IN DIFFERENT GEOGRAPHICAL AREAS OF THIS STATE.

(3) THE GOVERNOR SHALL APPOINT ALL OF THE MEMBERS, WITH THE EXCEPTION OF THE REPRESENTATIVES OF THE VARIOUS DEPARTMENTS IN THIS STATE WHICH ARE MENTIONED IN PARAGRAPH (2) OF THIS SUBSECTION.

(4) THE SECRETARY OF EACH DEPARTMENT OF THIS STATE WHICH IS REPRESENTED ON THE COMMISSION SHALL APPOINT THE REPRESENTATIVES OF THEIR DEPARTMENTS.

(B) BEFORE TAKING OFFICE, EACH APPOINTEE TO THE COMMISSION SHALL TAKE THE OATH REQUIRED BY ARTICLE I, §9 OF THE STATE CONSTITUTION.

(C)(1) THE TERM OF A MEMBER IS 5 YEARS, EXCEPT AS PROVIDED IN PARAGRAPH (2) OF THIS SUBSECTION.

(2) THE TERMS OF THE MEMBERS ARE STAGGERED ACCORDING TO THE FOLLOWING SCHEDULE:

(I) 9 MEMBERS WHOSE TERMS END IN 1986;

(II) 9 MEMBERS WHOSE TERMS END IN 1987; AND

(III) 8 MEMBERS WHO TERMS END IN 1988.

(3) AT THE END OF A TERM, A MEMBER CONTINUES TO SERVE UNTIL A SUCCESSOR IS APPOINTED AND QUALIFIES.

(4) A MEMBER WHO IS APPOINTED AFTER A TERM HAS BEGUN SERVES ONLY FOR THE REST OF THE TERM AND UNTIL A SUCCESSOR IS APPOINTED AND QUALIFIES.

9-1404.

FROM AMONG ITS MEMBERS, THE COMMISSION SHALL ELECT A CHAIRMAN AND A VICE CHAIRMAN.

9-1405.

THE SECRETARY OF HEALTH AND MENTAL HYGIENE SHALL PROVIDE STAFF SUPPORT TO THE COMMISSION.

9-1406.

(A) THE COMMISSION SHALL DETERMINE THE TIMES AND PLACES OF ITS MEETINGS.

(B) EACH MEMBER OF THE COMMISSION:

(1) MAY NOT RECEIVE COMPENSATION; BUT

(2) IS ENTITLED TO REIMBURSEMENT FOR EXPENSES UNDER THE STANDARD STATE TRAVEL REGULATIONS, AS PROVIDED IN THE STATE BUDGET.

9-1407.

(A) THE COMMISSION IS AN ADVISORY BODY THAT PROVIDES AN OVERVIEW TO THE DEPARTMENT OF HEALTH AND MENTAL HYGIENE AND OTHER CONCERNED STATE AND LOCAL AGENCIES TO ENSURE THAT SEWAGE SLUDGE IS GENERATED, UTILIZED, AND MANAGED IN THIS STATE IN A PROPER MANNER.

(B) THE COMMISSION SHALL HAVE THE FOLLOWING POWERS AND DUTIES:

(1) TO ATTEMPT TO GET A CONSENSUS VIEW OF THEIR MEMBERS;

(2) TO ADVISE THE STATE ON:

(I) PROPER SEWAGE SLUDGE MANAGEMENT PRACTICES;

(II) PRACTICAL DIFFICULTIES THAT RESULT FROM MANAGEMENT OF THIS TITLE; AND

(III) THE RULES AND REGULATIONS THAT THE DEPARTMENT ADOPTS TO MANAGE SEWAGE SLUDGE;

(3) TO MEET REGULARLY AT LEAST 4 TIMES A YEAR;

(4) TO DEVELOP LONG-RANGE PLANS AND MANAGEMENT GOALS CONCERNING SEWAGE SLUDGE;

(5) TO REVIEW AND EVALUATE THE IMPLEMENTATION OF THE RULES AND REGULATIONS OF THE DEPARTMENT CONCERNING SEWAGE SLUDGE TO SEE IF THE RULES AND REGULATIONS ARE ADEQUATE, EFFICIENT, ENVIRONMENTALLY SAFE, AND COST EFFECTIVE;

(6) TO PREPARE AND ISSUE A REPORT ANNUALLY TO THE GOVERNOR AND THE GENERAL ASSEMBLY CONCERNING THE EFFECTIVENESS OF THE DEPARTMENT'S RULES AND REGULATIONS AND THE MANAGEMENT OF SEWAGE SLUDGE AS A RESOURCE;

(7) TO SERVE THE NEEDS OF THE PUBLIC BY OBTAINING AN OVERALL VIEW FROM RURAL AND URBAN CITIZENS AND MUNICIPAL GOVERNMENTS CONCERNING METHODS:

(I) TO RECONCILE RURAL AND URBAN NEEDS AND CONCERNS IN THE MANAGEMENT OF SEWAGE SLUDGE; AND

(II) TO IMPROVE SEWAGE SLUDGE MANAGEMENT IN THIS STATE;

(8) TO TESTIFY AND PRESENT EVIDENCE ADOPTED BY THE COMMISSION AT ANY HEARING CONCERNING SEWAGE SLUDGE; AND

(9) TO HAVE STANDING AS AN AGGRIEVED PARTY UNDER THE ADMINISTRATIVE PROCEDURE ACT IN A CONTESTED CASE CONCERNING:

(I) ANY LICENSE FOR A SEWAGE SLUDGE GENERATOR; AND

(II) ANY LICENSE OR SITE SPECIFIC PERMIT FOR A SEWAGE SLUDGE UTILIZER.

SECTION 2. AND BE IT FURTHER ENACTED, That the Governor and the Secretary of each Department mentioned in this Act are requested to plan for and appoint the members of the Sewage Sludge Management Advisory Commission, according to the schedule provided in HE § 9-1403 of Section 1 of this Act, at their earliest possible convenience.

SECTION 3. AND BE IT FURTHER ENACTED, That this Act shall take effect July 1, 1983.

MARYLAND STATE DEPARTMENT OF HEALTH AND MENTAL HYGIENE

Projects employing sludge utilization on land can, in general, be divided into specific categories, i.e., agronomic utilization, land reclamation, and innovative projects. Loading rates and limitations for these projects shall be developed as outlined below:

I. AGRONOMIC UTILIZATION PROJECTS

In general, loading rates for sewage sludge or sludge materials used in agronomic projects involving production of food chain crops shall be developed using the guidelines and procedures as outlined in the publication entitled Application of Sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide (MCD-35), EPA, March 1978. Cadmium limits shall adhere to the provisions of 40 CFR Part 257.3-5, Application to land used for the production of food chain crops (44 FR 53462, September 13, 1979).

Pathogen Control

All sewage sludges applied to surface soils in Maryland shall first undergo a stabilization process recognized or accepted as sufficient to reduce pathogenic organisms to acceptable levels. Acceptable processes include:

1. Anaerobic digestion;
2. Aerobic digestion;
3. lime stabilization involving the addition of sufficient lime to raise and maintain the pH of the sludge to a level of 12.0 for a period of 2.0 hours; or to a level of 12.5 for a period of 30 minutes;

4. Thermal stabilization; or

5. Composting

6. Air drying

Other sludge stabilization processes may be utilized upon a determination being made by the Department that the process provides sufficient pathogen control. For lands to which sludge has been applied, public access shall be controlled for at least 12 months and grazing by animals whose products are consumed by humans is prohibited for at least 1 month. Crops for direct human consumption must not be grown for a period of three years.

Loading Rates

The allowable loading rates for metals and nitrogen shall be calculated for each project using the procedures and guidelines specified in publication MCD-35 as referenced above.

Nitrogen Rates

The crop nitrogen (N) requirement may be taken from Table I, or obtained as an N fertilizer recommendation from the Cooperative Extension Service or other source accepted by the Department.

Table 1 -- Annual Nitrogen, Phosphorus, and Potassium Utilization by Selected Crops

Crop	Yield	Nitrogen	Phosphorus	Potassium
		Lb. per Acre		
Corn	150 bu.	185	35	178
Corn silage	180 bu.	240	44	199
	32 tons	200	35	203
Soybeans	50 bu.	257+	21	100
	60 bu.	336+	29	120
Grain sorghum	8,000 lb.	250	40	166
Wheat	60 bu.	125	22	91
	80 bu.	186	24	134
Oats	100 bu.	150	24	125
Barley	100 bu.	150	24	125
Alfalfa	8 tons	450+	35	398
Orchard grass	6 tons	300	44	311
Brome grass	5 tons	166	29	211
Tall fescue	3.5 tons	135	29	154
Bluegrass	3 tons	200	24	149

+ Legumes get most of their nitrogen from the air, so additional nitrogen sources are not normally needed.

Other nitrogen rates may be set by the Department upon a showing by the applicant that the increased rate is necessary for a specific crop yield, or due to site-specific conditions, or sludge characteristics and after a determination by the Department that the increased rate poses no undue risk to public health and the environment.

For soils which have received sewage sludge during the previous three year period, the residual N value specified in Table 2 will be utilized.

Table 2 -- Release of Residual Nitrogen During Sludge Decomposition in Soil

Years After Sludge Application	Organic N Content of Sludge, %						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
1	1.0	1.2	1.4	1.7	1.9	2.2	2.4
2	0.9	1.2	1.4	1.6	1.8	2.1	2.3
3	0.9	1.1	1.3	1.5	1.7	2.0	2.2

The sludge loading rate to provide the crop nitrogen is then calculated as follows:

a. Available N in sludge

% Inorganic N (N_i) = (% NH_4-N) + (% NO_3-N)

% Organic N (N_o) = (% total N) - (% inorganic N)

i) Surface applied sludge
Lb available N/ton sludge=(% NH_4-N X 10) + (% NO_3-N X 20) + (% N_o X 4)

ii) Incorporated sludge
Lb available N/ton sludge = (% NH_4-N X 20) + (% NO_3-N X 20) + (%N_o X 4)

b. Residual sludge N in soil

If the soil has received sludge in the past 3 years, calculate residual N from Table 2.

c. Annual application rate

i) Tons sludge/acre = $\frac{\text{crop N requirement - residual N}}{\text{Lb. available N/ton sludge}}$

ii) Tons sludge/acre = $\frac{\text{2 lb. Cd/acre}}{\text{ppm Cd x .002}}$

iii) The lower of the two amounts is applied.

Allowable Metals Loadings

The total cummulative amount of sludge metals allowed to be placed on agricultural land shall not exceed the values specified in Table 3 below:

Table 3 Total Amount of Sludge Metals Allowed on Agricultural Land

Metal	Soil Cation Exchange Capacity (meg/100 g)*		
	0 - 5	5 - 15	> 15
	Maximum Amount of Metal (Lb/Acre)		
Pb	500	1000	2000
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20

* Determined by the pH 7 ammonium acetate procedure.

Once the correct value for the specified metal has been selected from Table 3, the limiting quantity of sludge is calculated for each metal as follows, using the sludge analysis data: (Note: Sludge metals should be expressed on a dry-weight ppm mg/kg basis).

$$\text{Allowable sludge (tons/acres)} = \frac{\text{Metals value from Table 3}}{\text{Metal conc. in sludge (in ppm) x .002}}$$

This value is calculated for each metal of concern, i.e. Pb, Zn, Cu, Ni, and Cd.

Crop Restrictions

Sludge may not be applied to soils intended for the production of tobacco within five years of the date of application of the sludge.

Information Requirements for a Sludge Utilization Permit

An applicant for a sludge utilization permit at agronomic rates shall submit a request on an application form specified by the Department along with the following information:

1. Written permission of the landowner(s).
2. A current analysis of the sludge performed either by the State Chemist or a laboratory acceptable to the Department of Health and Mental Hygiene.
3. Soil analyses results. Samples may be submitted to the University of Maryland Soil Testing Laboratory along with an analysis of the sludge. Instructions and soil cartons are available from the local extension offices or the University of Maryland Soil Testing Laboratory. Soil samples may be submitted to an approved commercial laboratory and must

include an analysis of the pH of the soils and representative cation exchange capacity tests. (The methods used for the analyses must be included with the report.)

4. Type and expected yield of the crop or cover species to be grown.

5. Calculations of lime requirements to maintain a soil pH at a minimum of 6.5 and not to exceed the recommended pH of the crop or cover species to be grown.

6. A site specific map (3 copies) of sufficient scale to include the following: the property boundaries of the site; the exact acreage to be sludged; the location of any streams, springs or seeps in the area; residences or buildings on site or bordering on the site; any roads on the site and the location of any domestic wells on the site. The map should also show the proximity of the site to major roads in the area.

7. Operations plan: type of sludge application equipment; type of seals on sludge transport vehicles; procedures for applying and spreading the sludge; and the procedure for keeping on site records of sludge received and areas sludged.

8. Any other information requested by the Department.

II. LAND RECLAMATION PROJECTS

Land reclamation projects utilizing application of sewage sludge may be authorized by the Department. The projects shall include but are not limited to:

a. Marginal Lands reclamations. In general, marginal lands are those areas where the A soil horizon has been removed as part of an excavation operation, mineral recovery activity, or filling and grading operation. Examples include:

- reclamation of coal strip mine areas;
- reclamation of strip mines for materials other than coal such as sands, clays, gravels, topsoil, rocks or other minerals;

b. Vegetative stabilization of slopes in highway cut and fill operations;

c. Vegetative stabilization of sanitary landfills, CHS landfills, industrial waste disposal sites or similar disposal operations;

d. Vegetative stabilization of fill areas where the soils characteristic do not support vegetative growth.

Loading Rates

The limiting sludge loading rate for land reclamation projects shall be that rate established by the Department, not to exceed the sludge quantity calculated to exceed the limiting allowable metal loading as calculated by the technique specified for Agronomic Utilization Projects.

Information Requirements for Land Reclamation Projects

An applicant for a Sludge Utilization Permit for a land reclamation project shall submit a request on an application form specified by the Department along with the following information:

1. Written permission of landowner(s)
2. A site specified topographic map (3 copies) of a sufficient scale to include the following: the areal extent of the site, the property boundaries, the exact acreage to be sludged, location of all buffer zones, an inventory of any domestic, commercial or municipal wells within a 1/2 mile radius of the site (water level and pumping rate for these wells to be included if available), the location of any streams, springs, and seeps in the area, the location of CEC and pH testings, and the location of all test borings or test pits in the area.
3. Location of slopes greater than 15% (to be indicated on above mentioned map).
4. Representative cation exchange capacity tests (state type of analytical method used) and analysis of the pH of the soils.
5. Representative test borings or test pits on the site (to include a description of the texture of the soils encountered and the depth to the ground water).
6. Recent analysis of the sludge performed either by the State Chemist or a laboratory acceptable to the Department.

7. Loading calculation per acre for sludge proposal.

8. Sediment and Erosion Control Plan (to be reviewed by the local Soil Conservation District for comments).

9. Type of crop or cover species to be grown with a calculation of the amount of seed mixture to be used per acre and the desired yield of the crop.

10. Calculation of the amount of lime required per acre to keep the soil pH at 6.5 or above.

11. A detailed operational plan to include the following: type of equipment, type of seals on sludge transport vehicles, days and hours of operation, procedures for dumping and spreading sludge and for controlling spills, procedure for keeping on-site records of sludge received and areas sludged, and the construction specifications for temporary storage facilities (if necessary.)

12. Future use of the site.

13. Any other information requested by the Department.

Innovative Projects

Innovative project include those operations in which sludge loading rates exceed the levels as would be calculated using the methods previously discussed, or where sludge processing or disposal takes place. Examples of innovative projects include but are not limited to:

1. Sludge composting facilities
2. Sludge landfilling
3. Sludge farming

4. Sludge trenching

5. Sludge incineration

6. Ocean disposal

7. Use of sludge in sear-drum or similar operations.

Loading Rates

Loading rates for innovative projects will be established on a case-by-case basis by the Department based upon the nature of the project and its potential environmental and public health consequences.

Informational Requirements

An applicant for such a sludge utilization permit shall submit a request on an application form specified by the Department. The Department will then specify such site specific information as may be necessary to evaluate the project. Such information may include the following:

1. A site specific topographic map (3 copies) with a minimum scale of 1"=200' and a contour interval of no more than 5', showing the areal extent of the site, the property boundaries, the exact acreage to be sludged and the location of all buffer zones.

2. Adequate test boring logs, at a minimum of three per ten acres; these should be specific as to the soil, sediment and/or rock types encountered, depth of ground water at completion and at 24,48, and 72 hours after completion, depth of auger refusal (if applicable), etc....location of each boring should be accurately mapped.

3. Description of the geology at the site, including a discussion of the geologic formations directly involved, the present and future use of these formations as a ground water source and their relationship to underlying formations, providing cross sections based on the information compiled from borehole data.

4. Hydraulic characteristics of the site, including a hydrologic contour map (superimposed on a topographic map) showing the location of the water table and the direction and rate of ground water flow, a discussion of the infiltration capacity of surface soils and the percolation capacity of subsurface soils and a calculation of a water balance method for the site.

5. Description of soils at the site and soils to be used for cover material, including a discussion of the texture, structure, pH, moisture and bulk density of the soils, results of representative cation exchange capacity tests (including soils to be used in the mixing procedure), and soil grain size analysis of the different soils found on the site.

6. Stream, spring and seep inventory, onsite and nearby (to be shown on the topographic map).

7. An inventory of any domestic, commercial or municipal wells with a 1/2 mile radius of the site, giving data from well driller's logs, such as the depth and altitude of the well, the aquifer to which it was drilled, etc.

8. Specify design dimensions: sludge fill depth, intermediate cover soil thickness, construction specification for temporary storage facilities (if necessary), etc.

9. A detailed operational plan: type of bulking agent to be employed, bulking ratio, equipment requirements, procedures for disposing of sludge and for controlling spills, procedure for keeping on site records of sludge received and areas sludged, days and hours of operation, methods for controlling on site drainage and drainage onto the site from adjoining areas, etc.

10. Final grading, vegetative cover, and future use of the site.

11. Evaluation of the existing ground water and surface water quality.

12. Detailed discussion of the methods to be used for the protection of the ground water, such as leachate control or natural attenuation.

13. Recent analysis of the sludge.

14. A proposed program for monitoring the chemical quality of the ground water and surface waters on the site, including the depth and location of monitoring wells.

15. Written permission of the land owner(s) for the operation to be carried out.

16. Erosion and Sediment control plan to be approved by the local Soil Conservation Service.

17. Procedures to be employed to control odors.

18. Location of the 100-year flood plain (if applicable).

19. Any additional information requested by the Department.

Application Review and Permit Issuance or Denial

Upon receipt of an application and supporting documentation deemed complete by the Department, copies of the information shall be distributed as follows:

- one copy to the County (or Baltimore City) Health Officer
- one copy to the County Director of Environmental Health.

For projects involving inter-county transport of sludge for utilization or disposal, one copy will be forwarded to the Chief Executive Officer or the County Governing body. In each instance the transmittal shall request comments concerning the application, and a deadline for submittal of the comments to the Department. The Department shall notify the parties indicated above of the date and time of the field evaluation and encourage joint inspections of the site, where such a joint

inspection is mutually convenient and does not unduly delay processing of the application. Failure to conduct a joint inspection shall not constitute grounds for denial of the permit or subsequent contesting of its issuance.

Upon satisfactory evaluation of a site and a determination by the Department that the site and the loading rates conforms to the guidelines previously outlined, the Department shall issue a permit with the terms and conditions deemed necessary by the Department to protect public health and the environment, to preserve and where possible enhance agricultural lands, and prevent nuisance conditions. The Department may deny a permit if, after evaluation of the site or the specifics of the proposal, it determines that the project poses an undue risk to public health or the environment, or when the Department determines that the applicant has demonstrated an inability to satisfactorily comply with previously issued permits either in this state or other jurisdictions outside of Maryland.

Permit Conditions

As a condition to issuance of the permit the Department may require an applicant to:

1. Post a performance bond with the Department in the amount of $100 per acre to be released by the Department upon a determination of satisfaction compliance with permit provisions.

2. Demonstrate adequate financial resources to adequately comply with the permit provisions.

3. Demonstrate adequate liability insurance.

4. Perform periodic tests on the soils, sludges, ground and/or surface water in the area.

5. Maintain records of quantities of sludge utilized or disposed, the areas sludged.

6. Periodically report such data and information to the Department.

As a specific condition to issuance of a permit, the permittee shall permit the Secretary, DHMH, or his authorized representatives, upon the presentation of credentials, to enter upon the permittee's premises or where any records are required to be kept under the terms and conditions of this permit, to access and copy, at reasonable times, any records required to be kept under the terms and conditions of this permit, to inspect, at reasonable times, any monitoring equipment or monitoring method required in this permit, to inspect, at reasonable times, any collection, treatment pollution managment, transport vehicles, or discharge facilities required under this permit, and to sample, at reasonable times, any ground or surface waters at the site, any sludges or permitted materials handled at the site, or soils or vegetation on the site, and to obtain any photographic documentation or evidence. Failure to comply with this provision constitutes grounds for revocation of the permit and forfeiture of the performance bond.

Buffer Distances

The Department may establish buffer distances between sludge boundaries and other land uses. The buffer may be adjusted by the Department on a site specific basis after considerations of adjacent land uses, sludge application technique, sludge loading rates, sludge quality, land slope, filter strips and other factors deemed relevant by the Department. As a general rule, the following buffer distances are adopted:

For surface applied sludges

- 100 ft. from occupied dwellings
- 100 ft. from potable wells
- 25 ft. from public roads
- 50 ft. from property lines
- 25 ft. from perennial streams
- 50 ft. from tidal waters or other water bodies.

Proposed Sludge Management Program
MARYLAND STATE DEPARTMENT OF HEALTH AND MENTAL HYGIENE

To properly manage all aspects of sludge utilization and disposal, certain resources are necessary. The following is an elaboration on the minimum program necessary to accomplish this task in a reasonable manner.

Personnel Needs

At present we are processing approximately 125 to 150 applications per year involving transport, utilization or disposal of sewage sludge or sludge materials such as compost. In addition, we have permitted over 800 sites for sludge disposal in the State. To adequately perform evaluations and permit compliance inspections this number of projects the following staff are needed:

2 Geologists (II or III level)
1 Engineer (Civil/Environmental Background)
1 Soils Scientist/Soil Engineer
1 Agronomist
1 Data Management/Computer Programer
1 Typist Clerk (II or III)
1 Supervisor - Section Head
6 Field Inspectors

The professional staff are necessary to evaluate the technical aspects of individual projects including the geologic/hydrogeologic characteristics of the site, sediment and erosion control provisions, technical specifications for storage/transfer facilities, crop management plans and site stabilization and

to evaluate the 201 facilities plans for adequacy regarding sludge utilization and/or disposal. A data specialist is necessary to develop and maintain the computerized records to allow the program to track sites over extended periods and to determine if sites have previously been permitted for sludge disposal. The field inspectors would be distributed as follows: one inspector per region, with 2 inspectors in the regions handling the Baltimore region and the Washington Metropolitan area where the greater number of sites are located.

Support Services

Support facilities and services are needed to properly administer the program. These are outlined as follows:

Laboratory services - to perform periodic sludge analyses, compliance checks, and monitoring activities.

Note: Sludge analyses may be obtained on a contractural basis through the Maryland Department of Agriculture (the State Chemist) who have expressed an interest in performing this service (for a fee). This option should be explored further.

Field evaluation - periodically, a few sites should be assessed in detail to evaluate the effectiveness of the sludge program, guidelines and field monitoring activities. This service could be performed in-house by Support Services Division staff.

Equipment Needs

Equipment needs for the sludge management program are minimal. They include:

7 vehicles - 1 pool vehicle for technical staff to be used in site inspections and field evaluations and 6 vehicles for the field inspectors.

Miscellaneous soils testing equipment and supplies including:

- hand augers
- soils classification manuals
- soils maps
- text books
- furniture
- typewriter
- files

Training

Sufficient funds should be allocated to provide periodic training of professional staff as to developments in sludge management.

Program Costs

The program, as outlined above would require the allocation of additional funds. Program costs are estimated as follows:

A. Personnel

Existing Personnel	Salaries & Wages
1 Sanitarian VII	$27,894
1 Public Health Engineer	29,179
1 Geologist	16, 451
1 Sanitarian V	24,039
Subtotal	$97,563
less turnover @4%	-3,903
Sub-Total - Existing Personnel (4 position)	$93,660

New Personnel	Salaries & Wages
1 Geologist III	$19,713
1 Soil Conservation Engineer III	18,303
1 Agronomist III	18,303
1 Data Processing Programmer Analyst Specialist IV	21,237
1 Typist Clerk III	9,297
3 Sanitarian II @ 14,666	43,998
3 Conservation Associates III @ 11,934	35,802
Subtotal	$166,653
less turnover @4%	-6,786
Subtotal New Personnel - 11 position	$159,867
Total Personnel - 15 position	$253,527

B. Operating Costs

In addition to the new personnel required to sufficiently manage the proposed sludge management program, it is estimated that the program will require the following funds for operation:

Existing Operating Budget FY 1984 Request

Project .603 Sludge Utilization

.03	Communication	$2,140
.04	Travel	548
.07	Motor Vehicle Operation and Maintenance	1,740
.08	Contractural Services	63
.09	Supplies and Materials	125
.13	Fixed Changes	171
	Total	$4,787

PROPOSED SLUDGE MANAGEMENT PROGRAM

INCREASED OPERATING COSTS

Object		Additional Funds Required
.03 Communications		
10 Telephones @ $535 each	$5,350	$5,350
.04 Travel		
3000 miles @ .19/mile	$570	
Meal, lodging, registration	$1,400	
Training - to provide education training and seminar attendance	$3,500	
		$5,470
.07 Motor Vehicle Operation and Maintenance		
Purchase of 7 compact automobiles @ 5,800	$40,600	
Operation and Maintenance		
7 vehicles x.0889/mile x 20,000 mile	$12,446	
Insurance 7 x 140	$ 980	
	$54,026	$54,026

Object		Additional Funds Required
.08 Contractural Services		
Laboratory services	$10,000	
Field evaluation	$10,000	
Contingency funding for corrective or clean up efforts on emergency basis	$100,000	
	$120,000	$120,000
.09 Supplies and Materials		
Office supplies 10 positions x 70/ position	$ 700	
Field supplies and text	$ 2,000	
	$2,700	$2,700
.11 Equipment Additional		
Office equipment		
9 administrative positions @ $917	$8,253	
1 secretarial position @ $1,469	$1,469	
	$9,722	$9,722
TOTAL		$197,268

Fringe Costs:

Additional Fringe Costs will be incurred by the State although not by OEP's budget if 10 new positions are established for this program. These fringe costs are estimated at $49,335 (159,867 net salaries x .3086)

PROPOSED SLUDGE MANAGEMENT PROGRAM

BUDGET SUMMARY

Existing Program:	
Salaries and Wages	$93,660
Operating Costs	4,787
Subtotal	$98,447
Program Expansion:	
Salaries and Wages	$159,867
Operating Costs	197,268
Subtotal	$357,135
Total Request Office of Environmental Programs Budget	$455,582
Fringe Costs	49,335
Total Program Cost	$504,917

Program Funding

To provide an adequate financing basis for the program outlined above, a generator fee on a "wet ton" basis is proposed. The following table contains the most recent estimate of the quantities of sludge generated on a jurisdictional basis.

Jurisdiction					Wet tons of sludge/year
1	00	002	AA	Anne Arundel County	7853
2	00	001	AL	Allegany County	9568
3	00	003	BA	Baltimore County	125
4	00	030	BC	Baltimore City	191,634
5	00	007	CC	Cecil County	2827
6	00	005	CE	Caroline County	447
7	00	006	CL	Carroll County	1267
8	00	008	CS	Charles County	1522
9	00	004	CT	Calvert County	124
10	00	009	DO	Dorchester County	4493
11	00	010	FR	Frederick County.	2302
12	00	011	GA	Garrett County	360
13	00	012	HF	Harford County	2749
14	00	013	HW	Howard County	2542
15	00	014	KT	Kent County	225
17	00	015	MO	Montgomery County	1624
18	00	016	PG	Prince George's County	11,674
19	00	017	QA	Queen Anne's County	129
20	00	018	SM	St. Mary's County	680
21	00	019	ST	Somerset County	365
22	00	020	TB	Talbot County	612
23	00	021	WN	Washington County	2553
24	00	022	WO	Wicomico County	1656

Jurisdiction					Wet tons of sludge/year
25	00	023	WR	Worcester County	1828
					249,159
	Blue Plains				273,750
				Grand Total	522,909

The estimated annual cumulative total is about 523 thousand wet tons of sludge. An annual assessment of $1/wet ton of sludge generated would provide an annual fund source of $523,000 which is sufficient to fund the overall program.

A lesser fee ($.75/wet ton) would provide sufficient funding once the initial fixed expenses of vehicles/supplies and equipment were obtained. However, maintenance of a $1/wet ton fee would provide sufficient contingency funding.

Additional funds may be available under 205(g) funds or 205(j). This should be explored.

Initial Seed Money

Given the existing limited staff and the absence of any special fund money, a "seed fund" of 250,000 would facilitate program expansion and upgrading to initiate the effort to bring in money to the special fund.

This money would be needed to hire the technical and some enforcement staff to conduct the main aspects of the program. Completion of staffing requirements and contingency funding would progress as fund money is generated (after repayment of the "seed fund").

COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF MARYLAND
COLLEGE PARK - - - EASTERN SHORE

Guidelines for Land Application of Digested Sewage Sludge and Composted Sewage Sludge

Fact Sheet 336

Introduction

Today's society is a massive generator of waste. Sewage sludge is being produced at a very fast rate, and it is becoming more difficult to safely dispose of it in our environment.

The Clean Water Act of 1977 emphasizes proper wastewater treatment and encourages the removal of pollutants from our nation's water. Many of the solid pollutants are removed from raw sewage during treatment. These solids are collected at the treatment plant to be disposed of as sludge.

The source of the raw sludge has a great influence on the content, uses and potential hazards of the resulting sewage sludge. Domestic sewage sludge is much more likely to have lower concentrations of heavy metals and persistent organic chemicals than sludge from industrial areas. Sludge from a given treatment plant varies widely in chemical composition. Recently developed composting methods appear to reduce this variation, as well as solve some other problems associated with land application of sewage sludge.

Sludge cannot be disposed of without some risk. Incineration requires a high capital investment, consumes large quantities of fuel, can pollute the atmosphere and produces a residual ash that must be disposed of. Ocean dumping is an attractive and simple solution to the problem for many coastal communities, but the long-term effects on ocean ecology are largely unknown.

Landfills have been widely used for sludge disposal, but suitable areas near large cities have become more and more difficult to locate. Citizens strongly object to the establishment of disposal sites in their areas and to the transportation of the sludge through or past their communities. The costs of the land for such use and transportation of large volumes of sludge from treatment plants to the disposal sites are very high. The danger of contamination of ground and surface waters is often a concern.

The utilization of sludge on agricultural land, while not without problems, allows nutrients and organic matter to be recycled. Increasing fertilizer prices, as well as the costs and problems associated with other disposal methods, tend to favor land application. Sewage sludge can provide plant nutrients and add organic matter to the soil.

The application of sewage sludge to agricultural land can result in the introduction and accumulation of heavy metals and harmful organic chemicals. Of immediate and long-term concern is the contamination of food chain crops. Both sludge quality and rates of application must be carefully monitored and controlled to insure that the amounts of heavy metals added are not toxic to crops or to the wildlife, livestock or humans who consume these crops. Annual application rates for commercial production should be limited to the nutrient requirements of the crops being grown to reduce the likelihood of polluting surface and ground waters.

Sewage Sludge Composition and Properties

When sewage wastewaters are treated, sludge is left behind in sedimentation tanks. These semiliquids have a chemical composition that varies greatly, dependent on the industries and communities served by the system. Maryland sewage sludge contains from less than 1 percent to more than 10 percent nitrogen (N), with 2 to 7 percent common on a dry-weight basis. Phosphate (P_2O_5) concentrations range from less than 1 percent to more than 14 percent, with 3 to 8 percent common. The nitrogen and phosphorous are valuable as plant nutrients. The organic matter in sludge is particularly useful as a soil amendment.

Sludge Types

Primary sludge. The solids that settle out of wastewater during processing in a primary treatment tank.

Activated sludge. The sludge that accumulates during secondary sewage treatment. This sludge consists mainly of the bodies of organisms which have been feeding on the soluble and suspended organic material in the sewage.

Digested sludge. The sludge that accumulates when mixtures of primary and activated sludge are further treated in tanks with or without oxygen. These systems produce a stabilized material that can be applied to agricultural land. It is the most common type in the United States.

Composted sludge. The sludge that is residual after microbiologically processing sludge in the presence of suitable amounts of air and moisture. When composted, this matter has little odor, is relatively free of pathogens and is a valuable soil amendment.

Implications for the Future

Can we achieve the potential benefits of sewage sludge to agriculture and to society, and at the same time provide acceptable limits to the risks of serious harm to the environment, to agricultural production and to human health? Scientists at the University of Maryland have reviewed sludge utilization research. The research completed at this point does not provide the final answer to this question.

Issued in furtherence of Cooperetive Extension work, ects of Mey 8 end June 30, 1914 in cooperetion with the U.S. Depertment of Agriculture, University of Merylend and locel governments. Creig S. Oliver, Director of Cooperative Extension Service, University of Merylend.

The implications of the uptake by plants of heavy metals and persistent organics from sludge, their intake by grazing animals and their ingestion by humans are not entirely understood. **Therefore, the University of Maryland cannot predict the long-term effects of sewage sludge on the environment and does not accept responsibility for any such effects.**

The available information, however, does emphasize the need to establish guidelines and procedures to minimize the risk in the use of sludge on agricultural land. These guidelines should be made a part of public policy and be used to monitor and regulate the disposal of sewage sludge in Maryland.

Such guidelines for use of sludge on agricultural land should include the following provisions:

1. Chemical analyses of sewage sludge to be applied to agricultural land should be required on a regular and frequent basis. These analyses should include pH, nitrogen, phosphorus and the content of heavy metals and potentially harmful organics.

2. Limitations for heavy metal concentration in the sludge should be established, beyond which a sludge cannot be applied to agricultural land.

3. Maximum allowable sludge application rates should be established for single applications as well as for lifetime loadings. These rates should be based on:

- characteristics of the sludge
- characteristics of the soil
- nutrient requirements of the crop.

4. Acceptable methods of application should be specified that will provide reasonable uniformity and prevent excess loadings on any part of the field.

Guidelines

The University of Maryland offers these guidelines to landowners and public officials as they consider the use of digested sewage sludge or composted sewage sludge.

General Recommendations

1. The annual rate of sludge application on productive farmland is currently determined according to the nitrogen requirement of the crop. For digested sludge, this rate is based upon the content of inorganic nitrogen plus 20 percent of the organic nitrogen. In the case of sewage sludge compost, it is estimated that 10 percent of the nitrogen in the compost is available to the crop.

2. Forage and pasture crops physically contaminated by sludge should not be consumed by animals.

3. There are two categories of land application of sludge: (1) application to productive farmland, and (2) application to marginal land (for example, land abandoned from mineral extraction, areas where the topsoil has been removed through grading, etc.). The maximum amounts of sludge-borne metals that may be applied are given in Table 1. No additional sludge-borne metals should be applied unless further research indicates that higher amounts are acceptable.

Table 1. Maximum Cumulative Sludge Metal Applications for Farmland and Marginal Land

Metal	Heavy Metal Application	
	Productive farmland[a]	Marginal land[a]
	------lbs/acre/meq[b]------	
Zinc (Zn)	18.9	37.8
Copper (Cu)	9.4	18.8
Nickel (Ni)	3.8	7.6
Cadmium (Cd)	0.28	0.56
Lead (Pb)	37.8	75.6

[a]These metal additions apply only to soils that are adjusted to pH 6.5 and maintained at a pH of at least 6.2.

[b]To obtain the maximum cumulative heavy metal loading in pounds per acre for a particular element on farmland or marginal land, multiply the appropriate value in Table 1 by the cation exchange capacity (C.E.C.) of the soil expressed as milliequivalents (meq)/100 grams; e.g., if the C.E.C. for a soil is 10 meq/100 grams, the maximum loading of zinc on farmland would be 10 meq x 18.9 lbs Zn/meq = 189 lbs/A zinc. This value must be reduced by the amount of extractable zinc already in the soil as determined by a soil test.

4. Sludge having a cadmium content greater than 1.5 percent of its zinc content should not be applied on farmland or marginal land. Sludge with a cadmium content of less than 1.0 percent of its zinc content is desired.

5. The cadmium loading rate should not exceed 1.0 pound per acre per year.

6. Sludge is not to be used on land where tobacco is to be grown.

7. Sludge should not be applied on soils with less than 20 inches of depth. The depth to the seasonal high water table should be a minimum of 20 inches.

8. Sludge exceeding the following content limitations on a dry-weight basis is not to be applied to farmland:

Zinc (Zn) — 2500 ppm
Copper (Cu) — 1000 ppm
Nickel (Ni) — 200 ppm
Cadmium (Cd) — 25 ppm
Lead (Pb) — 1000 ppm
Mercury (Hg) — 10 ppm
Chromium (Cr) — 1000 ppm
PCB's — 10 ppm

Sewage Sludge for Agronomic Crops

The rate of sewage sludge application on land for corn, soybeans, small grains, forage crops, turfgrasses and other agronomic crops is to be determined by the University of Maryland Agronomy Department according to University of Maryland Soil Test results and an official analysis of the sewage sludge by the Maryland Department of Agriculture.

Sewage Sludge for Vegetable Crops

Dewatered sewage sludge and composted sludge should **not** be applied to land to be used for commercial production

of vegetable crops. This use of sludge may be unsafe in the absence of adequate control and monitoring of cadmium levels in the sludge and in the soil, and without careful maintenance of the soil pH at or near 6.5.

Screened sewage sludge compost can be effectively used in media for production of vegetable transplants. Mixtures containing one-third screened compost, one-third peat moss or milled pine bark and one-third vermiculite or perlite give excellent results. Media should be adequately leached after planting to avoid injury from high-soluble salts. Soluble fertilizers may be needed for best plant growth when the seedlings are 2 to 3 weeks of age.

Screened Composted Sewage Sludge for Ornamental and Floricultural Crops, Forest Tree Seedlings and Establishment of Tree Fruit Orchards

Greenhouse and nursery flowering and foliage crops can be grown in containers or nursery beds amended with screened compost. The compost should be blended with equal parts by volume of peat moss or milled pine bark and vermiculite, perlite, sharp sand or expanded shale. Plants should be thoroughly irrigated immediately after transplanting and fertilizer applications should be delayed 2 to 3 weeks. Ericaceous plants can be grown in compost-amended potting mixtures if 5 pounds of wettable and 3 pounds of granulated sulfur are blended per cubic yard of potting mixture.

Nursery soils used for balled and burlapped (B&B) or balled and potted (B&P) production can be amended with screened compost. Soil tests are necessary prior to treatment. Repeated applications of composted sewage sludge should be made only after soil testing, between harvest and planting a new crop or green-manure crop.

Nursery seedbeds or transplant beds can be amended with screened compost only after soil testing. Repeated applications of composted sewage sludge should be limited to once every 4 to 5 years and according to soil tests.

For growing ericaceous crops in screened compost-amended soil, 150 to 200 pounds of sulfur must be added to every 25 tons of compost applied.

For transplanting ornamentals, blend screened compost at one-third by volume with existing soil for backfilling under landscape conditions. For ericaceous species, add 3 to 4 ounces of sulfur per bushel of compost used when blending the compost-amended backfill.

For the establishment of tree fruit orchards, use an application rate equivalent to 50 tons of dry compost per acre applied only in 5-foot-wide bands (manure spreader-wide band) only in the tree planting row. Incorporate 6 to 8 inches into existing soil prior to planting. Compost will supply all of the nutrient needs of the plants through the first growing season and will maintain the pH of the soil at above 6.5 for approximately 6 years. After plants are established, follow normal soil testing, fertilization and liming recommendations of the Maryland Cooperative Extension Service.

Screened Composted Sewage Sludge for Home Grounds

Turfgrass. In the absence of soil tests, 200 pounds of composted sewage sludge per 1,000 square feet can be used for the establishment of turfgrasses. The composted sewage sludge should be applied uniformly over the area and mixed with the top 4 to 6 inches of soil prior to seeding the grass.

Composted sewage sludge is not recommended for maintenance applications.

Flower gardens. Incorporate 1 to 2 cubic yards of screened composted sewage sludge per 1,000 square feet to a depth of 6 to 8 inches just prior to transplanting bedding plants or sowing seeds. Use the lower levels when establishing a flower garden on relatively fertile soil and the higher rate on poor soils. The compost will raise the pH of the soil to near 6.8 and supply all the nutrients of the flowers through the first growing season and partially through the second growing season. At the beginning of the second growing season, apply 10 pounds of 38-0-0 ureaform fertilizer per 1,000 square feet prior to tilling the soil for planting.

To maintain the productivity of flower garden soils, apply ½ to 1 cubic yard of screened compost per 1,000 square feet every other year and incorporate to a depth of 6 to 8 inches just prior to transplanting bedding plants or sowing seeds. The amount of compost to be used will depend on the performance of the garden during the previous year. Apply 10 pounds of 38-0-0 ureaform fertilizer per 1,000 square feet prior to tilling on alternate years.

Trees and Shrubs. For most deciduous trees, shrubs, junipers, cedars, yews, white pine, boxwoods and cherry laurel, mix thoroughly one-third by volume screened composted sewage sludge with existing soil excavated from the planting hole. The compost will raise the pH of the amended soil to near 6.8 and will supply all of the nutrient requirements for these plants for approximately 2 years.

For azaleas, rhododendrons, andromeda, leucothoe, mountain laurel, most pines, spruce and fir and all species of oak, mix thoroughly one-third by volume of screened composted sewage sludge and 3 to 5 ounces of wettable sulfur per bushel of compost used with existing soil excavated from the planting hole. Use 3 ounces of sulfur on lighter soil and 5 ounces of sulfur on heavy soils. The sulfur is needed to help maintain a desirable pH of near 5.5 for the species.

Potting and planter mixes. In the potting or repotting of houseplants, mix equal parts of screened composted sewage sludge, peat moss or milled pine bark and perlite, styrofoam beads or coarse sand. After potting, water the plant thoroughly but do not fertilize for at least 3 weeks.

To prepare potting mix for sowing seeds or for transplanting bedding plant seedlings, mix equal parts of screened composted sewage sludge with peat moss or finely milled pine bark and vermiculite. Water the plants thoroughly after transplanting, but do not fertilize for at least 3 weeks.

To avoid problems associated with potting mix shrinkage in large permanent planters, mix equal parts of

screened composted sewage sludge, milled pine bark and coarse sand or ⅛- to ⅜-inch expanded shale. For plant species that prefer growing in acid soils, blend 3 to 4 ounces of wettable sulfur or granular sulfur per bushel of potting soil. Resume a normal fertilizer program within 3 weeks after planting.

Vegetables. It is **not** recommended that composted sewage sludge be used on vegetable gardens. Unless the levels of heavy metals in the compost and in the soil are accurately known, and unless the soil pH is carefully controlled, there are possible risks to human health from the ingestion of vegetables containing excessive cadmium.

If composted sewage sludge is to be used on vegetable gardens, incorporate no more than 1 cubic yard per 1,000 square feet to a depth of 6 to 8 inches before planting. Make repeat applications of ½ to 1 cubic yard per 1,000 square feet no more often than every other year. Have the soil tested regularly and add lime as needed to maintain a pH of about 6.5.

Fruit Trees. Mix thoroughly one-third by volume of screened composted sewage sludge with existing soil excavated from the planting hole. The compost will raise the pH of the amended soil to approximately 6.8 and supply all of the nutrient needs of these plants through the first growing season. In the late fall of the first year or early spring of the second growing season, topdress only with nitrogen fertilizer (urea, ureaform or ammonium nitrate) at the rate of 2 to 3 tablespoons per tree. After the second growing season, follow the fertilizer recommendations in Maryland Horticulture Mimeo 28-76, "Tree Fruit Culture in Maryland," published by the Maryland Cooperative Extension Service.

Mulches. Composted sewage sludge is not recommended as a decorative mulch around ornamental plantings. Because it is neutral to alkaline, it will raise the pH of the soil creating problems in mixed plantings. It will stimulate rapid growth of existing weeds and encourage the germination of weed seeds. In damp, shady areas, compost mulch encourages the growth of fungus fruiting bodies and slime mold. A mulch of screened composted sewage sludge tends to crust after being exposed to heavy watering or rain, thus shedding water during subsequent irrigations or rains.

Sludge Application Methods

Sludge must be stabilized before land application to reduce public health hazards and to prevent nuisance odor and conditions. Liquid digested sludge may be applied to the land by using a spreading method such as a tank truck, liquid manure spreader or subsurface injection in the plow layer. Dried or dewatered stabilized sludge, or composted material from digested sludge, can be spread with a manure spreader.

It is very important that the sludge be applied uniformly over the field so that recommended rates are not exceeded. Dumping sludge in piles in the field and then spreading it is not an acceptable practice.

Land areas to receive applications of sludge should not be subject to flooding. Conservation practices should be carried out to prevent excessive runoff and erosion.

Determining Application Rates of Sewage Sludge

Analysis of soil sample. For the University of Maryland to determine the rate of sewage sludge to be applied to land, soil samples must be submitted to the Department of Agronomy, University of Maryland Soil Testing Laboratory, College Park, MD, 20742. Instructions and soil containers for submitting soil samples are available from the county offices of the Maryland Cooperative Extension Service or the University of Maryland Soil Testing Laboratory. An official analysis of the sewage sludge by the state chemist should be made available to the University of Maryland Soil Testing Laboratory at the time of submitting the soil samples.

Analysis of the sewage sludge. An official analysis of the sewage sludge is required for total nitrogen, ammonium nitrogen, phosphate, potash, calcium, magnesium, manganese, iron, chromium, zinc, copper, nickel, cadmium, lead, mercury, percentage of total solids, pH and PCB's. Contact the State Chemist, Maryland State Department of Agriculture, Room 0233, Chemistry Building, University of Maryland, College Park, MD 20742 (phone 301-454-2722) for an official analysis of sludge.

Economics of Land Application of Sewage Sludge

When sludge is applied at low and environmentally safe rates to some crops, it can replace some fertilizer requirements. Thus it becomes an economic resource. The economic value of sludge depends on the crops being grown, the desired yield level, the application rate, the nutrients in the sludge, and the price of other nutrients. An upper limit on the economic value of sludge can be determined by computing the market value of the nutrient in the sludge. In 1980 prices, this figure was about $20 per ton. However, the value of this sludge to a farmer will in general be less, because the differential uptake of nutrients by plants means that not all nutrients can be used at once. In addition, spreading and hauling costs must be absorbed. The value of sludge to farmers will depend upon individual cases.

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Table 1. - - A comparison of Various Suggested/Mandated Concentrations of Cumulative Metals Application on Agricultural Land

(In Pounds Per Acre)

Metal	Virginia[1]			New Jersey			University of Maryland[2]			Maryland Dept. of Health & Mental Hygiene[3]			Northeast[4]		
	Low CEC	Medium CEC	High CEC	Low CEC	Medium CEC	High CEC	Low CEC	Medium CEC	High CEC	Low CEC	Medium CEC	High CEC	Low CEC	Medium CEC	High CEC
Zn	222	445	890	250	500	1,000	95	227	340	250	500	1,000	50	150	300
Cu	111	222	445	125	250	500	47	113	169	125	250	500	25	75	150
Ni	44	89	178	50	100	200	19	46	68	50	100	200	10	30	60
Cd	2.22	4.45	8.9	5	10	20	1.4	3.4	5.0	5	10	20	2.0	3.0	4.5
Pb	445	890	1,780	500	1,000	2,000	189	454	680	500	1,000	2,000	100	300	600

1/ Mandatory by regulation; based on U.S.D.A. Biological and Waste Management Laboratory, U.S.D.A., Beltsville, Md.

2/ Guidelines for Land Application of Digested Sewage Sludge, "Fact Sheet #336" (Undated); for Productive Farm Land, with Low CEC = 5; Medium CEC = 12; High CEC = 18.

3/ Proposed concentrations; based on Application of Sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide (MCD - 35), U. S. E. P. A., March 1978.

4/ From "Soil Textural Classes" in Criteria and Recommendations for Land Application of Sludges in the Northeast (Draft), Northeast Soils Research Committee, January 1983. A specific CEC (or range in CEC) was not specified; rather, "soil textural classes" were cited - - which appear to correspond to the low, medium and high CEC categories used by most states and agencies.

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APPENDIX B

EFFECT OF SLUDGE QUALITY AND RATE, SOIL pH, AND TIME ON HEAVY METAL RESIDUES IN LEAFY VEGETABLES

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ABSTRACT

Romaine lettuce, chard, and collards were grown on field plots to evaluate crop uptake of Cd as affected by sludge Cd concentration, application rate, soil pH, and time since application. Cadmium concentrations in crops grown on calcareous, low Cd sludge plots were similar to the unamended controls. Acidic Heat-Treated sludge plots, and both acidic and limed Nu-Earth plots caused significant increase in lettuce Cd. Foliar Cd was increased by the lowest rate of these sludges, but higher rates caused only small further increase in lettuce Cd (at both pH levels). These results indicate a substantial influence of sludge Cd concentration on Cd uptake by crops, suggesting that sludge also supplied Cd-adsorption capacity to the soil. Sludge-applied Cd remained crop available for the 6 years studied. In contrast with lettuce and chard which accumulated high levels of Zn and Cd, collards were only slightly higher in Cd even on acidic Nu-Earth plots.

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Introduction

In the last decade, much has been learned about the potential for metal uptake by crops resulting from the use of sewage sludges as fertilizer or soil conditioner. Early research indicated that both metal accumulation and metal tolerance by crops were species and cultivar dependent. This research also indicated that metal uptake (particularly Zn, Cd, Mn, and Ni) is strongly reduced by increasing soil pH (Chaney and Hornick, 1978; CAST, 1980). However, questions remain regarding the length of time that sludge-applied Cd remains crop available, and the influence of both sludge application rate and soil pH on Cd availability to crops.

While the first CAST Report (1976) indicated that annual Cd application rate was important in crop uptake of Cd, the 1980 CAST Report suggested a relatively greater importance of cumulative than annual applied Cd. Many research approaches to these questions appear to lead to the same answer, that sludge-applied Cd remains crop available as long as it remains in the soil. One approach involved a study of crop uptake of Cd on long-term sludge utilization farms (Chaney and Hornick 1978; CAST, 1980; Lloyd et al, 1981). The studies of Lund et al. (1981) on Cd uptake from very old soils in California which were geochemically enriched in Cd is another approach to this question.

Dowdy et al. (1981) evaluated Cd uptake results from their repeated sludge application plots using a new method to separate cumulative and annual applied Cd factors in regression analyses. In their study, where soil pH remained relatively constant, cumulative applied Cd played a dominant role in Cd uptake. Actually, many of the purported effects of annual applied Cd could result from the applied NH_4^+ (Williams and David, 1976), soluble salts (Bingham, 1980), and organic matter degradation by-products with chelating capability (Wallace et al, 1977), all of which can increase Cd uptake by crops.

Although the great influence of soil pH in metal uptake is now generally recognized, research which included comparison of soil pH levels in the field is limited. While several researchers have adjusted pH up or down with sulfur, sludge-NH_4^+, or limestone, with confirmation of the predicted increased Cd uptake from lower pH soils (Chaney et al., 1978; CAST, 1980; Chaney and Hornick, 1978), few have established plots at specified pH levels for several years.

This field study was conducted to evaluate the effect on crop uptake of Cd due to 1) sludge Cd concentration, 2) sludge aplication rate, 3) soil pH, and 4) time after sludge application. Leafy vegetables were grown annually to assess potential Cd uptake by high Cd accumulating garden vegetables.

Materials and Methods

Sludges and Compost:

Sludges were selected to include different sludge processing technology and sludge Cd concentrations. The limed-raw sludge filter cake (Limed-Raw) met EPA requirements (30 minutes at or above pH 12). The anerobically digested sludge filter cake (Digested) was somewhat excessively limed to facilitate dewatering. The heat-treated raw sludge centrifuge cake (Heat-Treated) was not limed because the heat treatment process (combined raw sludge subjected to 176°C for 45 min.) replaces the need for dewatering chemicals. The composted limed-raw sludge (compost) was the standard product of the USDA-Maryland Environmental Service demonstration sludge composting facility. Woodchips and limed-raw sludge filter cake were composted 21 days in aerated piles, and held in curing piles in excess of 30 days; chips were screened from the compost product. A sludge high in Cd (Nu-Earth) became available as part of the W-124 Regional Cooperative Research Project. Primary sludge was collected and digested in Imhoff tanks, and dried on sand beds.

Soil:

A field of Christiana fine sandy loam (Typic Paleudults; clayey, kaolinitic, mesic) was selected from available land at the Beltsville Agricultural Research Center. The site was selected after verifying it had no identifiable history of heavy metal addition, met the soil type throughout the proposed plot area, and was moderately acidic in the surface horizon.

Plot design:

A completely randomized block design was used, with three replications. Each replicate was comprised of 2 rows of 18 plots per row. Sludges were applied to 21 x 26 ft plots. Crops were grown on and sampled from the central 15 x 20 ft area of each plot. With the Heat-Treated and Nu-Earth plots, where soil pH was varied, each sludge-pH combination was applied to a full plot, not a split plot.

The Limed-Raw sludge was applied at 56, 112, and 224 Mt/ha; Digested sludge, at 56, 112, 224, 336 and 448 Mt/ha; compost, at 56, 112, 224, 448, and 672 Mt/ha; Heat-Treated sludge, at 56, 112, 224 Mt/ha; and Nu-Earth, at 50 and 100 Mt/ha. Nu-Earth was applied in 1978, while the other sludges were applied in 1976.

Fertilizer and Lime:

Annual P and K applications (100 kg/ha P_2O_5 and K_2O) were made uniformily as superphosphate and muriate of potash. Nitrogen was applied annually at 100 kg N/ha as NH_4NO_3. All fertilizers were broadcast and incorporated. The lime requirement of plots assigned to Hi pH treatments were determined by

the Adams-Evans (1962) buffer method. Pulverized dolomitic limestone was applied to Hi pH plots at their full lime requirement. The calcareous control plots received 44 Mt limestone/ha in addition to their full lime requirement. In subsequent years, if soil pH fell below the desired level, limestone was applied according to the lime requirement test.

In 1981, sulfur was applied to the Lo pH Nu-Earth plots in order to achieve the planned pH 5.5. Amounts were based on trial incubations. Applications were made 6 weeks before transplanting the lettuce to the field.

Crops:

'Paris White Romaine' lettuce, 'Fordhook Giant Swiss' chard, and 'Georgia' collards were grown in the years indicated. Lettuce was grown from seed in 1976 thru 1979. Lettuce was not harvested in 1980 because of poor germination in the field. In 1981, lettuce transplants were grown in a peat-vermicullite media, and set out for fall crop. Chard (1976, 1978) and collards (1980) were grown from seed as fall crops.

Laboratory Analyses:

The leafy vegetable crops were harvested at marketable maturity, at least 10 plants per replicate. Non-edible leaves, and stems were discarded. The foliar samples were washed in 0.1% Na lauryl sulfate, rinsed 3 times with deionized water, and forced-air oven dried at 70°C. Dried plants were ground in a stainless steel Wiley Mill. For analysis, 2.0 g dry plant material was ashed in a 100 ml Pyrex beaker for 13 hours at 500° C. The ash was treated with 4 ml conc. HNO_3 and heated to moist-dryness. The sample was then dissolved with 10 ml 3N HCl, refluxed for 2 hrs, filtered, and diluted to 25 ml. Samples were analyzed for Zn, Cd, Pb, Cu, Ni, Fe, and Mn by flame atomic absorption spectrometry with background correction as required for Cd, Pb, and Ni.

A composite sample was collected for each field replicate for each sludge. These samples were dried, crushed, ground to 2 mm, and mixed to obtain homogenous samples. Aliquots were separately analyzed for %-solids. Sludge samples (2g) were ashed at 500°C, treated with 5 ml HNO_3 and heated to moist dryness, with 40 ml of 3N HCl, filtered, and diluted to 100 ml.

Soils samples were comprised of 20 cores (2 cm) from each plot (0-15 cm depth to sample A_p). Soil total metal analyses were similar to sludge analyses, except 5 g soil was used. DTPA-TEA extraction was conducted in the standard fashion (Lindsay and Norvell, 1978). Soil pH was measured in a 1:1 (by volume) slurry of soil in deionized water after 1 hr incubation.

Statistical Analysis:

Log transformed data were statistically evaluated as a randomized complete block design through use of the Statistical Analysis System (SAS). Only weighted means are presented. Specific treatment comparisons between sources were made by Duncan's New Multiple Range Test at 5% significance level. For Heat-Treated and Nu-Earth sludges, the effect of rate, soil pH, crop year after applications, and the appropriate interactions were evaluated by analysis of variance using orthogonal contrasts. Stepwise regression procedures (using the maximum R^2 improvement technique) were used to establish multiple regression models for each plant metal within each sludge source.

Results and Discussion

Sludge Composition:

The microelement, ash, and solids content of the sludges applied are shown in Table 1. The "Maximum Domestic" metal levels suggested by Chaney and Giordano (1977) are also shown for comparison. Metal content of all sludges except Nu-Earth were quite low compared to those of many urban sludges (Sommers, 1977).

Crop Response:

Sludge application may result in crop injury due to excessive soluble salts, or "initial toxicity" which is unrelated to heavy metal uptake. The high soluble salt concentrations (saturation extract 12 m mho/cm) in compost posed a potential for crop injury. However, even at the 672 Mt/ha rate, no salt toxicity was observed. Apparently, the natural leaching by rainfall between tilling and planting removed excessive salts from the root zone.

Inadequately stabilized sludges often cause a phytotoxicity referred to as "initial toxicity" due to anaerobic conditions and toxic biodegradation by-products from the rapid degradation of unstablized sludge organic matter. No initial toxicity was observed in this study even though Limed-Raw and Heat-Treated sludges were applied at 224 Mt/ha. Soybean and leafy vegetable yields were not measured.

Table 1. Microelement Content of Sludges and Compost Applied. 1/

Sludge	Solids %	Ash %	Zn ppm	Cd ppm	Cd/Zn %	Pb ppm	Cu ppm	Ni ppm	Fe %	Mn ppm
Limed Raw	28.3	60	599	4.9	0.82	215	277	17	2.5	598
Digested	21.6	67	639	5.9	0.92	217	259	15	2.5	722
Compost 2/	64.1		731	7.2	0.98	272	274	201	4.1	719
Heat-Treated	30.2	54	1329	13.4	1.01	360	404	37	8.3	854
Nu-Earth	47.8	64	4140	210.	5.07	865	1160	590	2.5	302
Max. Domestic	-	-	2500	25.	1.5	1000	1000	200	4.0	-

1/ Dry weight basis for all but %-solids.
2/ Since compost was obtained for this study, the implementation of an effective source control program has reduced compost Cd to 3.0 ppm.

Metals in crops:

Tables 2, 3, and 4 show the metal concentration in edible foliar portions of Romaine lettuce (1981), Swiss chard (1978), and collards (1980). The results for lettuce and chard are similar, while metal levels in collards were generally lower. Concentrations of Zn, Cd, Ni, and Mn were strongly influenced by soil pH. Chard absorbed more Zn, but similar Cd as lettuce. Although some metal concentrations in crop leaves were increased on acid plots of Heat-Treated and Nu-Earth sludges, levels of Zn, Cu, Mi, Cd, or Mn in the crop leaves were below those indicative of phytotoxicity (Chaney et al., 1978). Metal toxicity symptoms were not apparent on any of the crop studied. Plant Pb was not affected by applied sludges. Plant Cu was increased somewhat by sludge application, and slightly reduced in Hi pH compared to Lo pH plots.

Although Cd concentrations in lettuce and chard were greatly increased on the acidic Nu-Earth plots, only slight increases in Cd were found in collards. Cadmium "accumulator" crops include the beet family (beet greens, chard, spinach) and lettuce. However, many other crops classified by FDA as leafy vegetables are not noted for exceptional Cd accumulation in the field (collards, cabbage, turnip greens, kale, mustard). Although Bingham (1979) found turnip greens to be a strong Cd accumulator in a pot study, Preer et al. (1980) found much lower Cd in turnip greens than lettuce grown in acidic urban gardens.

Table 5 shows the Cd concentration in lettuce over the 6 years (5 crops) of the experiment to date (3 crops for Nu-Earth). One of the most important results is the lack of an

Table 2. Effect of Sludge Quality and Soil pH on Microelements in Romaine Lettuce in 1981.

Treatment	Rate Mt/ha	Cd kg/ha	Soil pH	Zn	Cd	Pb	Cu	Ni	Mn
				mg/kg dry matter					
Control	-	-	5.3	76b[2/]	1.26de	1.0a	7.7bc	1.8b	125a
Control	-	-	6.2	39d	0.62de	1.1a	7.5c	1.6bc	47b
Limed Raw	224	1.10	7.7	39d	0.81de	0.8a	8.9abc	0.7d	25c
Digested	224	1.32	7.6	36d	1.61cd	0.9a	10.2abc	0.5d	25c
Compost	224	1.61	6.9	45cd	0.44e	1.0a	9.4abc	0.6d	31bc
Heat-Trt.	224	3.00	5.4	225a	2.62c	1.0a	11.5a	2.4b	110a
Heat-Trt.	224	3.00	6.2	67bc	0.93de	1.0a	10.2abc	0.8cd	27bc
Nu-Earth[1/]	100	21.0	5.6	242a	30.6a	1.1a	10.7ab	4.5a	108a
Nu-Earth	100	21.0	6.6	74b	6.34b	0.6a	8.7abc	1.6b	25c

1/ Sulfur added 6 weeks before transplanting lettuce to achieve pH 5.5.
2/ Mean separation within columns by Duncan's new multiple range test, 5% level.

Table 3. Effect of Sludge Quality and Soil pH on Microelements in Swiss Chard in 1978.

Treatment	Rate Mt/ha	Cd kg/ha	Soil pH	Zn	Cd	Pb	Cu	Ni	Mn
				mg/kg dry matter					
Control	-	-	5.7	97c[1/]	0.70de	3.4a	10.3e	2.9c	203.a
Control	-	-	6.7	38d	0.33e	2.7ab	10.8de	1.7cd	51.7c
Limed Raw	224	1.10	7.7	40d	0.33e	2.3ab	14.0bc	0.8d	29.2c
Digested	224	1.32	7.6	39d	0.31e	2.0ab	12.9cd	1.2d	39.7c
Compost	224	1.61	7.2	42d	0.45de	2.1ab	12.9cd	0.8d	34.4c
Heat-Trt.	224	3.00	5.7	420a	1.63c	2.1ab	21.2a	8.3ab	102.b
Heat-Trt.	224	3.00	6.8	115c	0.98cd	1.5b	16.4b	1.5cd	38.1c
Nu-Earth	100	21.0	6.3	363a	18.9a	1.2b	15.8b	11.9a	102.b
Nu-Earth	100	21.0	6.7	163b	8.38b	1.5b	13.9bc	6.0b	32.5c

1/ Mean separation within columns by Duncan's new multiple range test, 5% level.

Table 4. Effect of Sludge Quality and Soil pH on Microelements in Collard Greens in 1980.

Treatment	Rate Mt/ha	Cd kg/ha	Soil pH	Zn	Cd	Pb	Cu	Ni	Mn
				mg/kg dry matter					
Control	-	-	5.5	47cd[1/]	0.62b	2.4a	5.5bc	2.9abc	81.3
Control	-	-	6.4	37d	0.53b	1.9a	4.5c	1.8a-d	35.4
Limed Raw	224	1.10	7.6	44cd	0.52b	2.0a	5.6bc	0.7d	32.0
Digested	224	1.32	7.7	54bcd	0.33b	2.2a	6.6ab	1.1cd	36.9
Compost	224	1.61	7.1	52bcd	0.41b	2.1a	6.3ab	1.5bcd	35.8
Heat-Trt.	224	3.00	5.6	170a	0.54b	1.9a	7.5a	2.4a-d	44.8
Heat-Trt.	224	3.00	6.3	74bc	0.42b	2.5a	6.9ab	1.5cd	29.1
Nu-Earth	100	21.0	6.3	88b	2.86a	2.2a	6.4ab	4.2a	35.9
Nu-Earth	100	21.0	6.8	75bc	2.20a	1.9a	5.9b	3.9ab	31.5

[1/] Mean separation within columns by Duncan's new multiple range test, 5% level.

Table 5. Effect of Sludge Quality and Soil pH on Cadmium in Lettuce from 1976 through 1981.

Treatment	pH[1/]	Cd kg/ha	1976	1977	1978	1979	1981	Over Years
			mg Cd/kg dry matter					
Control	Lo	-	0.80b[2/]	0.93b	0.56d	1.58cd	1.26de	0.99d
Control	Hi	-	0.40c	0.75b	1.14cd	0.68e	0.62de	0.70de
Limed Raw	C	1.10	0.62bc	0.87b	1.77c	0.75e	0.81de	0.93d
Digested	C	1.32	0.61bc	1.66b	1.00cd	0.82e	1.61cd	1.01cd
Compost	C	1.61	0.40c	1.00b	0.53d	0.58e	0.44e	0.58e
Heat-Trt.	Lo	3.00	1.68a	2.39a	0.97cd	2.28c	2.62c	1.92c
Heat-Trt.	Hi	3.00	1.30a	1.16b	0.49d	1.16de	0.93de	0.99d
Nu-Earth	Lo	21.0	-	-	23.6a	22.6a	30.6a	25.4a
Nu-Earth	Hi	21.0	-	-	8.47b	11.1b	6.34b	8.24b

[1/] Lo = about 5.5; Hi= about 6.5; and C = calcareous.
[2/] Mean separation within columns by Duncan's new multiple range test, 5% level.

increase in lettuce Cd when very high rates of calcareous low Cd sludges were applied (Tables 2,5). Cd concentrations were not increased even at 672 Mt compost/ha which applied 4.8 kg Cd/ha. Application rates of the Limed-Raw, Digested, and Compost exceeded the annual Cd rates specified by EPA, but did not significantly affect lettuce Cd concentrations.

The rate of sludge application and soil pH had a significant influence on metals in lettuce when either Heat-Treated or Nu-Earth sludge was the source (Table 6). Crop Zn, Cd, and Cu exhibited significant linear and quadratic relationships with rate of sludge application. As shown in Figure 1, Cd concentration in lettuce was 1) substantially higher when grown on Nu-Earth plots than on Heat-Treated plots, 2) not a simple linear function of applied Cd, and 3) greater on the Lo pH plots for both sludge sources. Thus, crop Cd response to applied Cd is very different for sludge Cd source compared to the usual linear response to applied soluble Cd salts (e.g. White and Chaney, 1980).

When Cd is applied as a component of sewage sludge, many Cd adsorbing materials are also added. Corey (1980. R. B. Corey, University of Wisconsin, personal communication) hypothesized that Cd activity in soils and crop Cd uptake might be controlled by the ratio of added Cd to the Cd specific-adsorption capacity of the amended soil. For many soils, sludge Cd adsorption capacity will greatly exceed the soil specific Cd sorption capacity, and thus sludge properties will dominate in controlling plant uptake. In this model, sorption is influenced by soil pH regardless of the source of the adsorption site. For the present results, the lowest sludge rate increased crop Cd, while higher rates had little further effect on crop Cd. Corey's hypothesis appears to be supported by these data at both soil pH levels. These results clearly indicate that sludge utilization can have only small effects on Cd in lettuce if sludge Cd concentration is low, and provide support for restrictions on use of high Cd sludges.

Multiple regression analysis was used to evaluate the relationship of lettuce Cd concentration to measured or controlled soil and plant variables. The equations found for each sludge source are shown in Table 7. Results from 1977, 1978, and 1981 were complete and available for timely regression analysis. Multiple regression analysis explained only a small part of the variation in lettuce Cd for Limed-Raw, Digested, and Compost. This probably resulted from the small change in lettuce Cd in response to applications of these sludges, and an appreciable coefficient of variation in lettuce Cd on these plots. Higher R^2 values were obtained from the analyses of results from the Heat-Treated and Nu-Earth plots. This should be expected when the controlled variables more strongly influence lettuce Cd, and $R^2 = 0.85$ was reached for Nu-Earth. Soil pH was adjusted at two levels for these sludges, and soil

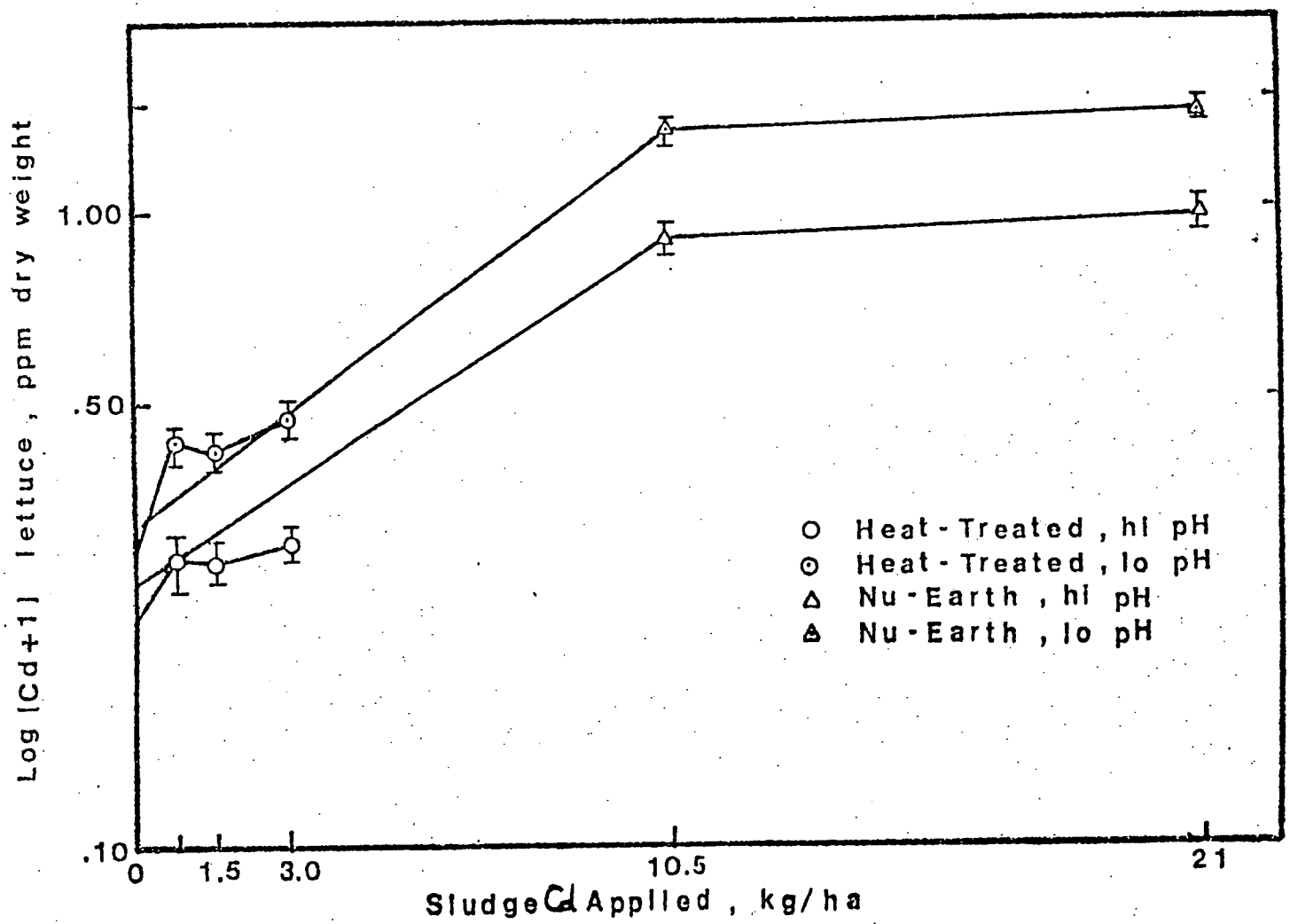

Figure 1. The effect of sludge concentration, soil pH, and applied Cd on Cd in Romaine let (averaged over years).

Table 6. Analysis of variance for metals in Romaine lettuce over five years (Heat-Treated) or three years (Nu-Earth).[1/]

Source	Zn	Cd	Pb	Cu	Ni	Mn
Heat-Treated:						
Rate	**	**	-	**	-	**
Rate^2	**	*	-	**	-	**
pH	**	**	-	**	**	**
Year	**	**	**	**	**	-
Rate x pH	*	-	-	-	-	-
Rate^2 x pH	-	-	-	*	-	**
Rate x year	-	-	-	-	-	-
Rate^2 x year	-	-	*	-	-	-
Year x pH	**	-	-	*	-	**
Rate x year x pH	*	-	-	-	-	**
Nu-Earth:						
Rate	**	**	-	**	**	**
Rate^2	**	**	-	**	-	-
pH	**	**	-	*	**	**
Year	-	-	**	**	-	**
Rate x pH	-	**	*	-	**	-
Rate^2 x pH	-	*	**	-	-	-
Rate x year	-	-	-	-	**	-
Rate^2 x year	-	-	-	-	-	**
Year x pH	**	**	-	-	-	**
Rate x year x pH	-	-	-	-	-	*

1/ Orthogonal contrasts for log transformed results.
*,** Significant at 5% and 1% levels, respectively.

Table 7. Multiple regression equations for Cd concentration in Lettuce (over years) grown on field plots amended with several sludge sources. The Maximum R^2 Improvement technique was used with soil variables only, or both soil and plant variables.

		R^2
Limed Raw:		
Soil:	LCd = 0.921 + 0.466 SCd	0.25
Both:	LCd = 0.588 + 0.785 SZn - 0.745 SCu - 0.250 LMn	0.40
Digested:		
Soil:	LCd = 0.372 + 0.229 year + 0.127 SCd	0.21
Both:	LCd = 0.372 + 0.229 year + 0.127 SCd	0.21
Compost:		
Soil:	Not significant	N.S.
Both:	LCd = 0.179 + 0.654 LZn - 1.16 LCu + 0.498 LNi	0.33
Heat-Treated:		
Soil:	LCd = 1.51 + 0.113 SCd - 0.288 SPb - 0.159 pH	0.45
Both:	LCd = 0.0634 + 0.593 LZn + 0.215 LPb + 0.700 LCu + 0.160 SCd - 0.149 SCu	0.62
Nu-Earth:		
Soil:	LCd = 3.40 - 0.0878 year + 0.507 SCd - 0.356 pH	0.85
Both:	LCd = -1.01 + 0.956 LZn + 0.237 SCd	0.90

1/ LCd denotes log (lettuce Cd + 1); LZn, log (lettuce Zn + 1); etc.
SCd denotes log (DTPA-Cd); SZn, log (DTPA-Zn); etc.

pH was a dominant variable influencing lettuce Cd in both models. In the models for both soil and plant data, soil pH was replaced by lettuce Zn, but lettuce Zn was in turn strongly influenced by soil pH.

Other relevant points are illustrated by the present results. First, lettuce Cd varied among crop years (Table 5) for Heat-Treated and Nu-Earth. Although some of the variation of Cd in Nu-Earth grown lettuce resulted from the adjustment of soil pH in 1981, little pH change occurred on the Heat-Treated plots. One should be careful in predicting the effect of time on crop Cd after two years study; the second year crop can be higher or lower in Cd in response to uncontrolled variables. In general, lettuce Cd remained relatively similar over time unless soil pH was changed. Second, one should be careful in using simple linear regression to predict crop Cd at selected sludge Cd applications. If application rate also has quadratic effects, or soil pH has varied in response to sludge application rate, simple linear regression is inappropriate. Others have misused the results of Schauer et al. (1980) in both of these aspects. Lastly, it is inappropriate to extrapolate beyond the

maximum sludge Cd application studied, a restriction often violated by regulators seeking to base maximum acceptable sludge Cd applications on available field results with low cumulative applied Cd.

The present results indicate that sludge Cd concentration is a more important effector of lettuce Cd than amount of sludge Cd applied. Unfortunately, sludge Cd concentration is not a part of the EPA (1979) regulations, or many State regulations. The EPA-FDA-USDA (1981) Policy Statement recommended use of low Cd concentration sludges. The present results indicate that great protection is provided against excessive dietary Cd from Cd accumulating garden crops grown on soils amended with low Cd sludges and composts even when very high total rates of sludge and sludge-Cd are applied.

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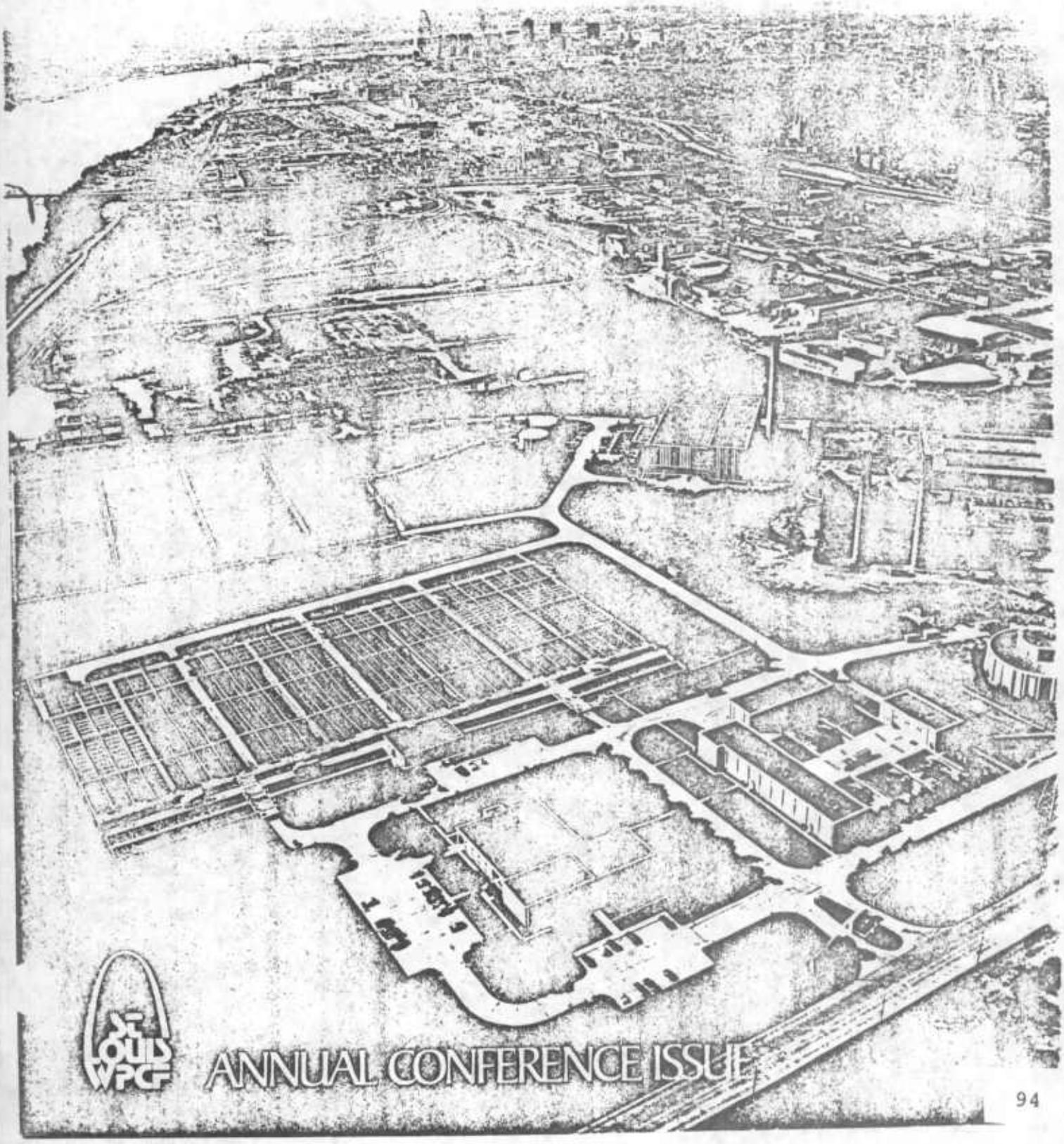

MONITOR

Sludge on Land

Where we are, but where are we going?

The person who invents a way to make municipal sludge disappear will probably win the Nobel prize and become very wealthy in the process. In the meantime, however, management of our sludges remains the current primary environmental problem. Yet, the problem lies not with our ability to manage it through technology and common sense, but with our inability to convince the public that we can manage the utilization and disposal of our sludges. This month's Monitor *looks at sludge and reviews what we know and don't know about its uses, treatment, regulation, and risks.*

Tevye, the earnest peasant in the musical "Fiddler on the Roof," resolves his dilemmas by considering his options "on the one hand . . ." and then "on the other hand . . ." His review of the facts is a fair assessment, but he never seems to make up his mind. Yet, when Tevye does this type of analysis, the audience can't help wondering if it's because he just can't make up his mind or if he really wants to make *all* of his arguments valid to solve *all* his problems.

Tevye would have been right at home if he were a decision-maker on sludge management, and he could have kept up his deliberations for hours. On the one hand, you can incinerate the sludge, but the fuel costs would make it very expensive. On the other hand, you could bury the sludge in landfills, but land is expensive and you might contaminate the ground water. On the other hand, you could dispose of the sludge in the ocean, but that would be wasting a resource and you may have to spend a lot of time and money in court during the process. On the other hand, numerous scientists report that sludge can be stabilized and successfully applied to land for agricultural purposes, but other scientists report that sludge is laden with toxic and pathogenic materials that preempt any usage for agriculture.

Tevye could very well have made it as a bureaucrat who regulates the management of sludge. On the one hand, because it's an environmental problem, it should be regulated by the U.S. Environmental Protection Agency (EPA). On the other hand, because it's something put on farmland to help fertilize food crops, maybe the U.S. Department of Agriculture (USDA) or the Food and Drug Administration (FDA) should administer sludge? Or perhaps also the Consumer Product Safety Commission, if it's used on home gardens?

Assuming that Tevye could decide to place the responsibility for sludge at EPA, then he would only have to decide if sludge should be utilized or disposed of in the air, water, or land, which would then involve every media office in the agency and at least six federal environmental laws, not to mention the state and local agencies and other laws that would be involved also.

Tevye didn't have to consider what to do with sludge, but we do. Every man, woman, and child in the U.S. contributes to the estimated 8.6 million dry metric tons of sludge produced each year in this country. It contains our feces, paper fibers, food wastes, paints, motor oil, detergents, caustic cleaning agents, and a variety of industrial wastes. Chemically, it contains nearly every inorganic and organic compound known. Biologically, it is the home for numerous viruses, bacteria, and parasites. You can't really blame the public for thinking of sludge as a potentially harmful, vile material that they wouldn't want disposed of in their towns and cities.

The reality of the situation is that we have no choice. Sludge volumes are increasing daily in this country and elsewhere because populations are increasing, technology to remove solids from wastewater is improving, and public attitudes have changed to where we waste more than we recover.

This article primarily considers land application for the utilization

of sludge. By concentrating on land application, there is no intent to eliminate incineration or other thermal considerations, nor is there the intent that ocean disposal should not be a viable alternative. The emphasis here is on proper management, reclamation of resources, risk considerations, and a review of the realities of sludge—and, finally, on how all these relate to the use of land application of sludge.

How sludge is managed

Sludge management in the U. S. is accomplished through five basic options—land application, landfilling, incineration, ocean disposal, and others (lagooning, for example).

Trends for each of these uses are shown in Table 1. Land application of sludge and composts at 42% has emerged over a 5-year period as the most common method of sludge management, followed by incineration at 27%. Many believe the growing preference for land application is based on the management approach of considering sludge as a resource to be used, rather than as a waste to be discarded.

It's also a matter of cost. For any wastewater treatment plant project under the construction grants program, between 40 and 60% of the construction costs are for sludge treatment, handling, and utilization/disposal. Nearly half of the operation and maintenance costs for an on-line treatment facility are for sludge management. Table 2 shows the estimated costs for managing sludge.

Incineration of sludge is an effective method for rendering the material to an ash residual that is reduced in volume, devoid of harmful organic chemicals, and pathogen free. For a large metropolitan area, such as Detroit, where land disposal/utilization options are not readily available or cost effective, incineration is a viable option. The problem for many cities is the cost to incinerate the sludge, because of the price of fuel oils and the need to dewater the sludge considerably prior to incineration. As a result, many cities operate their dewatering and incineration processes at a loss. Another negative consideration is that incineration will convert any chromium (III) in the sludge to a chromium (IV) state—the former is insoluble, the latter soluble and capable of leaching. Residuals must still be disposed, and clean air requirements must be met.

Ocean dumping is currently the most controversial method of sludge disposal. There are numerous arguments and studies debating the pros and cons of ocean dumping, but the principal considerations for U.S. coastal communities that favor this approach are the low transportation costs of barging and the benefit of not having to dewater their sludges. As with incineration, much of a potentially valuable resource is being discarded. Furthermore, the federal criteria for ocean dumping preempt most cities from considering the option. Probably the paramount concern with the practice at this time is the changing attitudes of the courts in response to various suits filed to stop ocean dumping—events being watched very closely by several coastal cities.

Landfilling seems to work well in less-populated areas where land is available and affordable. It does, however, render the sludge and the recipient landfill unusable for long periods of time—perhaps never—because of attendant hazards such as gas release and degradation-resistant toxic chemicals. Furthermore, landfills must be monitored and protected from leaching into ground water and other drinking water supplies. Because of the need to situate landfills away from the populace, transportation costs become a significant concern. Lagoons have similar considerations as landfills.

The advantages of land application of sludge are that sludge, stabilized either through digestion or composting to a form that can be

Table 1—Estimated nationwide wastewater sludge management methods.

Management method	Percentage of total volume		
	1976	1978	1981
Land Application	25	31	42
Landfill	26	29	15
Incineration	35	22	27
Ocean disposal	15	12	4
Other (lagoons, for example)	—	6	12

Source: U.S. EPA.

Table 2—Estimated operating and maintenance costs for sludge management methods in (1979 dollars).

Method	$/dry ton
Incineration	80–240[a]
Composting	70–200[b]
Surface impoundments (facultative lagoon)	approx. 25[c]
Landfills	73–226[d]
Ocean dumping	30–50[e]
Ocean discharge	approx. 20[f]
Land application	40–210[g]
Distribution	Income of 12 to cost of2[h]

[a] Includes fuel costs and dewatering costs.
[b] Includes costs for dewatering, bulking agents, labor, capital amortization, and distribution.
[c] Located at POTW and excludes sludge removal costs.
[d] Includes treatment, dewatering, and transportation, but excludes monitoring.
[e] Cost based on transportation costs.
[f] Through outfalls at Los Angeles, Calif.
[g] Includes treatment, dewatering, transportation, and application.
[h] Data only for finished composted sludge (20–50% moisture); excludes treatment and preparation costs.
Source: U.S. EPA.

used again, is applied to the land in either an agricultural setting as a fertilizer or as a soil conditioner, or in a reclamation project (such as a strip mine) to recover an area that was previously of little value. In most cases, pathogens have been significantly reduced, leaving primarily organohalogen chemicals and heavy metals to fuel the debate, which will be discussed presently.

The arguments against choosing land application are similar to those for landfills and include the problems of available land, transportation costs, and interstate transport. Also, there are areas in the U.S. that are sole source aquifiers for drinking water—a situation that would preclude any land application of sludge. A final consideration is the potential for land use conversion, where today's land application site may some day be changed to a public use that could conceivably expose people to hazards in the soil.

Why land application should be considered

Think of it as keeping solids in a solids medium. As opposed to disposal in water or air, sludge applied on or in the land essentially remains in the soil, unless leaching is a local problem. In any case, it can be more readily monitored and contained than in water or air.

Although not the best fertilizer money can buy, sludge does contain many of the nutrients needed to promote agricultural growth. Furthermore, it can be an excellent soil conditioner, improving the aeration of the soil and promoting water retention. At a time when commercial fertilizers are increasing in price and decreasing in availability, using sludge in its place should be an attractive consideration. In fact, many municipalities offer their sludges to farmers at no cost, thus imparting significant cost savings to the farmers, as well as the community, because its sludge is being utilized beneficially. Land application is endorsed by the National Association of Soil Conservation Districts.

For a municipality, the use of land application is not only eligible for funding through the construction grants program (purchase or leasing of land), it is also potentially grant-eligible for innovative/alternative (I/A) technology funding. The I/A technology funding provision of the Clean Water Act, already used extensively for many land application or composting projects, should be an even more attractive option following the passage of the 1981 amendments to the act.

With the number of categories eligible for funding to be reduced, and the once attractive 75% federal share of funds also to be reduced—to 55%—Congress set up incentives for municipalities to consider I/A technology. Section 202(a)(2) of the act provides federal funding 20% higher than conventional funding, but not to exceed 85%. Section 205(i) establishes mandatory set-asides of construction grant funds of between 4 and 7.5%, as determined by the state governor, for I/A technology.

The following land-based alternatives for sludge management are potentially eligible for I/A funds:

- Land application,
- Sludge landfilling—area fill,
- Sludge landfilling—sludge trenching,
- Sludge lagoons,
- Composting sludge—static pile, and
- Composting sludge—windrow process.

Yet, land application of sludge is hardly limited to agricultural use. It has also been used in the U.S. for parkland development, reforestation, and strip mine reclamation projects. Its use on land is only limited by a sludge manager's imagination . . . and the toxic chemical or pathogen content of the sludge.

Sludge and its contents

Everyone agrees that sludges can contain potentially hazardous chemicals and pathogens; the significant concern is which are present and

Table 3—Some constituents of sludge.

Nutrients	Percent of dry solids
Nitrogen	4.2–4.6
Phosphorus	2.7–3.0
Potassium	0.3–0.4

Primary pathogens	Reported range	Average	Median
Ascaris (ova/kg)	0–38 000	2 616	200
Virus (PFU/g dry wt)	30–410	178	200
Salmonella (organism/g dry wt)	3–1 240	126	80

Contaminants	Range (mg/kg—dry basis)	No. of samples
Aldrin[a]	ND[b]–16.2	5
Dieldrin[a]	0.08–1.4	7
Chlordane[a]	3.0–32.2	7
DDT & DDD[a]	0.1–1.1	7
PCBs[c]	ND–352.0	69

Metals	511 POTWs treating industrial & domestic wastewater (mg/kg)		51 POTWs treating domestic wastewater only (mg/kg)	
	Range	Mean	Range	Mean
Cadmium	0–1 320	46	0–30	9
Lead	4–10 800	541	9–1 200	319
Copper	8–23 124	1 034	0–2 600	586
Nickel	8–9 450	230	3–443	62

[a] Examined in 1971.
[b] ND = no data.
[c] Examined in 1971, 1973, and 1975.
Source: U.S. EPA.

in what quantities. Typical concentrations of chemicals and pathogens are given in Table 3. Nevertheless, it should be noted that there is no epidemiologic evidence, to date, suggesting that land application of municipal sludges has resulted in actual human illness, where sludge has been properly treated and applied. With that in mind, what must be considered in this discussion from this point on is whether we should fear what we know, or what we don't.

Land application of sludge is best complemented by a stabilized sludge, which is accomplished by aerobic or anaerobic digestion, composting, or heat treatment. Such stabilization decreases pathogens and eliminates odors, as well as breaks down unstable, decomposable constituents into more stable organic compounds. If needed, further stabilization can be produced by adding lime, which—by raising the pH—will make insoluble certain heavy metals and further reduce pathogens. Stabilization is an important first step to safe land application of sludge, and atlhough it reduces potential hazards of pathogens, organic chemicals, and heavy metals, it does not eliminate them. But, consider the following.

Pathogens. Anaerobic digestion greatly reduces pathogens, but not completely. The same is true for aerobic digestion, except that fairly completely aerobic and anaerobic digestion may result in a pathogen-free sludge. Composting provides a greater assurance of pathogen destruction than aerobic or anaerobic digestion because of the combination of thermal-kill and antimicrobial action. Heat-drying of sludge and composting normally allows adequate time and temperature for greater pathogen destruction.

Any pathogens surviving the stabilization process face further reductions of their numbers in the soil following land application. Sunlight, soil moisture, and temperature can all affect microorganism densities. Depending on conditions, bacteria, protozoa, and viruses generally are inactivated within a few days to a few months, but helminth ova—under high moisture and shade conditions—could survive for years in the soil.

Yet, hazards from infection by primary pathogens (infecting apparently healthy people) to compost site workers, communities surrounding compost sites, and people utilizing composts have been observed in studies to be very low. As a precautionary measure, however, use of respirators by compost workers and periodic water spraying of compost sites would further reduce the possibility of inhaling potentially harmful dusts.

Organic chemicals. Potentially harmful organic chemicals can occur in some sludges and could be the critical factor in future decision-making on land application. In particular, two groups of toxic organic compounds—organohalogen chemicals and polynuclear aromatic hydrocarbons (PAHs)—occur in municipal sludge. Organochloride chemicals resist degradation in soil, and may pass through the food chain to humans where they can bioaccumulate in fat and fatty tissues. Although some organochloride compounds are proven carcinogens in animals, none, except benzopyrene, has been implicated as a human carcinogen. PAHs, on the other hand, seem to be rapidly metabolized in mammalian systems.

Different chemicals, of course, behave differently in different soils, and one should not overlook the ability of land to degrade and buffer these chemicals. In fact, organic chemicals generally are not taken up by plants; rather, they stay in the soil.

Heavy metals. The most talked about, and probably the most studied, contaminants in municipal sludge are the heavy metals, particularly cadmium. Human and animal studies have shown that direct ingestion of relatively high doses of cadmium over a long period of time can cause deposition of the metal in the kidneys and liver, resulting predominantly in kidney dysfunction. Other metals present at times in sludge, such as lead and mercury, can exhibit central nervous system effects when consumed in large concentrations.

It is possible to ingest cadmium and other heavy metals as a result of eating food-chain crops fertilized with municipal sludge, either directly by consumption or indirectly by consuming animals that ate food-chain crops. However, one should be aware that Americans consume cadmium in their diets every day, without any contribution from municipal sludge.

FDA estimates that between 30 and 39 μg of cadmium are consumed by Americans every day in a typical diet, based on an average 50-year period. And, for those who smoke cigarettes—which contain between 1.5 and 2.0 μg of cadmium per cigarette—about 0.1 to 0.2 μg are inhaled for each cigarette. Thus, a person smoking a pack each day would retain some 25 μg of cadmium. Based on this information and risk studies, FDA recommends that the maximum acceptable dietary intake of cadmium be 70 μg/d, leading some scientists at EPA and elsewhere to extrapolate that annual application rates of sludge to crops containing cadmium at 0.5 kg/ha would only cause cadmium dietary intakes of 30 μg/d over the typical 39 μg/d and still be under the maximum 70 μg/d.

Risk assessments are difficult to develop and require a number of assumptions, some of which have been questioned. EPA has been criticized for one of its risk assessment scenarios, which assumed that the standard human for the cadmium assessment was a teenage American male who was a vegetarian, ate only vegetables grown on the same sludge-applied land, did so continuously for 50 years, and who may possibly be affected at age 70.

The 0.5-kg/ha approach has its critics too. Cadmium toxicity in soil

results from cumulative loadings, and some metropolitan sanitary districts contend that they would be unable to meet the 0.5-kg/ha application rate with their sludges. Others point out that yearly sludge application rates resulting in cadmium at 0.5-kg/ha are relatively light. Using the recommended application rates, a crop field would likely receive an overdose of nitrogen and phosphorus long before it would reach a toxic limit for cadmium.

Arguments aside, the ability to manage cadmium in the soil exists. Adjusting and maintaining the pH of soil to 6.5 and above substantially decreases plant uptake of heavy metals, and various plant and soil factors come into play, too.

Plant factors that affect uptake of heavy metals include:

- Soil-root barrier—varies not only with plant species but also plant strains (see Table 4);
- Plants absorbing heavy metals decrease the metals' activity in the soil;
- Metals taken up by plants accumulate preferentially in the stems and leaves and are not generally translocated to fruits and grains; and
- Metal toxicity in plants usually inhibits growth before concentrations toxic to humans have been reached in the plant parts used for food.

Soil factors that alter the uptake of heavy metals by plants include pH. clay content, cation-exchange capacity, redox potential, and soil texture.

There are certain mammalian factors that come into play when discussing food-chain bioaccumulation of heavy metals. For example, the bulk of any cadmium ingested is not retained in the body tissues; in fact, most would be rapidly excreted in the feces, leaving only 3 to 8% to be slowly excreted and retained.

Another factor in the land application debate is that the majority of food crops (grains and corn) that are grown on sludge-applied land are destined for animal feed purposes. As such, an animal barrier between humans and plants exists regarding heavy metal bioaccumulation in food-chain crops, thus effecting another safety factor. Regarding animal ingestion of plants grown on sludge-applied land or direct ingestion of sludge itself, studies show that although sludge contaminant levels will increase in animal tissues, there seems to be little hazard that heavy metals or persistent organics would be elevated above normal tissue levels, even for extended periods of time. In most cases, animals generally are not exposed to these potential hazards for very long during their lives.

Table 4—Relative accumulation of heavy metals into edible plant parts by different crops.

High uptake	Moderate uptake	Low uptake	Very Low uptake
Lettuce	Kale	Cabbage	Snapbean family
Spinach	Collards	Sweet corn	Pea
Chard	Beet	Broccoli	Melon family
Escarole	Turnip Root	Cauliflower	Tomato
Endive	Radish globes	Brussel aprouts	Pepper
Cress	Mustard	Celery	Eggplant
Turnip greens	Potato	Berry fruits	Tree fruits
Beet greens	Onion		
Carrot			

Note: Classification is based on response of crops grown on acidic soils that received a cumulative cadmium application of 5 kg/ha. It should not be implied that higher uptake crops cannot be grown on such a soil, or on soils of higher cadmium concentrations. Such crops can be safely grown if the soil pH is 6.5 or greater at the time of planting, because the tendency of the crop to accumulate heavy metals is significantly reduced as the soil pH increases above 6.5.

Source: U.S. EPA.

EPA and the politics of sludge

The 1977 amendments to the Federal Water Pollution Control Act provided new emphasis to the original Section 405, which up to that point only addressed the issuance of permits to dispose of wastewater sludges. Section 405(d) required the EPA administrator to develop and publish regulations providing guidelines for the disposal and utilization of sludge. And, in case anyone interpreted compliance with the guidelines to be solely voluntary, Section 405(e) noted that the guidelines were mandatory.

When EPA sought to regulate sludge, it found there was little available information regarding "how to" or "how not to" dispose of sludge. This paucity of data was of particular concern to construction grant applicants, who needed to document their sludge management plans as part of the application process. The result was the publication by the agency of "Municipal Sludge Management: Environmental Factors" (MCD-28), in October 1977, parts of which contained relevant *Federal Register* notices on sludge management.

EPA's next significant regulatory effort relating to sludge and land application came with the September 13, 1979, issuance of the criteria for classification of solid waste disposal facilities and practices (44 FR 53438-53468). The agency-intended follow-up regulations on the distribution and marketing of sludge were drafted, but never went any further because of being shelved to free up EPA staff to work on the new hazardous wastes emphasis that the agency initiated in 1980.

The marketing/distribution regulations have never seen the light of day, nor have the Section 405(d) regulations that were required within 1 year of the 1977 amendments. Many publicly owned treatment works (POTWs) are more than happy that these regulations have not been issued, because they would have required extensive record-keeping and monitoring of sludge concentrations and of sludge dis-

posal sites. Although the marketing/distribution regulations are being talked about at EPA for future consideration, action does not seem forthcoming. On the other hand, work to consider the needs of Section 405(d) has recently been initiated through the creation of a Sludge Policy Committee. Before anyone gets excited about this, consider that there have been a series of task forces and sludge committees in the past at EPA that were created with the same mission.

EPA's task force efforts in the past to resolve sludge disposal problems have been complicated by turnovers of staff through reassignment and changes in presidential administrations, causing delays until new task force members are briefed.

By far the biggest hindrance to EPA's resolution of sludge management is the overlapping of responsibilities between the offices of water and solid waste. The solid waste office traditionally was responsible for sludge disposal; but sludge produced by wastewater treatment plants built through the construction grants program prompted the water office to become more involved. Although both offices share the responsibility, the water office currently is more involved because of the solid waste office's efforts primarily toward hazardous wastes.

Nevertheless, there seem to be fundamental differences between the two offices on sludge management. The water office tends to emphasize the utilization role of sludge, whereas the solid waste office seems to adhere to the requirements of the Resource Conservation and Recovery Act—to protect health and safety first, and when that is achieved, then consider resource conservation. As such, the solid waste office promotes more regulation of municipal sludge use on land.

Yet, regulation of sludge may not occur because of the policies of the current administration. There is little argument that regulation is considered a dirty word by the Reagan Administration; so Section 404(d) regulations may not be forthcoming. In fact, when queried about whether the mission of the new sludge committee was to develop the regulations, EPA staff responded that the goal of the committee was to consider whether there was a need for regulations or whether the need could be satisfied through less prescriptive guidelines.

How the private sector fostered federal policy

There is an existing federal policy on land application of sludge for the production of fruits and vegetables, cosigned by EPA, USDA, and FDA in January 1981. What prompted the three agencies to break from the traditional policy of "no policy" on municipal sludge was the action by the Del Monte Corporation in February 1980, when it gave notice to the growers of its fruits and vegetables that it would not accept crops grown on soil to which wastewater sludge had been added. The company's official reason was that it viewed the existing EPA sludge application regulations as not providing enough safeguards for the company to guarantee protection for its customers.

Del Monte is the only food processor that has gone public with its concerns about sludge on land, but other processors agree privately, contending that because they do not control the farmer's rate of sludge application to land and that there are no tolerance levels for sludge contaminants in fruits and vegetables, they have no way of knowing whether their products are safe or not.

The federal agencies offered the federal policy to respond to the food processors' concerns, with little appeasement. The policy recommended the following:

- Sludge shall be applied at an annual rate not to exceed cadmium at 0.5 kg/ha, with cumulative loadings of cadmium not to exceed 5, 10, or 20 kg/ha, depending on background soil pH and cation exchange capacity;
- Soil pH shall be 6.5 or greater;
- If the sludge contains PCBs greater than 10 mg/kg, it must be incorporated into the soil;
- The sludge must be treated for pathogen reduction before being applied to the soil, and a 12- or 18-month waiting period may be required, depending on the degree of public access to the land; and
- Growers should use only "high quality" sludges on their lands, containing the necessary nutrients but with contaminant levels of not more than 25 mg/kg for cadmium, 1 000 mg/kg for lead, and 10 mg/kg for PCBs, on a dry weight basis.

Although critics of the federal policy said that it was vague and confusing, what probably damaged its credibility the most was a paragraph that was inserted at the insistence of FDA, which stated:

> Of necessity, it sould be understood that by following the guidelines of this document, the Federal government cannot offer any indemnity against product recall, seizure, or other enforcement actions, since these measures could result from unforeseen circumstances beyond the control of the Federal government. However, the risk of such enforcement actions would be no greater than the risks associated with normal farming or processing practices.

This caveat by the government did little to convince the food processors that the risks were "normal."

The Del Monte ban continues to exist, as does the federal policy; so the controversy continues. A December 3, 1981, letter from the National Food Processors Association (NFPA) to officials at EPA, USDA, and FDA stated the association's position regarding the use of sludge on cropland. Although recognizing that the use of sludge on cropland can be beneficial when proper management and safe sludges are used, NFPA felt that the poten-

tial risks to public health had not been adequately evaluated. Additionally, NFPA stated that:

- It wants the federal government to establish tolerance levels for residues of wastewater sludge that may be found in raw agricultural commodities.
- Sludge content analyses, the determination of sludge application rates, and all monitoring should be the responsibility of the sludge-generating municipality. Record-keeping should include specific locations where sludge has been applied, amount of sludge applied/unit area (dry basis), date of application, and results of soil and sludge analyses.
- The monitoring results should be available to the public.

Sludge and public acceptance

Because all sludges vary in their concentrations of contaminants, there are those sludges that are safe and those that are not. It is for this reason that federal, state, or local authorities are reluctant to state unequivocally that sludge use on land is safe. EPA has in principle supported land application of sludge for some time, but don't look for the massive promotional campaign; it has never existed, primarily because of EPA's inability to take a strong stance on sludge. In a 1980 guide put out by the agency on disposal of municipal sludge, the on disposal of municipal sludge, the section on land application of sludge discussed the question of liability by operators of land-spreading facilities and food processors as follows:

> . . . Ultimately such questions of liability are matters for the courts to resolve and are primarily *matters of State law*. Under most circumstances, compliance with Federal or State regulations and guidelines concerning land-spreading *may* provide a strong defense for POTWs against charges that they are responsible for the adverse consequences associated with land-spreading their sludge. Likewise, *written disclaimers* of *responsibility* for the effects of the sludge *may* also protect a POTW from liability. Nevertheless, it should be made clear that *neither* compliance with Federal or State regulations, *nor* written disclaimers, can guarantee that those participating in a sludge landspreading program would not be held liable for adverse consequences. (emphasis added)

EPA not only excluded itself from any responsibility for possible liability, but proceeded to explain how landspreaders and farmers could try to protect themselves in court. EPA's confidence in land application of sludge has traditionally been weak at best.

When public concern was raised a few years ago about Chicago's "NuEarth" sludge product containing high levels of cadmium, the EPA Region V office quickly responded to the public outcry by placing two-page ads in both major Chicago newspapers describing the hazards of sludge and cadmium. Hardly a vote of confidence for land application. Nu-Earth, incidentally, was eventually removed from the consumer market.

There is little argument also that the major consideration by Del Monte and the other food processors regarding landspreading sludge is the potential negative reaction from the public that the food they eat is being fertilized with their bodily wastes and other noxious chemicals. That a plaintiff would have little chance of proving his allegations in court regarding adverse effects from sludge is of little concern to a company such as Del Monte. The mere suggestion of guilt in the past has been enough to make some businesses go bankrupt, and so consumer-oriented Del Monte's position is "Why risk it?" Some can hardly blame the company for this approach.

In many cases, the concerns of the food processors and growers are justified. Although some POTWs monitor their sludges, others do not. Similarly, some states regulate sludges, and others do not. Regarding land application of sludge, more often than not, the farmer has little idea of the contaminants in the sludge he receives, and he controls the rate of application. NFPA has argued that farmers would be more amenable to using sludge on land if the generating POTW took the responsibility for monitoring that sludge is "safe" and for the accurate application of the product to the soil. Interestingly, this approach was to be part of the marketing/distribution regulations that EPA never issued.

Sludge and the POTW

A POTW can do much to improve the quality of the sludge it produces, but there are limits. Cities such as Chicago and Philadelphia have strict industrial waste ordinances, the enactment of which significantly decreased the heavy metal concentrations in treatment plant influents. A 40-city study by EPA of well-operating secondary treatment facilities showed typical heavy metal percent removals (median) of 61, 70, and 76% for cadmium, lead, and chromium, respectively; and for organics, 72% removal for cyanide and 75% for volatile organics.

There is, however, a catch to enforcing industrial compliance. Studies in several metropolitan areas have shown that the cadmium content of many treatment plant influents is predominantly from the non-industrial sector—in some cases over 60% of the cadmium.

Many metropolitan sanitary districts often find themselves in a no-win situation over sludge. Public adversity notwithstanding, the sanitary districts have long had to cope with EPA's lack of responsibility on the issue of sludge management. The Association of Metropolitan Sewerage Agencies made a series of recommendations on sludge man-

agement in September 1981, most of which were aimed at EPA and include that:

- All sludge management guidelines and regulations be the responsibility of a single individual in EPA, specifically the associate administrator for policy and resource management;
- A comprehensive set of guidelines for sludge management be developed incorporating cross-media comparisons for the selection of sludge management options; and
- EPA should give active support to municipal agencies in the siting process, including public education and technical assistance.

What do we do with sludge?

Sludge must be managed. Continued indecision could result in the material collecting on our doorsteps. The world we live in is not risk free, and the public adversity to sludge disposal and utilization will in the long run complicate the issue. Sludge can be managed; if it isn't, there will be "midnight dumpers" who *will* handle the situation—hazardously.

Based on the existing status of sludge management in this country, one thing is certain—with all the technical data and governmental guidance and regulation regarding sludge, few people are happy with the situation. Thus, regulation seems in order, and it should enhance a multimedia approach that *minimizes* risks in a realistic manner. Those who would be regulated are universal on one point—it is better to be regulated so as to know what must be done, than to be given no direction at all.

Land application of sludge and compost is currently the most widely practiced management option for sludge and presents the control medium that can be best monitored and controlled. The possible uses for sludge products are numerous and usually safe (strip mine reclamation and reforestation, for example). Regarding land application for food crop fertilization, it should be noted that the bulk of the crops produced are destined for animal feeds and not direct human consumption. Furthermore, concern is warranted for food crops when sludges contain harmful quantities of pathogens, chemicals, and metals; in these cases usage on food crops should be the lowest priority, in view of other, safer agricultural options, such as ornamental and sod farming.

Further research is needed on sludge management. Some researchers worry about the many unknown variables regarding organics in sludge and the need for food-chain trials to track sludge contaminants. WPCF recently compiled a report on the most important research needs concerning the treatment, utilization, and disposal of treatment plant sludges. The report can be obtained from the Federation.

For every horror story that surfaces in the news about the dangers of sludge, one should try to remember the success stories in Philadelphia, Chicago, Los Angeles and Orange Counties, Madison (Wis.), Salem (Oreg.), and other communities—successes that tend to buffer and outweigh those situations where we fail, but rarely make the news. As stated earlier, there is no epidemiologic evidence of harmful effects resulting from land application of sludge. Research has shown that proper management of sludge will protect public health. Without proper management, there will be little change in the public's opinion of sludge.

D. V. Feliciano

Sludge marketing: the quiet revolution

For most of the water pollution control profession, sludge is considered to be a problem in need of disposal. Rising quantities, pathogens, organic chemicals, heavy metals, odors, and political uncertainties all have pushed sludge to the forefront of many communities' water pollution control problems. But for a growing number of people, sludge isn't a problem—it's a product, and there's a market for it.

"Milorganite" is changing its bag design, and Bob Welch is excited. "We'll finally be getting rid of the warning label," he says, referring to the notice of heavy metals—particularly cadmium—prominently shown on bags of the Milwaukee sludge sold since 1978.

Welch is the marketing manager for Milorganite, a heat-dried sludge bagged and sold by the City of Milwaukee Sewerage Commission. Milorganite is big business—more than 54 000 metric tons (60 000 tons) of it are sold each year in 20-kg (44-lb) bags—shipped by rail cars from Milwaukee's treatment plants to every state in the U. S.

Thanks to an aggressive pretreatment program, the city has cut its cadmium levels to about 45 ppm, far below the levels found in the late 1970s that sparked the cadmium controversy. The warning has been changed to a recommendation for use on lawn, shrubs, and ornamental plants. The citizens' groups involved have "blessed" the new bag, according to Welch.

Milwaukee's success in selling sludge—with or without warning labels—is not new. The city has been selling sludge since 1928. What is new is the interest other communities have shown in selling sludge.

According to an unpublished survey prepared for the U. S. Environmental Protection Agency (EPA), about 50% of the sludge produced in the U. S. is now applied to the land, much of it going through distribution and marketing programs run by municipalities. The figure was only 25% a few years ago.

The reasons for the shift are complex. They include a significant turn away from ocean dumping by some large communities. That, combined with the development of a simple technology for composting of wastewater sludge by the agricultural scientists at the Beltsville Agricultural Research Center of the U. S. Department of Agriculture (USDA), has resulted in a quiet revolution in the acceptance of sludge distribution and marketing.

Many communities have found it easier to market their sludge to commercial growers and landscapers than to the general public. Others find farmers and agricultural interests willing to accept sludge, despite controversial bans by New York State and large growers such as Del Monte.

Distributing and marketing sludge is not cheap. Few communities recover their costs. Milwaukee, for example, sold $4 million worth of Milorganite in 1980, but still operates at a loss. Nonetheless, communities have turned to distribution and marketing as an environmentally acceptable disposal method with the lowest net cost.

The Philadelphia experience

Philadelphia has become the darling of the sludge marketers, for its total commitment to a comprehensive combination of sludge composting, bulk give-away, and sales. The city, which once dumped 63 500 metric tons (70 000 tons) of sludge in the ocean each year, now sells sludge through a contractor. According to Frank Senske, chief of sludge management for the city's water department, the project has enjoyed a relatively successful first year, although there have been marketing problems.

"We had a tough time cracking the market," says Senske, referring to the bagging and selling of what Philadelphia calls "Gardenlife."

Senske points out that "the real market was in commercial growers, landscapers, and contractors in the metropolitan area." The city extended the sales area to commercial growers in Maryland, Delaware, New Jersey, and New York State.

Philadelphia is under a consent decree reached in 1979 that called for the city to end ocean dumping of sludge beginning in 1981. The city approached the ban with research and creative technology. Marketing of sludge is only part of the sludge management program, which includes the reclamation of strip mines in western Pennsylvania and development of sophisticated recycling centers.

The city has its own set of effluent limitations for industrial dischargers to the city's treatment facilities. The result has been a significant lowering of metals concentrations in the sludge.

All sludge in Philadelphia goes through 15 days of anaerobic digestion, after which it is either used as liquid digested sludge (called "Philorganic"), or further processed. Liquid Philorganic is available to be sprayed or injected on grain or sod farms. The city used to give away dried Philorganic. But it recently discovered that sales could help offset part of the distribution costs.

The composted sludge, after it is screened, is sold to a contractor for $1 per ton plus a percentage of the contractor's gross sales. The contract calls for up to 36 000 metric tons (40 000 tons) per year to be sold by the contractor.

Would Philadelphia go back to the ocean after all its work on marketing and distribution? "It would be cheaper," says Senske. But Philadelphia, which has made a success out of a difficult situation, would think twice about the prospect.

A million bags

For Clay Kellogg, an independent sludge marketer who uses sludge from Los Angeles County, it's hard to understand the commotion about sludge. After all, he's been in the business for 54 years.

"For the first 25 years," Kellogg says, "we dealt pretty much with the farm trade." Now Kellogg sells several million bags of sludge a year, mostly from the Los Angeles County treatment plants, throughout the western U. S. "Anyone who says they don't like sludge," comments Kellogg, "never used it."

The primary problem in the marketing of sludge, according to Kellogg, is a "lack of understanding" of the product. "Most government agencies consider sludge to be a waste product," Kellogg adds. "If they spent as much money telling people how good it is, rather than what's wrong with it, it would be much less of a problem."

Sludge marketers throughout the U. S. are noting the increase in demand for their product. Joe Horvath, a Montana marketer, chose that state because of the high quality of the sludge available, and spent 6 years composting and selling sludge before he realized a profit.

"Last year," Horvath says, "we saw a 300% increase in sales of bags of sludge. But we've been pushing hard, with newspaper and television advertising. If I'd known the hardships involved, I wouldn't have gotten into it."

Horvath, who grew up with sludge composting projects in Hungary, finds the biggest problem in the U. S. is "overcoming the general ignorance" that the product is superior. His main sales outlets now are supermarket chains, garden stores, and nurseries.

Composting made simple

Sludge composting and bagging is not for every community. Most experts agree that a small community with nearby farms would be better off giving liquid digested sludge to farmers instead of composting. Some farmers prefer liquid sludge, with its higher nitrogen levels, over compost. But scientists at the Beltsville agricultural research center have developed a relatively simple composting process that could be used by many small communities.

In May 1980, USDA and EPA jointly published a "Manual for Composting Sewage Sludge by the Beltsville Aerated-Pile Method," and the Beltsville scientists now believe upwards of 200 cities are composting their sludge, about half by the Beltsville method.

"The process is low in costs, fairly simple to manage, and quick to start up," says George Willson, an agricultural engineer at the center. The manual identifies at least three markets for composted sludge:

- A high-profit but usually small market for intensive plant culture practices ("the luxury garden market");
- A market for restoration of disturbed lands by mixing compost into the unproductive soil of such areas as strip mines, road construction sites, gravel pits; and urban development; and
- A market for use as a fertilizer soil conditioner for farm crops.

"It is important to appraise the value of the compost for its potential uses," the report states. However, it adds that "a realistic evaluation of the potential market relative to the amount of compost produced is especially important."

Sludge for the nation's capital

One community that has benefited directly from the Beltsville research has been the Washington metropolitan area. Using sludge generated at the huge Blue Plains wastewater treatment plant in the District of Columbia, local governments have been able to produce compost and have had little trouble finding markets.

Some of the composted sludge has found its way to the National Park Service, which created Constitution Gardens on the Mall area of Washington with composted sludge. Compost has also been used on parks throughout the National Capital Parks area.

The largest composting project in the Washington area is now operated at Dickerson, Md., by the Maryland Environmental Service (MES), which produces up to 360 metric tons (500 tons) of compost each day. MES began an aggressive promotional effort in 1980, and developed a network of distributors and dealers. When MES compost went on the market in the spring of 1982, there was a big demand for the product. Like other large-scale operations, MES concentrates on selling to "the trade," which means landscapers, contractors, golf courses, and other big users of composted sludge. The manager of the sludge utilization program is Grove Teates.

Developing the market for the product took considerable planning. Teates spent an entire winter contacting greenhouse owners, landscapers, and representatives of institutional and government. Teates

believes such salesmanship is critical to the success of the program. "The last thing you want to do," he told a reporter, "is to drive up in a state vehicle wearing a three-piece suit and say, 'I'm from the state of Maryland and I'm here to solve all your problems.' That approach just does not work."

Modern marketing techniques are also important in give-away programs. Several midsize communities have created an identity for their sludge, complete with logos and trademarks.

Biogro: Sludge from Salem, Oreg., is applied to cropland in liquid form, using truck spreaders with special high-flotation tires. An intensive program of monitoring and record-keeping has convinced both farmers and local residents of the safety of the program. After 5 years of consistent use and testing, no harmful effects have been found.

Metrogro. Madison, Wis., uses truck spreaders to inject liquid digested sludge into farmland in the surrounding countryside. Madison's climate means that the sludge can be injected only from mid-March through November each year; a stockpiling effort solves the problem. The sludge program includes public meetings, intense monitoring and recordkeeping, and efficient delivery methods.

Many other sludge application programs are springing up across the U. S. An EPA report mentions agricultural reuse programs in small communities such as Binghamton, N.Y.; Effingham, Ill.; Manhattan, Kans.; and Little Falls, Minn.

Ironically, the EPA effort to publicize the recycling of sludge has encountered severe budget constraints. The report on Biogro and Metrogro was not published by EPA, but by the Southwestern Illinois Metropolitan and Regional Planning Commission.

Not only has EPA reduced the amount of information being published, the agency also has held up any regulations—required by the Clean Water Act—on the distribution and marketing of sludge.

The agency attempted to write regulations several years ago, but ran into a great deal of opposition over proposed levels of heavy metals in sludge.

The Reagan administration's strong emphasis on regulatory reform has put a crimp in EPA's writing of regulations. "It has caused us to seriously question whether regulations are appropriate," says David Davis, head of an EPA task force studying the problem. "Can they, for example, deal adequately with the wide range of local circumstances that distribution and marketing systems must be adapted to?" According to Davis, the entire regulatory process is under discussion.

Meanwhile, the quiet revolution of sludge composting and agricultural reuse continues. Some communities prefer the absence of regulations. "Any restrictions on the use of sludge will hurt," says Clay Kellogg of Los Angeles. "At least the delays show that EPA has been thinking about the problem."

Philadelphia's Frank Senske thinks "no city could meet those proposed regulations." Philadelphia sludge is registered with the Pennsylvania Department of Agriculture, which regulates fertilizers.

Milwaukee's Bob Welch says that in some ways he wishes EPA would come out with regulations. "At least we would know where they stood," says Welch. Milorganite is now sold in every state in the U. S. through 75 distributors.

Even environmental groups seem resigned to the lack of federal regulation on the distribution and marketing of sludge. "There's no way to get anything acceptable," contends Bill Forcade of Citizens for a Better Environment (CBE), a group that has done a considerable amount on work on the sludge controversies in Milwaukee and Chicago.

Forcade sees little hope for action at the federal level. "What is needed is someone to say sludge is safe. Any effort to do that at the federal level is likely to be petitioned, re-petitioned, and litigated forever."

Forcade's group has been working with local agencies instead of state or federal governments. Forcade has concluded that "states are reluctant to regulate sludge until the federal government makes up its mind."

In the meantime—with or without regulations—the marketing and distribution of sludge is likely to expand.

K. C. Flynn

Chaney -1-

APPENDIX D

In Proc. International Symp. Land Application of Sewage Sludge. Oct. 13-15, 1982. Tokyo, Japan. In Press.

FATE OF TOXIC SUBSTANCES IN SLUDGE APPLIED TO CROPLAND

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United States of America

1. ABSTRACT

Heavy metals and some organic compounds persist in soil long after applied to land. Unregulated sludge application can lead to phytotoxicity or food-chain risk under some conditions. Application of industrially contaminated sludges at high rates can cause phytotoxicity due to heavy metals such as Zn, Cu, or Ni, or excessive plant uptake and accumulation of Cd and certain organic compounds. The human food chain is protected from excessive levels of most elements in foods by the "Soil-Plant Barrier". Monitoring of sludge composition, limiting maximum levels of potentially toxic elements and organics in sludges, and regulating cumulative applications of potentially toxic materials, can prevent adverse effects on soil productivity and ensure crop safety (even under the conditions of very protective "worst-case" scenarios). The effects of certain sludge, soil, and crop characteristics on the potential for phytotoxicity or food-chain risk from sludge-borne cadmium and toxic organic compounds are discussed in relation to methods for risk analysis and control.

2. INTRODUCTION

This paper presents an overview on principles of movement of sludge-borne heavy metals and toxic organic compounds into the food chain. It summarizes the evidence showing why regulations are needed for land application of sewage sludge, and the scientific background for many of the regulations. The reader should be careful in interpreting

published research studies, since many experiments exceed metal applications or exposure conditions allowed in the U. S. regulations. Thus many of the examples of heavy metal phytotoxicity, excessive cadmium uptake, and excessive movement of cadmium and toxic organics into the food-chain reviewed here demonstrate the need for regulations to protect cropland and food-chain, rather than predicted results when sludges are utilized on cropland under present regulations. Results from studies with low metal sludges usually differ substantially from studies of high metal sludges. Thus, this paper especially discusses the results from utilization of recommended quality municipal sewage sludge.

3. BENEFITS OF SLUDGE UTILIZATION

One might ask, "Why put sludge on cropland at all?" There are many benefits of sludge use, and we should separate our consideration of risk from our consideration of benefit. Each sludge can supply macronutrients like nitrogen, phosphorus and potassium. Sludge is also a good microelement fertilizer; zinc, copper, and iron can correct deficiencies of those elements in soils and can be very beneficical (Chaney and Giordano, 1977). Sludge adds organic matter which acts as a soil conditioner; this improves soil physical properties and water holding capacity. Further, sludge-amended soils have to be cropped to utilize the applied nitrogen so that nitrate doesn't leach into the groundwater in excess. As long as sludges are applied at a rate that doesn't apply more nitrogen than the crop's need, sludge nitrogen is not really any different as far as potential for contaminating ground water with nitrate than is routine use of chemical fertilizers. Further, sludge use on cropland reduces net cost of sludge disposal.

A number of uses of sludge which can be especially beneficial were reported by other scientists in the Biological Waste Management and Organic Resources Laboratory: Hornick (1982), Sikora (1982), Colacicco (1982), and many other scientists. Another important beneficial use is in preparing soilless potting media (Chaney et al., 1980b). When compost-applied soluble salts are leached, potting media containing up to 50% compost, by volume, proved as good as the present best commerical media for vegetable transplants (Sterrett, 1980). Compost provided P, N,

microelements, and organic matter, yet compost use in potting media had no influence on heavy metal concentrations in edible parts of vegetable crops.

4. POTENTIAL PROBLEMS FROM SLUDGE USE

On the other hand, there are potential problems from sludge use which must be managed to protect cropland productivity and food safety. These are divided into two groups, the temporary and the persistent potential problems. The temporary potential problems are gone after the first year or at most 3 years after sludge is applied. These include malodor, surface run-off of pathogens, phytotoxicity from excessive soluble salts or too rapid biodegradation of inadequately stablized sludge, excessive nitrate leaching to groundwater if too much sludge N is qpplied, and if sludge is not treated properly, pathogens possibly could cause disease problems. On the other hand, if sludge or compost is used according to the regulations in the United States (EPA, 1979), none of these would be allowed to cause impacts.

After these temporary problems are all past (the pathogens are all dead, etc.), there remains the persistent potential problems, those that have to do with heavy metals, and with persistent organic compounds like the PCB's. These toxic materials have to be considered persistent because they remain in the soil for a prolonged period, heavy metals with a half-life of about a thousand years (Bowen, 1977), and polychlorinated biphenyls (PCB's) with about a 10 year half-life (Fries, 1982).

Besides sewage sludge, there are other urban wastes which are either now being utilized or are being considered for use on farmland and which require similar consideration of risk: wastewater irrigation, refuse composting and application, air pollution, and high Cu manures.

Potential problems from sludge-borne toxic materials fall into two general groups. First, is phytotoxicity (poisoning of plants); zinc, copper, nickel and boron are present in urban wastes and can poison plants. The second group have potential impacts on the food chain; Cd, Pb, Se, and Mo and PCB's are considered at length in this paper.

4.1 Sludge Composition

The real problem with sludge is that not all sludge is "domestic," containing low levels of potentially toxic materials.

Industries use the sewers too; in many cities those industries dump so much metals down the sewer that it results in very high levels of metals or toxic organics in sludge. Table 1 shows the range of heavy metal levels found in many sludges, typical median levels reported for several sludge composition surveys, and maximum levels for "Domestic" anaerobically digested sludges. Zinc, for example, varies from 500 to 50,000 ppm, a hundred-fold range. The lower levels are typical for sludges from suburban areas.

Sludge contains much higher levels of many elements than do soils, even when the sludge arises from domestic (non-industrial) sources (Sommers, 1980; Chaney, 1980). Recent British surveys have shown the wide range in Co, F, and Mo as well (Sterritt and Lester, 1981; Rea, 1979; Davis, 1980). For the time being we must consider land application of not only the low metal level "Domestic" sludges, but also the industrially polluted sludges with high levels of metals or organics.

Refuse composts usually contain somewhat lower levels of heavy metals than most sewage sludges (Law and Gordon, 1979, Haynes et al., 1978). Co-composting sewage sludge with refuse usually raises metal and nutrient levels. Refuse can contain excessive levels of B (Purves and Mackenzie, 1974; Gogue and Sanderson, 1973), while high B sludge has not been reported. The B in refuse appears to come from glues used on labels and cardboard. The Cd in refuse comes largely from pigments and stabilizers used in plastics; Cd is usually only 2-4 ppm in refuse composts since much of the plastics are removed during screening.

4.2 Heavy Metal Reactions in Soils

When sludges are mixed into soil, chemical species of heavy metals present in the sludge are transformed and heavy metal availability to plants is controlled by the equilibrium processes of the amended soil. Metals and persistent organics are chelated by or adsorbed to soil constituents (organic matter, hydrous oxides of Fe, Mn, etc., clays) so that only very small amounts of the added metals remain soluble in the water phase of soil, the soil solution. A new book by Lindsay (1979) describes these equilibrium processes. Most of the soluble Zn, Cu, etc., in soil solution is present as chelates with low molecular weight organic

molecules such as fulvic acid; free metal ion activity is very low. Soil pH strongly affects each of these chelation, adsorption, or precipitation processes in soil; metal cation levels in the soil solution are reduced, and metal anion levels are increased, as pH increases. Metals in soil solution can move from the solid phases of soil to the roots and be absorbed by the plant. Soluble salts (Bingham, 1980) or organic chelators (Wallace et al., 1977) increase metal movement to the roots and uptake by plants.

5. PHYTOTOXICITY

When plants absorb exessive amounts of heavy metals, the plant can be injured and its growth reduced. Severe phytotoxicity can kill a plant or allow normal environmental stresses on plants to kill the plant. Of the elements commonly found in organic wastes, only Zn, Cu, Ni, and Mn are likely to cause phytotoxicity with improper management of sludge use. Because soil pH affects sorption of these metals by soil so strongly, soil pH has a dominant effect on potential for phytotoxicity. Further, natural soil Mn can become more plant available due to sludge use, and Zn plus Mn phytotoxicity result; this process is especially pH dependent (White et al., 1979). Excess Cu and Ni cause injury of the plant's roots, and Cu and Ni toxicity is generally expressed as yellow (chlorotic) young leaves which is Cu- or Ni-induced Fe-deficiency. Zn and Mn are translocated more freely to the leaves; although Zn and Mn can injure roots and induce chlorosis, their toxicity is usually manifested through injury of older leaves and reduction of plant growth through interferences with biological processes. Boron toxicity has resulted when sensitive crops are grown on soils amended with high rates of refuse compost (Purves and Mackenzie, 1974). We have previously reported on some of the phytotoxicity studies at Beltsville (Chaney et al., 1978c), and I have reviewed heavy metal phytotoxicity (Chaney and Giordano, 1977; Foy, Chaney, and White, 1978). A summary of responses of different crops to sludge applied metals is shown in Table 2. Most vegetable crops and legumes were relatively sensitive to metals in acidic soils.

USDA has provided recommendations for maximum cumulative applications of Zn, Cu, and Ni so that phytotoxicity will occur only under

conditions of poor pH management (and be fully corrected under pH conditions [$\geq$ 6.2] which are normal good agricultural management practices). Table 3 shows those recommendations.

Although phytotoxicity can result from these recommendations (sensitive crops, pH $\leq$ 5.5), phytotoxicity can cause the landowner to add limestone; the landowner is made aware of his mismanagement by the natural process of phytotoxicity. This, in turn, prevents high plant levels of Cd and other metals because visibly sick crops are substantially reduced in yield. This role of phytotoxicity will be discussed more in the food-chain section.

Sludges apply not only potentially phytotoxic metals, but also other materials (e.g. organic matter and phosphate) which counteract phytotoxicity. Mixtures of metals may not be as toxic as individual metals due to interactions. We have not seen phytotoxicity resulting from use of the very good low metal sludges and composts that are characteristic of the Washington D. C. metropolitan area. There appears to be a relationship between potential for phytotoxicity and absolute level of metals in sludge. The need to keep sludge metals low is not dealt with in US-EPA regulations (Chaney et al., 1980a), although it is part of the U.S. Department of Agriculture recommendations. It seems clear that potential for metal phytotoxicity problems is greater with high metal sludges and that application of high metal sludges on private cropland should be discouraged by Governmental regulations. Present regulations do not even consider phytotoxicity (EPA, 1979).

6. FACTORS AFFECTING MICROELEMENT UPTAKE

6.1 Microelement Properties

Each element has its unique chemical and physical characteristics in waste-soil-plant systems. If the compounds of an element are essentially insoluble at practical soil pH levels (5.5-8), then that element has a very low concentration in the soil solution and cannot be absorbed at an appreciable rate. If an element is adsorbed or chelated very strongly by the soil, even though it is not precipitated, it has low uptake. If an element is weakly adsorbed, and not precipitated, then the element is subject to plant uptake or leaching through the soil.

6.2 Soil Properties

As noted above, soils adsorb and/or chelate many microelements. Adsorption occurs on hydrous oxides of Mn and Fe, clays, organic matter, and other soil minerals. Organic matter can chelate microelements. Adsorption, chelation, and dissolution of precipitated mineral forms of an element, are all pH-dependent. Cations are weakly bound at lower pH, strongly bound at high pH. Selenite and molybdate (anions) are more strongly sorbed at low pH than at high pH. Boron forms soluble H_3BO_3 at low pH and greater plant uptake occurs at low pH.

The pH of the soil immediately adjacent to plant roots (the rhizocylinder) is important in plant uptake of metals. Uptake occurs after movement (diffusion) of the metal from the soil particles to the root surface. When roots absorb NH_4^+, the pH of the rhizocylinder soil declines, and when the roots absorb NO_3^-, the pH rises (Barber, 1974; Smiley, 1974). The form of N absorbed by the root has a strong influence on metal uptake (Barber, 1974). Most crop N is absorbed as NO_3-N which raises rhizosphere pH (Nye, 1981). Use of NH_4-fertilizers also causes the pH of the bulk soil to decline since H^+ is generated when NH_4^+ is oxidized to NO_3^- (Jolley and Pierre, 1977).
Application of limestone corrects soil acidity. Applying excessive limestone minimizes metal cation uptake, but promotes uptake of anions. (Mo, Se).

Soil pH and organic matter are the soil factors most important in plant uptake of microelements. Other factors which influence uptake (soil temperature, soluble salts, added soluble chelators, soil moisture status, and fertility) have been reviewed (Foy, Chaney, and White, 1978; CAST, 1980; Sommers, 1980).

6.3 Common Errors in Study of Toxic Elements

Researchers have noted two types of major errors in experiments conducted to evaluate potential metal uptake into crops (CAST, 1980). First, the source of metals added may strongly affect the result; and second, the location in which the experiment is conducted may affect the result. The first error is generally called the "salt vs. sludge" error. When metals are added as soluble salts, they generally cause greater plant

uptake and toxicity than when applied as environmentally relevant forms such as sewage sludge or metal oxides in stack emissions. Metals in the wastes should be much nearer to equilibrium with sludge organic matter binding sites, or in sparingly soluble inorganic compounds, or occluded in $CaCO_3$ or other minerals. Sludge organic matter adds metal sorption capacity to the soil (Soon, 1981), and raises the soil C.E.C.; further, sludge adds hydrous oxides of Fe and other elements which can adsorb metals (Garcia-Miragaya and Page, 1978). Usually, the sludge source raises the pH of the sludge-soil mixture, while metal salts lower the pH by displacing adsorbed H+ from the soil. Soluble salts are greatly increased by the sulfate or chloride of the metal salts. Numerous authors have reported results in agreement with the above description (Singh, 1981; Cunningham, Keeney, and Ryan, 1975; Dijkshoorn, Lampe, and Broekhoven, 1981; Dowdy and Ham, 1977.

The second error is generally called the "greenhouse vs field" error. Greenhouse studies offer greater manageability and reproducibility, and lower cost than field studies. However, researchers have found that crop Cd, Zn, and Mn concentrations are increased 1.5 to 5 fold over field studies of the same soil, sludge, and crop. This appears to result from 1) use of NH_4-N fertilizers which lowers soil pH more in pots than field; 2) higher soluble salt levels in greenhouse pots than field due to smaller soil volume for required fertilizer salts; 3) confinement of plant roots to the small volume of treated soil in pots; and 4) abnormal watering of soil required in pots. The smaller the pots, the greater the error. DeVries and Tiller (1978) and deVries (1980), reported larger effects. Another common error in greenhouse pot studies is inadequate supply of required fertilizer nutrients to obtain maximum plant growth rates (Terman, 1974). Although pot studies in greenhouse and growth chamber allow the control needed to characterize details of soil-plant interactions, most researchers agree that regulations must be based on field research.

6.4 Plant Factors

Crop plants differ widely in uptake of an element, all other factors held constant (Chaney and Giordano, 1977; Sommers, 1980). Growing

on the same soil, spinach may contain 10 times more Zn than tall fescue, orchardgrass 15 times more Ni than corn, and chard 5 times more Cu than tall fescue.

Some plant differences are inherent in the uptake by roots (can be observed in nutrient solutions). Other differences in metal uptake are due to soil-plant interactions, and can be observed only in soil (pots in the greenhouse) studies. And still other plant differences can result from differences in root distribution in the soil with depth, and can only be found in field studies.

To date, plant differences are discovered by empirical research. Although specialists can select appropriate crops for specific metal-rich soils, they have a very limited data base to work from. Climate and soil drainage must also be considered in selecting crops for a particular soil.

6.5 Factors Affecting Microelement Translocation

After a microelement enters the root cells, its translocation to shoots is controlled by metal and plant characteristics. Root cell sap contains high levels of organic acids and amino acids which can chelate many elements. Membrane surfaces and proteins contain functional groups which can chelate some metals. Thus, a metal can be caught in the roots if chelates formed in the root cells sap can not be transported into the xylem. Xylem is the system of non-living tubes in plants in which water and nutrients are translocated from roots to shoots. Most metals reaching the xylem are pumped into it by specialized cells. These cells, and chelates formed in the root cytoplasm, control whether a plant translocates a metal.

Generally, Zn, Cd, Mn, B, Se, and Mo are easily translocated because they are weakly chelated. Copper, Ni, and Co are more strongly chelated; a much smaller portion of the absorbed Cu is translocated to shoots than of Zn. Lead, Cr, and Hg are so strongly held in the root cells that very little is translocated to the shoots of crop plants. Research has characterized chelation of Fe, Ni, Cu, Co, Zn, and Cd in xylem sap, but only Fe citrate has been unequivocally identified (Tiffin, 1967, 1971, 1972, 1977; Foy, Chaney, and White, 1978; White, Chaney, and Decker, 1981; Cataldo, Garland, and Wildung, 1981). Amino acids control

translocation of Ni and Cu in crop plants (Tiffin, 1971, 1977; Thompson and Tiffin, 1974; Cataldo, Garland, and Wildung, 1978; Cataldo et al., 1978). Citrate probably chelates Zn and Cd in xylem sap (White, Chaney, and Decker, 1981; Chino and Baba, 1981), although Cataldo et al., (1981) concluded that plant-absorbed Cd appeared in non-citrate complexes.

Many crops form storage or reproductive organs (edible roots or tubers; fruits; seed) which are used as food or feed rather than whole plant shoot. Crops differ widely in botanical type of storage organ formed, and in translocation of microelements into the organ as it forms. The stored fat, protein, and starch come from sugars and amino acids via phloem from foliar photosynthesis. Some species have close control on composition of their storage organs (corn; beans; fruits), while storage organs of other crops readily increase in microelements when the leaves are increased (wheat, oat, rice, soybeans; root crops) (CAST, 1980).

A further source of difference among crops can be expressed as a result of food processing. When many grains are processed into "refined" flour products, the starchy endosperm is separated from the mineral and fiber rich bran. Metals in rice, wheat, and corn refined products are substantially lower than in whole grain products (Hinesly et al., 1979; Chino, 1981; Kitagishi and Obata, 1981). However, oat groats contain the bulk of metals in oat grain (Kirleis, Sommers, and Nelson, 1981), and soybean cotyledons and normal soy protein products are as high in Cd as the whole grain (Braude et al., 1980).

7. FOOD-CHAIN CONSIDERATIONS

7.1 Pathways for Transfer of Toxic Chemicals in Wastes to the Food-chain

Liquid sludges can be spray-applied to cropland and tilled into the soil. Alternatively, liquid sludge can be sprayed onto forage or pasture land where it can contact plants and/or remain on the soil surface. Dewatered or dried sludges or composted wastes can be applied and mixed with or remain on the soil surface. These management options allow substantially different quantities of waste-borne toxic chemicals to enter the food chain, by quite different routes. Some options allow animals to directly ingest sludges, while other options use reactions in soils and properties of plants to largely prevent exposure.

7.1.1 Sludge adherence to existing crops

When liquid sludges (0-10% solids) are sprayed on pastures or forage crops, a thin film of the sludge coats the plant foliage. Research has found that some wastes dry and adhere strongly while others dry and flake off upon weathering. The first records of organic waste adherence came from a study of land application of high copper pig manure slurry (Batey, Berryman, and Line, 1972); forage grasses were enriched in Cu due to adhering manure.

Based on these findings, research was begun on sewage sludge adherence to forage crops and effects on grazing cattle. Chaney and Lloyd (1979) found that once liquid digested sludge dried on tall fescue forage it was not readily washed off by rainfall. Growth of the crop biomass diluted the sludge percentage in harvested forage. Sludge adherence was greater at higher application rates. Jones et al. (1979) found that sludge could be washed off forages before it dried, but not after. They also found that the amount of adhering sludge was approximately a linear function of the %-solids of the applied liquid sludge.

Sludge has adhered to all crops studied (Chaney and Lloyd, 1979; Lloyd and Chaney, unpublished; Jones et al., 1979; Bertrand et al, 1981). Sludge adherence is easily characterized since the levels of some microelements in sludge-contaminated forage are much greater than levels ordinarily possible by uptake-translocation by forage plants. Plant uptake and translocation to shoots of Cu, Pb, Cr, Fe, etc., is so limited that high levels of these elements indicates direct sludge contamination (see Chaney and Lloyd, 1979). Many reports on uptake of micro- elements from surface applied sludges presumed uptake when in fact sludge adherence fully explains their observations (Boswell, 1975; Fitzgerald, 1978). Industrial aerobic sludges adhere to forages in a manner similar to that of sewage sludge (Chaney and Hornick, unpublished results).

Another route for entry of microelements into the food chain is through farm equipment. Studies with pig manure indicate that organic wastes on the soil surface can be lifted and mixed into baled hay (Dalgarno and Mills, 1975).

When increased levels of microelements in forage indicate sludge

adherence, all constituents present in the sludge contaminate the forage. Not only microelements, but also macroelements, pathogens (Brown, Jones, and Donnelly, 1980), and toxic organics (Fitzgerald, 1978) are increased.

7.1.2 Ingestion of sludge-amended soil or sludge on the soil surface

Several research programs have established that grazing animals consume soil as a part of the normal grazing process. Teeth of sheep and cattle wear out more rapidly when the forage is contaminated with soil (Healy and Ludgwig, 1965; Nolan and Black, 1970). Study of the teeth wear problem led Healy (1968) to more fully develop Field and Purves' (1964) method of soil ingestion measurement in which the Ti level in forage and feces is compared to that of soil. Titanium present in soil is not appreciably absorbed and translocated by plants. Forage Ti level thus becomes a label for soil in/on forages. Healy, Rankin, and Watts (1974) found that wet weather and excessive stocking rates caused forages to be trampled into the soil, thereby increasing soil adherence to forages. Although soil was normally 1-2% of sheep's diet, it reached 24% in the worst cases. In other research, Mayland et al. (1975) and Mayland, Shewmaker, and Bull (1977) found that cattle grazing on dryland-grown crested wheatgrass consumed considerable quantities of soil. Because the cattle consumed plants complete with soil-laden roots, the ingested diet contained 20% soil. Silage contains soil as well, and the soil can interfere with microelement availability (Lamand, 1979). Fries et al. (1982) have recently reviewed soil ingestion by dairy cattle.

Ingested soil can cause Pb poisoning of livestock when cattle graze soil naturally high in Pb (Egan and O'Cuill, 1970; Harbourne, McCrea, and Watkinson, 1968; Thornton and Kinniburgh, 1978). Even after closure of a smelter, Pb enriched crop residues remain on the soil surface, exposing cattle to possible Pb poisoning. Reclamation of Pb-smelter-polluted rangeland required incorporation of the organic sward thatch into the soil to prevent ingestion by cattle (Edwards and Clay, 1977).

Similarly, sewage sludge or composted sludge are ingested from the soil surface. Decker et al. (1980) found 6.5% (1977) and 2.0% (1978) compost in feces of cattle grazing sludge compost fertilized pastures.

Compost did not adhere to the plant surfaces but lay on the soil surface.

Soil ingestion can also expose humans to waste-applied microelements in land treatment sites subsequently developed for housing. Some children and adults deliberately consume soil in a practice called "pica". If the soil is high in Pb (over 500-1000 ppm), individuals may absorb excessive amounts of Pb (Wedeen et al., 1978; Shellshear et al., 1975). Children also ingest soil and dust due to hand-to-mouth play activities and by mouthing of toys, etc. (Lepow et al, 1978; Sayre et al, 1974; Hammond et al, 1980; Baker et al, 1977; Rice et al, 1978; Roels et al, 1980; NRC, 1980a). Recent research has also identified potential risk to children from ingestion of smaller amounts of Pb (Needleman, 1979, 1980).

Soil or sludge ingestion can be an important process which allows entry of a sludge-borne microelement or toxic organic into the food chain especially when the element is normally not absorbed by plants (plant level < soil level). For some elements (Zn, Cd, Mn, Se, etc.), plant levels often exceed soil levels, and plant uptake is a more important process than soil ingestion. However, soil ingestion is a potential route for allowing excessive Pb, Fe, Cu, F, As, Hg, Cu, Co, Mo, Se, and other elements into the food chain. Further, soil ingestion can interfere with availability of microelements in plants to animals.

Research has shown that by applying sludge to recently mowed fields, waiting to allow the crop to grow and dilute the adhering sludge keeps the sludge content of forages below 3-5%. These practices coupled with use of sludges low in toxic materials protects the health of livestock and safety of animal food products. Subsurface injection of sludge removes this food-chain pathway for sludge-borne toxic materials.

Soil ingestion is an especially important pathway for persistent lipophilic toxic organic compounds. Harrison, Mol, and Healy (1970) found increased DDT in sheep grazing pastures where DDT was on the soil surface. They also studied lindane (Harrison, Mol, and Rudman, 1969; Collett and Harrison, 1968). Bergh and Peoples (1977) noted PCB movement from surface applied dewatered sludge to milk of a grazing cow, but did not estimate sludge ingestion. Hansen et al. (1981) noted PCB retention

by swine grazing a field where the surface soil was largely sewage sludge.

7.2 Soil-Plant Barrier" to Microelements in the Food-Chain

As discussed in the text regarding plant uptake of microelements, some elements are easily absorbed and translocated to food-chain plant tissues (e.g. Zn, Cd, Mn, Mo, Se, B), while others are not. These other elements are strongly bound to soil or retained in plant roots, and are not translocated to plant foliage in injurious amounts, even when soils are greatly enriched (e.g. Fe, Pb, Hg, Al, Ti, Cr^{3+}, Ag, Au, Sn, Si, Zr). Even though an element may be easily or relatively easily absorbed and translocated to plant foliage, phytotoxicity may limit plant levels of these elements to levels safe for animals (e.g. Zn, Cu, Ni, Mn, As, B).

During the last 40 years, these concepts were developed by many researchers. Important reviews of the research supporting these concepts have been prepared but had not named the general theory (Underwood, 1977; Allaway, 1968, 1977a, 1977b; Bowen, 1966, 1979; Baker and Chesnin, 1976; Chaney, 1980; Lisk, 1972; Kienholz, 1980; Loneragen, 1975; Reid and Horvath, 1980; Cataldo and Wildung, 1978; Leeper, 1978; Ammerman et al., 1977; Shacklette et al., 1978; Beckett and Davis, 1979; Page, 1974; and Walsh, Sumner, and Corey, 1976). Chaney (1980) introduced the term "Soil-Plant Barrier" to describe these concepts when considering waste-soil-plant-animal relationships of toxic microelements. A "Soil-Plant Barrier" protects the food chain from toxicity of a microelement when one or more of these processes limit maximum levels of that element in edible plant tissues to levels safe for animals: 1) insolubility of the element in soil prevents uptake, 2) immobility of an element in fibrous roots prevents translocation to edible plant tissues, or 3) phytotoxicity of the element occurs at concentrations of the element in edible plant tissues below that injurious to animals.

Unfortunately, the "Soil-Plant Barrier" does not protect animals from toxicities of all elements. The exceptions important in assessing risk from land application of municipal sludge are Cd, Se, and Mo; a few more elements may have to be considered for land application of industrial wastes (Be, Co). Ingestion of amended soil or sludge can circumvent the "Soil-Plant Barrier". Many elements are so insoluble or non-toxic that

animal health is not influenced even if ingested soil or waste contains the element (e.g., Cr^{3+}, Zr, Ti, Al, Sn, Si). However, direct ingestion of soil or wastes rich in some elements (e.g., Cu, F, Zn, Pb, Fe^{2+}, As, Co, and Hg) allows risk to livestock when risk would have been insignificant if the sludge were mixed with the surface soil (0-15cm).

7.3 Interactions Among Dietary and Sludge Constituents Influence Microelement Impact on Food-Chain

Evaluation of the potential impact of microelements on animals via their consumption of sludge, sludge-amended soil, or crops grown on sludge-amended soil, is very complex. Animal species differ in tolerance of microelements. Tolerance to microelements is also influenced by age; younger animals are generally more sensitive than older. Crop species absorb unequal amounts of microelements. Total and relative microelement uptake is affected by crop species and cultivar, soil pH, organic matter, soil temperature and other factors. Wastes differ in levels of elements and ratios among elements. Individual potentially toxic elements interact with other elements in the diet, often reciprocally. These interactions are often the basis for physiological toxicity; hence, interactions are of great importance in assessing risk.

Interactions affecting Cu deficiency in ruminant animals were among the first studied, and have been intensely examined because of their practical significance. Animals can experience simple Cu deficiency, Mo-induced, sulfate-induced, or Zn-, Cd-, or Fe-induced Cu deficiency. Among the most complex is the 3-way Cu-Mo-S interaction. Dietary sulfate is reduced to sulfide in the rumen; sulfide reacts with Mo to form a thiomolybdate. Thiomolybdate reacts with Cu to form an insoluble compound which is unavailable and is excreted; this leads to depletion of liver Cu reserves and subsequently to clinical Cu deficiency (Mills et al., 1978; Bremner, 1979; Spence et al., 1980). Copper is of lower bioavailability in young forage plants than mature plants, and in fresh forages than in dried hay (Hartmans and Bosman, 1970). Forage species differ in bioavailability of Cu (Stoszek, et al., 1979). Soil consumed with forages reduces Cu absorption by sheep, perhaps due to soil Mo, Zn, or Fe but probably due to Cu sorption by soil constituents preventing Cu absorption

in the intestine (Suttle, Alloway, and Thornton, 1975).

After the Cu-Mo-S interaction in ruminants was identified, it became clear that Zn, Cd, and Fe also interact with Cu bioavailability to both ruminants and monogastric animals (Bunn and Matrone, 1966; Hill et al., 1963; Matrone, 1974; McGhee, Creger, and Couch, 1965; Mills, 1974, 1978; Standish et al., 1971; Standish and Ammerman, 1971; Suttle and Mills, 1966; Campbell and Mills, 1979; Bremner and Campbell, 1980). Reciprocally, high dietary Cu interacts to reduce absorption and toxicity of Zn, Fe, and Cd (Bunn and Matrone, 1966; Grant-Frost and Underwood, 1958; Cox and Harris, 1960; Lee and Matrone, 1969; L'Estrange, 1979; McGhee, Creger, and Couch, 1965). Other elemental interactions have been studied and found to be important in assessing risks (Underwood, 1977; Matrone, 1974; Levander, 1979; NRC, 1980b; Mills and Dalgarno, 1972; Mills et al., 1980; Mahaffey and Vanderveen, 1979; Fox, 1974, 1979; Fox et al., 1979; Bremner, 1979.)

In many cases, food chain toxicity is a result of microelement imbalance as much as it is a result of increased supply of one potentially toxic element. When one element is so increased that the ratio of it to other elements or dietary constituents is great enough to induce a deficiency of another, then animal weight gain declines and a health effect is observed. Chaney (1980) noted that domestic sewage sludge contains a mixture of potentially toxic elements. Consumption of sludge or sludge-amended soil is a very different case for risk assessment than standard toxicological studies where a soluble salt of one element is added at rates to cause health effects (and often to purified rather than practical diets). With sludge ingestion, increased levels of dietary Zn are balanced by increased levels of Cu and Fe. Recently, research on potential toxicity from ingestion of high Cu swine meanure has led to the same conclusion -- interactions can reverse toxicity predicted from "toxicology" studies (Bremner, 1981; Poole, 1981). A number of elements are considered in regard to sludge-soil-plant-animal interactions influencing the food chain in my other publications (Chaney, 1980, 1982), and are summarized in Table 4. Cadmium is discussed below.

An important reference for tolerance of microelements by animals has recently been published by the National Research Council (NRC, 1980b). The NRC committee considered increased levels of only the element being evaluated, although they discuss interactions. Their tolerance levels are shown in Table 4. Unfortunately, these levels may not be valid for sludge fertilized crops or for ingestion of sludge or soil because of the noted interactions.

7.4 Potential Food-Chain Impacts of Cadmium Applied in Organic Wastes

7.4.1 Cadmium in Soils and Crops

Cadmium is not essential for plants. Although one study indicated Cd was essential for rats (Schwartz and Spallholz, 1978), it is not generally agreed that Cd is essential for animals (NRC, 1980b; Fox et al., 1979).

It now appears that Cd activity in most soils is controlled by adsorption rather than by formation of crystalline inorganic compounds (Street, Lindsay, and Sabey, 1977; Soon, 1981). Street, Lindsay, and Sabey (1977) found that $CdCO_3$ can form in low cation exchange capacity, low organic matter, calcareous soils. Under anaerobic conditions, CdS forms in soil; CdS has very low solubility and is unavailable to plants (Takijima and Katsumi, 1973; Bingham et al., 1976b) but is readily oxidized in aerobic soil. Unfortunately, formation of CdS is not a practical management practice to minimize Cd uptake for crops other than rice.

A recent consensus review of Cd relationships in sewage sludge, soil, and plants summarized this complex topic (CAST, 1980). Of all soil properties affecting Cd level in plants, soil pH has the greatest effect. Increasing soil pH causes stronger adsorption of Cd by soil and reduces Cd uptake. Of other soil chemical properties, soil organic matter has been shown to have some effect; since higher organic matter reduces Cd uptake (e.g., White and Chaney, 1980). Other soil factors which affect Cd uptake include: temperature, soluble salts, chelators, and water status (Haghiri, 1974; Giordano, Mays, and Behel, 1979; Wallace et al., 1977; Bingham, 1980; Shaeffer et al., 1979).

The CAST (1980) report also summarized evidence which indicates that soil Cd remains crop available for a prolonged period after application. Availability to crops decreases only in calcareous soils. These conclusions are based on sludge field plots, sludge utilization farms, (CAST, 1980) and natural high Cd soils (Lund et al., 1981). Recent studies by Lloyd et al. (1981) indicated that sludge applied Cd remained nearly 100% labile many years after application.

Crops differ remarkably in their Cd accumulation, Cd tolerance, and translocation of Cd to edible plant parts (CAST, 1980; Bingham, 1979; Bingham et al., 1975, 1976a, 1976b; MacLean, 1976; Furr et al., 1976a, 1976b; Dowdy and Larson, 1975; Chaney and Hornick, 1978). Figure 1 shows Cd concentration in leaves and edible plant tissues of many crops grown on a neutral pH sludge amended soil containing 10 ppm Cd (based on data from Bingham et al., 1975, 1976a, 1976b). Tobacco, lettuce, spinach, chard, endive, cress, and turnip accumulate much higher foliar Cd levels than other leafy crops (e.g., kale, collards, cabbage). Although Cd in edible root of radish, turnip, and beet is only a small fraction of the Cd level in the shoots of the plants, carrot root Cd is about half of carrot leaf Cd. Similarly, the ratio (Cd in grain):(Cd in leaf) ranges from very low for corn to relatively high for wheat, oat, and soybean; Chaney, White and Tienhoven (1976) found that this ratio in soybean was reduced from >1 to <0.2 by increasing soil Zn.

The wide variation in crop tolerance of Cd causes difficulty in assessing the impact of soil Cd on the food chain. The foliar Cd associated with phytotoxicity (25% yield reduction) varies in different crops from 7 to 160 ppm dry weight (Bingham, 1979). Further, the foliar Cd concentration causing 50% yield reduction in lettuce and chard is greater in acidic soils (470 ppm in lettuce; 714 ppm in chard) than in calcareous soils (160 ppm in lettuce; 203 ppm in chard) (Mahler, Bingham, and Page, 1978). Some plants are unusually tolerant of Cd; Simon (1977) and Wigham, Martin, and Coughtrey (1980) have reported tolerance of Cd by ecotypes of grasses adapted to Cd-enriched Zn and Pb mining wastes. In summary, phytotoxicity of Cd does not limit crop Cd to acceptable levels.

7.4.2 Cd in the Food-chain

Cadmium is an unusual and difficult case for evaluation of risk to the food chain. In contrast to other elements, Cd has a quite long biological half-life in humans -- generally considered 20 years. Absorbed Cd is bound to a low molecular weight protein to form metallothionein which is accumulated and retained in the kidney for a long period. High metallothionein-Cd in the kidney can lead to adverse health effects in the kidney.

Over one's lifetime, chronic food chain Cd exposure can cause different health problems than those experienced from acute exposure. Long-lived animals (e.g., humans) are at greater risk of this health effect than are short-lived animals (wildlife; domestic animals). Accumulation of Cd in organ meats (liver, kidney) was the basis for suggesting a low dietary Cd tolerance in domestic animals rather than a direct health effect to the animals (NRC, 1980b).

The potential risk of excess soil Cd to humans has been clearly documented. Adverse health effects resulted from prolonged consumption of foods grown locally on Cd enriched soils (Tsuchiya, 1978; Friberg et al., 1974; Fulkerson and Goeller, 1973; Hammons et al., 1978; Yamagata and Shigematsu, 1970; Kobayashi, 1978; Nogawa, 1978). A large number of Japanese farmers suffered Cd health effects after long-term ingestion of Cd-enriched rice grown in paddies polluted by Zn- and Pb-mining wastes or Zn-, Pb-, and Cu-smelter emissions in at least 7 different areas of Japan (Kobayashi, 1978; Takijima and Katsumi, 1973; Shigematsu et al., 1979; Kjellstrom, Shiroishi, and Evrin, 1977; Kojima et al., 1979; Saito et al., 1977; Nogawa, 1978; Nogawa, Ishizaki, and Kawano, 1978; Nogawa and Ishizaki, 1979; Nogawa et al., 1975; 1980). Rice Cd concentration and number of years exposure were both strongly related to the incidence rate of Cd health effects. A smelter enriched area in Belgium may have caused Cd-indiced renal disease (Roel et al., 1981a) although route for exposure and increased kidney Cd have not yet been demonstrated.

The name "itai-itai" disease (translated as ouch-ouch disease) came from expressions of pain by elderly women suffering repeated bone fractures due to Cd-induced osteomalacia. Although the osteomalacia

brought attention to this environmental Cd disease, severe osteomalacia does not frequently result in humans ingesting excessive Cd. Renal proximal tubular dysfunction (Franconi syndrome) is the first health effect of excessive chronic Cd exposure. The renal disease had high incidence in areas where Cd exposure was increased, and showed a dose-response relationship with Cd exposure (expressed as "Cd level in rice-times-years ingested"). All individuals with advanced itai-itai disease had severe proteinuria characteristic of the kidney disease. Renal disease subsequently proceeded to osteomalacia in some workers who ceased exposure when the kidney disease was identified (Kazantzis, 1979). However, this aspect of Cd disease is poorly understood. Sub-clinical osteomalacia is found in many of the Japanese farmers who experience renal disease (Mulawa, Nogawa, and Hagino, 1980).

Renal tubular dysfunction (Franconi syndrome) resulting from Cd ingestion is quite different from classic kidney failure. Franconi syndrome seldom proceeds to kidney failure requiring dialysis. Kjellstrom (1978) indicated that Franconi syndrome (low molecular weight proteinuria, glucosuria, aminoaciduria, phosphaturia, etc.) is the first Cd health effect; if Cd-exposure (rate-times-duration) is increased, kidney stones and osteomalacia/osteoporosis may result. Kjellstrom, Friberg, and Rahnster (1979) found greater mortality (shorter life span) in Cd exposed workers, but this may not be relevant to ingested Cd. Neither hypertension nor prostrate cancer incidence are increased even when proteinuria is severe (Friberg et al., 1974; Doyle, 1977; Hammons et al., 1978; Tsuchiya, 1978; Ryan et al., 1979; Commission of the European Communities (CEC), 1978; Kjellstrom and Nordberg, 1978; Kjellstrom, Friberg, and Rahnster, 1979; Pahren et al., 1979; Lauwreys et al., 1980; Nogawa, 1978; Shigematsu et al., 1979). Although laboratory studies with rats and other animals have shown that anemia, enteropathy, and teratogenesis (due to Cd-induced Zn or Cu deficiency in the fetus) can result from ingested Cd, these are very unlikely with practical diets.

A number of researchers and groups have attempted to clarify the dose-effect and dose-response relationships for Cd (CEC, 1978; Friberg et al., 1974; Kjellstrom and Nordberg, 1978; Ryan et al., 1979;

Tsuchiya, 1978; Hammons et al., 1976). The first sign of renal tubular dysfunction (increased excretion of B_2-microglobulin, a specific proteinuria characteristic of Cd injury) is generally agreed to occur at about 200 mg Cd/kg wet kidney cortex. Some research indicates that the critical kidney cortex Cd level may be as high as 300 mg/kg (Roels et al., 1981), but 200 mg/kg is the level generally accepted for use in risk analysis.

Kjellstrom and Nordberg (1978) developed a sophisticated multicompartmental dose-effect model for Cd metabolism in humans: "This present model predicted that a daily intake corresponding to 440 µg at age 50 would give 200 µg Cd/g of (wet) kidney cortex at age 45-50." These results were obtained by assuming a high, constant Cd concentration per unit calories, and that calorie (hence Cd) ingestion varied with age in the manner of the average diet of the Swedish population. The "best fit" calculated 4.8% lifetime average absorption of dietary Cd, 440 µg Cd/d at age 50, and a 12 year biological half-life for Cd to achieve the 200 µg Cd/g wet kidney cortex at age 45-50.

Other researchers have used different ways to express Cd-exposure information, thus complicating interpretation of results from these many sources. In the U.S., the Food and Drug Administration (FDA) has measured food Cd concentrations and average Cd ingestion (FDA, 1977). Food consumption was based on USDA's 1965 dietary intake survey but adjusted; FDA, USDA, and EPA agreed to use a food consumption model based on teenage males (highest food consuming group) in a pesticide residue survey program. Thus, for the same food supply, a mean food Cd ingestion of 39 µg/day from FDA corresponds to about 23 µg/day intake at age 50 in Kjellstrom and Nordberg's (1978) model. Their model reflected 3430 cal/d for Swedish teenage males vs. 2045 cal/d for 50-year-old Swedish individuals (Fig. 4.32 and 4.34 in Friberg et al., 1974). Thus, the critical 440 µg Cd/day ingestion rate for 50-year-old individuals in Kjellstrom and Nordberg's (1978) model corresponds to approximately 738 µg Cd/d ingestion in U.S. teenage male diets. The present exposure is only 5.2% of the critical exposure (23 ÷ 440 or 39 ÷ 738).

Chaney (1980) and Ryan et al. (1979) discuss difficulties in interpreting dose-response relationships for dietary Cd. Individuals vary widely in self-selected diet and dietary Cd (Yost, Miles, and Parsons, 1980), in Cd absorption rate (Flanagan et al., 1978; McLellan et al, 1978), and in sensitivity to absorbed Cd. These phenomena are generally assumed to vary in a log-normal fashion in a population. Kjellstrom (1978) extended the 440 µg/d model "critical" level to a population by arbitrarily using a geometric standard deviation of 2.35 based on studies of Cd in autopsy tissues (see Ryan et al., 1979 for details). However, Kjellstrom's (1978) model would require greater than 100% absorption of dietary Cd by the most sensitive individuals (see Figure 1 in Chaney, 1980). The highest Cd absorption rate observed for humans is 25% reported by Flanagan et al. (1978) for a woman with mild anemia; Fe stress strongly increases Cd absorption. Several researchers (Chaney, 1980; Ryan et al., 1979) argued that it was unreasonable to extrapolate the 440 µg Cd/d "Average Human" model result to an assumed maximum sensitivity group with greater absorption of Cd than ever observed in humans. Further, individuals are unlikely to be in this greatest risk group for their whole lifetime.

Ryan et al. (1979) concluded that a 200 µg/d (150 µg/d after protecting smokers) threshold model (based on average lifetime daily Cd intake) was more appropriate for dose-response considerations, as did the CEC (1978) workgroup. This value corresponds to about 14.1% lifetime Cd absorption rate for the most sensitive individuals [4.8(440/150)].

7.4.3 Cd bioavailability

Cadmium absorption by animals is strongly influenced by other dietary factors (Fox, 1976, 1979; Fox et al., 1978, 1979; Jacobs et al., 1978a, 1978b, 1978c; Flanagan et al., 1978; Welch, House, and Van Campen, 1978; Welch and House, 1980; Neathery and Miller, 1975; Kostial et al., 1979; Cousins, 1979; Kobayashi, 1978; Washko and Cousins, 1977). Iron status of the animal appears to be the most important control of % absorption of Cd. Zinc status of the animal and dietary Zn level is the next most important factor, followed by dietary Ca. Protein and fiber in the diet and age of animal also influence Cd retention. These factors

should allow a greater %-absorption rate for women than men. Women as a group showed greater Cd absorption (Flanagan et al., 1978), and women's kidney Cd exceeds men's in autopsy kidney studies, as did women's susceptibility to excessive dietary Cd in Japan.

Dietary interactions can thus influence bioavailability of Cd. Leafy and root vegetables which are enriched in Cd may also be a good dietary supply of Zn, Fe, and Ca. Leafy vegetables have been shown to provide bioavailable Fe and Zn (Welch, House, and Van Campen, 1977, 1978; Van Campen and Welch, 1980; Wien, Van Campen, and Rivers, 1975). Chaney (1980) suggested that leafy and root vegetables grown on soils enriched in Cd from being fertilized by low Cd, low Cd:Zn sewage sludges comprise a separate risk scenario. In this case, consuming sufficient food Cd to pose a risk to susceptible individuals would result in increased dietary Fe, Zn, and Ca, thereby shifting the individuals to a less susceptable population group.

Feeding studies have been conducted with sludge and with crops grown on sludge-fertilized soil. Ingestion of sludge Cd has been evaluated in ruminant and monogastric animals with most work done with cattle. When sludges with high Cd and high Cd:Zn were fed, kidney Cd was significantly increased (Kienholz, 1980; Baxter, Johnson, and Kienholz, 1980; Hansen and Hinesly, 1979; Hinesly et al., 1979; Edds et al., 1980; Fitzgerald, 1980; Johnson et al, 1981). However, when sludges with lower Cd and low Cd:Zn were fed, kidney Cd was not significantly increased (Decker et al., 1980; Kienholz, 1980; Baxter, Johnson, and Kienholz, 1980; Smith et al., 1977; Smith, Kiesling, and Sivinski, 1978; Edds et al., 1980; Smith, Kiesling, and Ray, 1979; Smith et al., 1980). Sludge Cd was less bioavailable to swine than equal Cd added as $CdCl_2$ (Osuna et al., 1979; Edds et al., 1980). Food products of animals are unchanged in Cd except for liver and kidney (e.g., Sharma et al., 1979). Kienholz (1980) noted that dietary interactions could avoid even this impact of sludge Cd. Thus, risk analysis for ingested sludge Cd requires evaluation of several factors other than dietary Cd concentration.

Similarly, risk analyses for ingestion of Cd in foods grown on Cd-enriched soils requires careful evaluation of factors other than Cd.

Far too little research has been conducted to characterize bioavailability of food Cd. Further, very little of the completed research conforms with the experimental designs which Fox et al. (1978, 1979) and Fox (1976) indicated were needed to allow interpretation. Dietary Cd level should correspond to the range of nutritional relevance to humans. Intrinsically Cd labelled foods should be fed in the state ordinarily ingested by humans (e.g., fresh leafy vegetables). Nutritional status of the experimental diet should be adequate for all known essential factors or varied as part of the experiment. The feeding period should be of sufficient length to allow nutritional status of animals to be under control of experimental diet for the bulk of the experimental period. Several animal species should be studied. Bioavailability of Cd in a food or a sludge grown food can only be determined experimentally.

7.4.4 Cd in tobacco

Tobacco is an especially high risk crop in terms of potential for Cd effects on humans. Among all crops studied to date, tobacco accumulates more Cd per unit soil Cd than any other (Chaney et al., 1978a; MacLean, 1976). Tobacco is normally grown on strongly acid soils to prevent crop loss from root diseases. This soil pH management leads to maximum Cd uptake under normal crop production conditions. In contrast, most other crops are best grown at pH 6.5 to 7. Tobacco is normally high in Cd compared to leaves of other crop plants, and high leaf Cd levels in some production areas are being studied (Frank et al., 1977; Westcott and Spincer, 1974). When tobacco is grown on sewage sludge-amended soils, crop Cd level can be increased from 1 to as high as 44 ppm Cd in dry leaves (Chaney et al., 1978a) with only 1 ppm soil Cd.

Cadmium in tobacco is an important source of Cd for humans. Individuals who smoke one pack of cigarettes per day have about 50% higher Cd in kidney cortex than non-smokers (Lewis et al., 1972; Elinder et al., 1976). About 15% (5-25%) of cigarette Cd enters the mainstream smoke (Szadkowski et al., 1969; Menden et al., 1972; Westcott and Spincer, 1974). Filters can remove much of this Cd and reduce Cd exposure of smokers (Westcott and Spincer, 1974; Franzke, Ruick, and Schmidt, 1977). Based on the potential of sludge-applied Cd to increase risk of chronic

kidney disease in smokers if sludge were applied to tobacco cropland, EPA (1979) regulated and discouraged this practice.

7.4.5 Setting limits on Cd application

Several food crops are of especial importance to evaluating Cd-risk for humans. While grains supply much Cd to individuals in the general population (Braude, Jelinek, and Corneliussen, 1975; Jelinek and Braude, 1978; Ryan et al., 1979), gardeners are unlikely to grow a significant portion of their food grains. Rather, individuals are likely to grow leafy and root vegetables, legume vegetables, garden fruits, and potatoes. If the Cd:Zn ratio of an acidic Cd-enriched garden soil is high, edible crop tissues of leafy, root, and legume vegetables, garden fruits, and potatoes can be greatly increased in Cd concentration with no injury to the crop and provide excessive bioavailable Cd. If the Cd:Zn ratio of an acidic Cd-enriched garden soil is low (≤ 0.010), these crops are not greatly increased in Cd when Zn phytotoxicity limits crop yield, and bioavailable Cd would be only slightly increased. The difference in risk from low Cd:Zn and high Cd:Zn gardens is due to: 1) Zn-phytotoxicity at low pH in the low Cd:Zn garden causing the gardener to add limestone which reduces crop Cd or have little yield (hence, reduced exposure), 2) interactions between Cd and Zn in plant uptake and translocation to edible plant tissues (Chaney, White, and Tienhoven, 1976; Chaney and Hornick, 1978); and 3) interactions in the diet which influence Cd bioavailability (Chaney, 1980).

It is much more difficult to evaluate Cd bioavailability from foods grown on waste-amended soils than from Cd-amended purified diets. Freeze-dried lettuce and chard grown on acidic soils amended with domestic sludge were fed at a high % of diet to mice or guinea pigs (Chaney et al., 1978b, 1978c). Although dietary Cd was increased by up to 5-fold by lettuce or chard grown on acidic, domestic sludge-amended soil, kidney Cd was not increased. In other studies with high Cd and/or higher Cd:Zn sludges, feeding sludge-grown crops has caused increased kidney Cd (Chaney et al., 1978b; Miller and Boswell, 1979; Bertrand et al., 1980; Williams, Shenk, and Baker 1978; Hinesley, Ziegler, and Tyler, 1976). Clearly, many more sludge-soil-plant-animal studies are needed to characterize the

bioavailability of Cd in crops grown on waste-amended soils. It seems very likely that factors besides background soil pH, and annual and cumulative Cd application will eventually have to be considered in setting allowed Cd loadings on land treatment sites (EPA, 1979, 1980b; Chaney, Hornick and Parr, 1980).

Much of the potential risk from Cd in waste-amended soils has now come under regulation in the U. S., although these regulations do not have to be enforced for several more years. The highest risk case, application of sludges to gardens as fertilizers or soil conditioners, has not yet been regulated (Comptroller General, 1978; Chaney, Hornick and Parr, 1980). Further, pretreatment of Cd-bearing industrial wastes, segregation of waste streams, and avoidance of Cd use for non-critical applications offer great opportunity to avoid all Cd health effects (Dage et al., 1979; Gurnham et al., 1979; Chaney and Hundemann, 1979).

In the process of developing Federal Regulations for land application of sewage sludge (EPA, 1979), EPA prepared a "worst case" scenario relating sludge-applied soil Cd to potential for kidney dysfunction (EPA, 1979b). The worst case which may occur appears to be the acid garden case. Individuals in the U.S. do not grow their own food grain on acidic, Cd-enriched soils. Similarly, consumption of liver and kidney enriched in Cd from sludge utilization, is a minor source of dietary Cd.

Thus, the acidic garden scenario was used. It presumed that 1) the garden contains the full allowed Cd application, 5 kg/ha; 2) the garden is continuously acidic, about pH 5.5; 3) the gardener obtains 50% of his annual supply of garden vegetables from the acidic, sludge-amended garden, including potatoes, leafy, root, and legume vegetables, and garden fruits; 4) the individual eats these amounts of garden vegetables for 50 years from the acidic sludge-amended garden; and 5) the individual is part of the sensitive-to-cadmium portion of the population. Further, EPA relied on the FDA teenage male diet model, which supplies 39 µg Cd/day. They subtracted this 39 µg Cd/d from the 71 µg/d WHO-FAO (1972) provisional maximum daily Cd ingestion to obtain a maximum allowed increase due to sludge use. Others have noted that U.S. adult dietary Cd

is about 20 µg/d (Ryan et al., 1982).

It appears now that several linked assumptions of EPA's acidic garden scenario may well be mutually exclusive, and provide excessive protection. First, individuals who grow 50% of their garden vegetables have such a large time and work investment in their gardens that they learn about the effects of acid soils on yield of vegetable crops, and carefully manage soil pH at 6.5 to 7. Second, presuming that a low Cd, low Cd:Zn ratio sludge applied the soil Cd, and that soil pH declines slowly due to fertilizer use, phytotoxicity in sensitive crops will cause a "50% gardener" to learn about soil pH management and interrupt the necessary 50 year acid garden exposure. Third, vegetables supply microelements which counteract Zn, Fe, and Ca deficiencies; these deficiencies are the identified basis for sensitive individuals. Thus, consumption of the vegetables which comprise the minimal Cd risk to sensitive individuals may push them out of the sensitive population. Recall that increased Cd in "domestic" sludge grown chard and lettuce did not cause increase in kidney Cd (Chaney et al., 1978b, 1978c). In their discussion of Cd dose-response models, Ryan et al., (1982) concluded that U.S. sensitive individuals are protected at the 150 µg Cd/day level of exposure (150-20 = 130 µg/d vs 71-39 = 32 µg/d). Also, the FAO-WHO 71 µg Cd/d value should be adjusted from adult diet to teen age diet if the 39 µg/d result is to be used (=119 µg/d, with 119-39 = 80 µg/d increase tolerable in teenage diet model). Based on the above discussion, it seems clear that the EPA (1979, 1980b) limits are very protective of the worst recognized case when recommended low Cd sludges are managed by land treatment. As a result of these newer understandings discussed above, the regulatory and advisory Federal agencies developed a policy statment on utilization of sewage sludge on cropland for production of fruits and vegetables (EPA-FDA-USDA, 1981).

In summary, the "Soil-Plant Barrier" does not protect the food chain from excessive Cd. Unregulated application of Cd-bearing wastes can cause health effects in humans. Cadmium is not easily kept out of food crops; conversion of treated land to gardens is a worst case scenario upon which regulations to limit Cd applications were based (EPA, 1979a,

1980b). Recent research on gardens polluted with Cd by mining wastes or smelter emissions support the view that gardens can provide much Cd in locally grown foods to the family maintaining the garden for many years (Davies and Ginnever, 1979; Chaney et al., 1980. Unpublished.). Many aspects of the waste-soil-plant-animal food chain are not well established, and research is needed to avoid unnecessarily restrictive limits in the regulations.

8. POTENTIAL FOOD-CHAIN IMPACTS OF TOXIC ORGANIC COMPOUNDS APPLIED IN ORGANIC WASTES

8.1 Introduction

Animals can be exposed to toxic organic compounds (TO's) present in wastes by the pathways described above: 1) direct ingestion of wastes, wastes adhering to forages, wastes lying on the soil surface, or soil treated with wastes; 2) ingestion of plant tissues which are increased in TO content after plant uptake or volatilization from the soil to the plant; or 3) consumption of animal products enriched in TO by other routes. The chemical and physical properties of a TO control its adsorption by soil, volatilization, plant uptake and translocation, biodegradation (in soil, plant or animal), and accumulation in animal tissues. Because each TO is chemically and pharmacologically unique, each compound will have its unique behavior in waste-soil-plant-animal systems (Fries, 1982; Majeta and Clark, 1981; Dacre, 1980).

Although much research has been conducted on insecticides, fungicides, and herbicides, insufficient information is available to assess food chain risk of waste-borne TO's. Environmentally relevant research on waste-borne TO's is quite limited even among pesticides.

Thus, this subsection will describe the processes which influence movement of TO's in waste-soil-plant-animal food chains. PCB's in sewage sludge will provide a particularly relevant example, as regulations were developed based on the available research (EPA, 1979a).

8.2 Bioavailability of Ingested Waste-borne Toxic Organics

Lipophilic toxic organics in ingested sludges and soil are bioavailable. DDT and lindane in ingested soil were absorbed by sheep and stored in their fat (Harrison, Mol, and Healy, 1970; Harrison, Mol, and

Rudman, 1969; Collett and Harrison, 1968). PCB's and other compounds in ingested sludge were absorbed and stored in fat of cattle (Kienholz, 1980; Baxter, Johnson, and Kienholz, 1980; Fitzgerald, 1978, 1980), cow's milk (Bergh and Peoples, 1977), and fat of swine (Hansen et al., 1981). In general, PCB residues in fat reached 5-fold levels in dry feed.

Based on these studies and basic research on bioaccumu- lation of PCB's, Fries (1982) concluded that PCB's should not exceed 2.0 mg/kg dry sludge if milk cows are to be allowed to graze pastures under worst-case conditions which allow 14% sludge in their diet. This was based on a biomagnification from diet to milk fat of 5- fold, and FDA tolerances of 1.5 mg PCB/kg milk fat (FDA, 1979). Forages grown on soils containing PCB's have PCB residues about 0.1 that of the soil, or lower. Good management practices (delay grazing for 30 days after surface application of sludge, and supply feed concentrates during periods of low forage availability) reduce sludge ingestion so that 10 ppm PCB's could be allowed in sludge surface applied at 10 metric tons/ha/yr. Injection of sludge below the soil surface would further reduce exposure.

A seldom considered concentration step involves soil fauna. Earthworms accumulate Cd (Helmke et al., 1979; Beyer, Chaney, and Mulhern, 1982), and lipophilic toxic organics. Beyer and Gish (1980) noted substantial residues of DDT, dieldrin, and heptachlor in earthworms many years post application. Birds and shrews consume appreciable earthworm biomass and are thereby exposed to Cd and pesticides. More study is needed to assess the importance of this unusual foodchain pathway in relation to land treatment of industrial wastes and potential effects on wildlife.

8.2.1 Plant "Uptake" of Toxic Organics in the Soil

Toxic organics can enter edible parts of plants by two processes: 1) uptake from the soil solution, with translocation from roots to shoots, or 2) adsorption by roots or shoots of TO's volatilized from the soil. "Systemic" acting pesticides are applied to the soil, absorbed and translocated by the plant, and act to protect the plant leaves. These compounds are quite water soluble and would probably not appear in industrial wastewater treatment sludges at appreciable levels.

Some systemic TO's are prohibited from use on food crops (other than seed protectants) since residues of the compound or its metabolites on or in food may be unacceptable. The EPA-approved label for each compound lists acceptable uses.

8.2.2 Halogenated hydrocarbons

The lipophilic halogenated pesticides represent the case for water insoluble compounds which are largely sorbed by plants from the soil air or the pesticide-enriched air near the soil surface. Beall and Nash (1971) developed a method to discriminate between movement of a TO through the plant vascular system (uptake-translocation) vs. vapor phase movement. They found soybean shoots were contaminated by soil-applied dieldrin, endrin, and heptachlor largely by uptake-translocation. Vapor transport predominated for DDT, and was equal to uptake-translocation for endrin. Using this method, Fries and Marrow (1981) found PCB's reached shoots via vapor transport, while the less volatile PBB's did not contaminate plant shoots by either process (Chou et al., 1978; Jacobs, Chou and Tiedje, 1976). Suzuki et al. (1977) found that PCB's with a low number of chlorines could be absorbed and translocated at low rates by soybean seedlings from sand treated with high levels of PCB's.

Root crops are especially susceptible to contamination by the vapor-transport route. Carrots have a lipid-rich epidermal layer (the "peel") which serves as a sink for volatile lipophilic TO's. Depending on the water solubility and vapor pressure of the individual compound, it may reside nearly exclusively in the peel layer of carrots, or penetrate the storage root several mm (Lichtenstein, Myrdal, and Schulz, 1964, 1965; Jacobs, Chou, and Tiedje, 1976; Lichtenstein and Schulz, 1965; Iwata and Gunther, 1976; Iwata, Gunther, and Westlake, 1974; Fox, Chisholm, and Stewart, 1964; Landrigan et al., 1978).

Carrot cultivars differ in uptake, and in peel vs. pulp distribution of the chlorinated hydrocarbon pesticides endrin and heptachlor (Lichtenstein, Myrdal, and Schulz, 1965; Hermanson, Anderson, and Gunther, 1970). Other root crops (sugar beet, onion, turnip, rutabaga) are much less effective in accumulating lipophilic TO's in their edible roots, possibly because the surface of the peel is lower in lipids

(Moza, et al., 1979; Moza, Wiesgerber, and Klein, 1976; Fox, Chisholm, and Stewart, 1964; Chou, et al., 1978; Lichtenstein and Schulz, 1965).

The level of chlorinated hydrocarbon in carrots is sharply reduced by increased organic matter in soil. The increased organic matter adsorbs the TO's and keeps them from being released to the soil solution or soil air (Filonow, Jacobs, and Mortland, 1976; Weber and Mrozek, 1979; Chou, et al., 1978; Strek, et al., 1981). Added sewage sludge increased the ability of soils to adsorb PCB's (Fairbanks and O'Connor, 1980). At some low level of PCB's in sludge, the increased sorption capacity may fully counteract the increased PCB's.

Assessing risk from environmental exposure to PCB's, or other TO's is difficult. PCB's and other persistent chlorinated hydrocarbons seldom occur at excessive levels in present municipal sludges (Sprague et al., 1981). The residue of PCB's in waste products is depleted of the relatively more volatile lower chlorinated compounds, but most research is conducted with the commercial mixture. It is clear that plant contamination by the higher chlorinated compounds is much less than for the lower chlorinated ones at equal soil levels (Iwata and Gunther, 1976; Suzuki et al., 1977; Moza, Weisgerber, and Klein, 1976; Moza et al., 1979; Fries and Marrow, 1981). Recently, research has begun with the individual ^{14}C-labelled PCB's; risk evaluation should focus on the 5, 6, and more highly chlorinated compounds which remain in wastes and soils. Assuming peeling of carrots, the only significant exposure to these higher chlorinated PCB's is to grazing ruminants through soil ingestion. One field research study with a "domestic" sludge (contained 0.93 ppm PCB's) evaluated PCB uptake by carrots; Lee et al. (1980) were unable to detect PCB's in the carrots even though they applied sludge at 224 Mt/ha and immediately grew the crops.

8.2.3 Polycyclic aromatic hydrocarbons

Another research effort centered on assessing risk from polycyclic aromatic hydrocarbons (PAH's). Some PAH's are carcinogenic (e.g., benzo(a)pyrene). Researchers found PAH's in composted municipal refuse, and that carrots roots (but not mushrooms) accumulated many PAH's from compost-amended soils (Muller, 1976; Linne and Martens, 1978; Wagner

and Siddiqi, 1971; Siegfried, 1975; Siegfried and Muller, 1978; Neudecker, 1978; Ellwardt, 1977; Borneff et al., 1973). The level of 3,4-benzypyrene in carrot roots declined with successive cropping of compost amended soil. Multi-generation feeding studies of control and compost grown carrots found no risk to rats (Neudecker, 1978). Most of the PAH's in human diets result from deposition on plant foliage; root vegetables are a minor source.

8.2.4 Nitrosamines

Many other carcinogenic or toxic compounds may be present in wastes, and contaminate the food chain through plant uptake, volatile contamination of crop root or shoots, or soil ingestion. Very little information is available on these. Nitrosamines have been found in sewage wastes (Yoneyama, 1981; Green et al., 1981) and are accumulated from nutrient solution and soil by plants (Brewer, Draper, and Wey, 1980; Dean-Raymond and Alexander, 1976). However, nitrosamines appear to be rapidly degraded in soils and plants. Research on N-nitrosodimethylamine and N-nitrosodiethylamine found rapid degradation in soil; plant uptake did occur but these compounds were rapidly degraded there (Dressel, 1976a, 1976b). Traces of nitrosamines are found in nitroanaline based herbicides. These compounds are rapidly degraded and no detectable nitrosamine was found in soybean shoots (Kearney et al., 1980a). An IUPAC committee assessed the environmental consequences of these trace nitrosamines, and found no risk to the food chain (Kearney, et al., 1980b).

8.2.5 Aflatoxin

Aflatoxin comprises another useful example on fate of toxic organic compounds. Aflatoxin contaminated agricultural wastes are usually tilled into cropland. Aflatoxin is readily decomposed or transformed to nonextractable forms in soil, although detectable aflatoxin remained for about 50 days when 2 ppm was applied (Angle and Wagner, 1980). If present in nutrient solution or freshly amended soil, aflatoxin can be absorbed by corn or lettuce (Mertz et al., 1980; 1981). Thus, although it is possible for plants to absorb aflatoxin from aflatoxin amended land treatment sites, none would remain after closure and little would remain at the time of crop growth after preparing the soil for seeding.

8.2.6 Mutagens

Land treatment appears to be an effective method for destruction of mutagens present in sludges. Sewage sludge, feces, and some crop residues contain mutagenic activity (Hopke et al., 1982). Donnelly and Brown (1981), and Brown, Donnelly, and Scott (1982), have characterized reduction in concentration of mutagens during land treatment of petroleum refinery and other industrial sludges. Angle and Wagner (1980) reported biodegradation of aflatoxin, a potent mutagen, when it was added to soil. These studies indicate that mutagens in land-applied sludge should be rapidly degraded. Recently Babich et al. (1981) have voiced concern about TO's in land-applied sewage sludge. These concerns seem to rely on mis-management of land treatment sites, and presume very high (unlawful under EPA, 1979) application rates followed by immediate cropping with food crops (usually considered prohibited under a 18 month waiting period to prevent pathogen contamination of foods). Boyd (1981) recently grew 4 vegetables (snapbeans, beets, cabbage, and squash) on a soil amended with 112 Mt/ha sludge from Syracuse, N.Y.; this industrially contaminated sludge was applied in the Fall, and crops grown the next season. The edible portion of the sludge-grown and control crops were fed to rats at 25% of their diet. Mutagen assays were conducted on the crops and the rat urine; liver enzyme changes were followed; and alpha-fetoprotein (indicates pre-neoplastic transformations) was assayed. Weight gain was comparable from control and sludge-grown crops. No evidence of change in alpha-fetoprotein was observed in rats consuming the 4 sludge-grown vegetables. The liver mixed-function-oxidase enzymes (aminopyrine-N-demethylase and p-nitroanisole- O-demethylase) were affected by type of crop, but no additional changes were observed due to growing the vegetables on sludge-amended soils. No ultrastructural abnormalities were observed in rat liver cells as a consequence of sludge-grown vegetables. Rat urine may have shown increased amounts of mutagens when the urine extract from rats fed sludge-grown crops was activated with mammalian microsomes. The extracts of control and sludge-grown vegetables did not show significant "sludge effects" in normal or activated assays. Thus, although this topic has received little

study to date, land treatment appears to provide sufficient biodegradation and adsorption to protect the food-chain from mutagenic compounds present in sludges applied to land under well managed programs. Food crops would not be grown during active land treatment periods.

Land application of sludge can be managed to avoid all unacceptable effects on the food-chain from waste-borne TO's. Wastes can be injected below the soil surface. Mechanically harvesting fresh forages or feed grain crops avoids soil contamination of food chain. And, if necessary, pretreatment may be used to remove TO's which are not acceptable in land-applied sludge.

FIGURE 1. Crop differences in Cd accumulation. Crops were grown on calcareous Domino silt loam amended with 1% of a Cd-enriched sewage sludge (1000 ppm Cd) such that the amended soil contained 10 ppm Cd. Where a plant tissue other than leaves is normally eaten, its Cd concentration is shown by the black bar; foliar Cd for each plant is the full open bar (turnip leaves = 163 ppm Cd). (From Chaney and Hornick, 1978, based on Bingham et al., 1975, 1976a, 1976b).

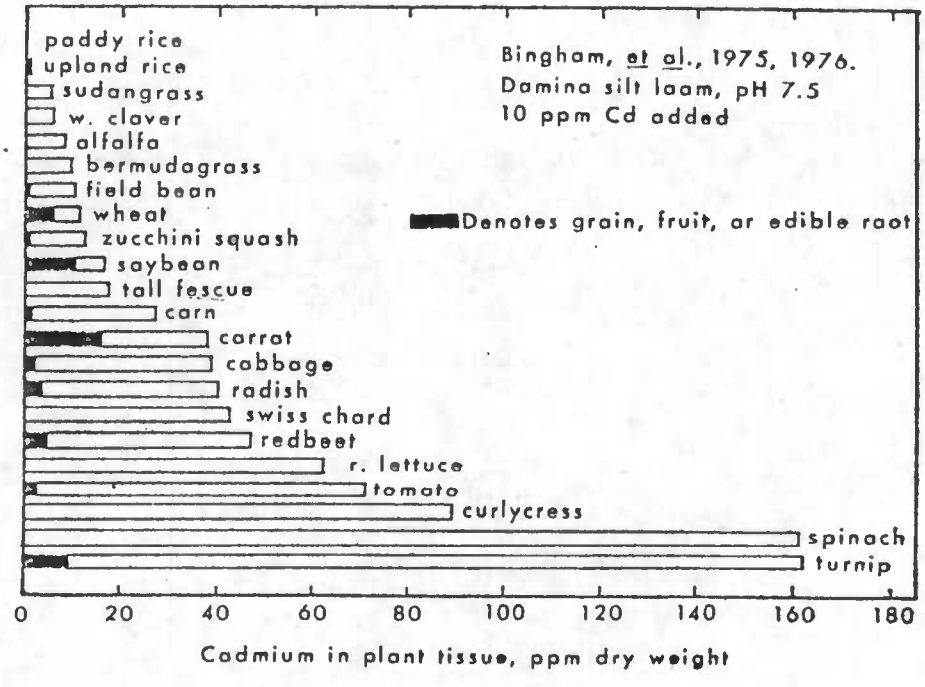

Table 1. Concentrations of selected trace elements in dry digested sewage sludges[1/].

Element	Reported Range		Typical Median Sludge	Typical Soil	"Maximum Domestic Sludge"
	min.	max.			
As,ppm	1.1	230.	10.	-	-
Cd,ppm	1.	3,410.	10.	0.1	25.
Cd/Zn, %	0.1	110.	0.8	-	1.5
Co, ppm	11.3	2490.	30.	-	200.
Cu,ppm	84.	17,000.	800.	15.	1000.
Cr,ppm	10.	99,000.	500.	25.	1000.
F,ppm	80.	33,500.	260.	200.	1000.
Fe, %	0.1	15.4	1.7	2.0	4.0
Hg,ppm	0.6	56.	6.	-	10.
Mn,ppm	32.	9,870.	260.	500.	-
Mo,ppm	0.1	214.	4.	-	25.
Ni, ppm	2.	5,300.	80.	25.	200.
Pb, ppm	13.	26,000.	500.	25.	1000.
Sn, ppm	2.6	329.	14.	-	-
Se, ppm	1.7	17.2	5	-	-
Zn, ppm	101.	49,000.	1700.	50.	2500.

1/ Composting using wood chips as a bulking agent generally produces composted sludge 50% as high in trace elements as a digested sludge from the same treatment plant.

TABLE 2. Relative sensitivity of crops to sludge-applied heavy metals. (Chaney and Hundemann, unpublished).

Very Sensitive[1]	Sensitive[2]	Tolerant[3]	Very Tolerant[4]
chard	mustard	cauliflower	corn
lettuce	kale	cucumber	sudangrass
redbeet	spinach	zucchini squash	smooth bromegrass
carrot	broccoli		'Merlin' red fescue
turnip	radish	flatpea	
peanut	tomato		
	marigold	oat	
ladino clover		orchardgrass	
alsike clover	zigzag, Red Kura and crimson clover	Japanese bromegrass	
crownvetch	alfalfa	Switchgrass	
'Arc' alfalfa	Korean lespedeza	Red top	

TABLE 2. Continued. Relative sensitivity of crops to sludge-applied heavy metals. (Chaney and Hundemann, unpublished).

Very Sensitive[1]	Sensitive[2]	Tolerant[3]	Very Tolerant[4]
white sweetclover	Sericea lespedeza	Buffelgrass	
yellow sweetclover	Blue lupin	Tall fescue	
	Birdsfoot frefoil	Red fescue	
Weeping lovegrass	Hairy vetch	Kentucky bluegrass	
Lehman lovegrass	Soybean		
Deertongue	Snapbean		
	Timothy		
	Colonial bentgrass		
	Perennial ryegrass		
	Creeping bentgrass		

1/ Injured at 10% of a high metal sludge at pH 6.5 and at pH 5.5.

2/ Injured at 10% of a high metal sludge at pH 5.5, but not at pH 6.5.

3/ Injured at 25% high metal sludge at pH 5.5, but not at pH 6.5, and not at 10% sludge at pH 5.5 or 6.5.

4/ Not injured even at 25% sludge, pH 5.5.

TABLE 3. Recommended maximum cumulative sludge metal applications for privately-owned cropland.

Metal	Soil Cation Exchange Capacity		
	0-5	5-15	15 meq/100g
	maximum application, kg/ha		
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20
Pb	500	1000	2000

1. Annual Cd application should not exceed 2 kg/ha from dewatered or composted sludge, or 1 kg/ha from liquid sludge; sludge should not supply more crop available nitrogen than the crop requires.

2. Sludges with Cd 25 ppm should not be applied unless the Cd/Zn 0.015; if Cd/Zn exceeds 0.015, an abatement program to reduce sludge Cd should be initiated.

3. These recommendations apply only to soils that are adjusted to pH 6.5 when sludge is applied, and are to be managed to pH 6.2 thereafter.

4. Leafy vegetables or tobacco cropland should not receive sewage sludge application.

5. The cation exchange capacity is for unamended soil.

TABLE 4. Maximum tolerable levels of dietary minerals for domestic livestock in comparison with levels in forages.

Element	"Soil-Plant Barrier"	Level in Plant Foliage[a]		Maximum Levels chronically tolerated[b]			
		Normal	Phytotoxic	Cattle	Sheep	Swine	Chicken
		--mg/kg dry foliage--		----------mg/kg dry diet--------			
As, inorganic	yes	0.01-1	3-10	50.	50.	50.	50.
B	yes	7-75	75	150.	(150.)	(150.)	(150.)
Cd[c]	Fails	0.1-1	5-700	0.5	0.5	0.5	0.5
Cr^{3+}, oxides	yes	0.1-1	20	(3000.)	(3000.)	(3000.)	3000.
Co	Fail?	0.01-0.3	25-100	10.	10.	10.	10.
Cu	yes	3-20	25-40	100.	25.	250.	300.
F	yes?	1-5	-	40.	60.	150.	200.
Fe	yes	30-300	-	1000.	500.	3000.	1000.
Mn	?	15-150	400-2000	1000.	1000.	400.	2000.

TABLE 4. Continued. Maximum tolerable levels of dietary minerals for domestic livestock in comparison with levels in forages.

Element	"Soil-Plant Barrier"	Level in Plant Foliage[a/]		Maximum Levels chronically tolerated[b/]			
		Normal	Phytotoxic	Cattle	Sheep	Swine	Chicken
		--mg/kg dry foliage--		----------mg/kg dry diet--------			
Mo	Fails	0.1-3.0	100	10.	10.	20.	100.
Ni	yes	0.1-5	50-100	50.	(50.)	(100.)	(300.)
Pb[c/]	yes	2-5	-	30.	30.	30.	30.
Se	Fails	0.1-2	100	(2.)	(2.)	2.	2.
V	yes?	0.1-1	10	50.	50.	(10.)	10.
Zn	yes	15-150	500-1500	500.	300.	1000.	1000.

a/ Based on literature summarized in Chaney et al. (1982).

b/ Based on NRC (1980). Continuous long-term feeding of minerals at the maximum tolerable levels may cause adverse effects. Levels in parentheses were derived by interspecific extrapolation by NRC.

c/ Maximum levels tolerated based on human food residue consideration.

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Virginia's Land Application (Sewage Sludge) Program
Regulatory Review Aspects
By C. M. Sawyer, P.E.*

Introduction

A considerable volume of the mixture of liquid/solid material called sludge is removed from wastewater during certain treatment processes. As the degree of liquid treatment increases from primary to secondary to tertiary, the amount of sludge accumulation increases and the chemical/biological nature of the sludge changes.

The solid fraction (SS) removed from sewage (domestic wastewater) by conventional (primary/secondary) treatment consists of 50 to 75 percent organic matter (VSS), which is the more resistant part of the organic matter in relation to rapid biological decomposition. The remaining sludge fraction (25-50%) is inorganic material of various kinds. Plant nutrients, such as nitrogen and phosphorous are present in varying amounts. This so-called raw sludge is usually further stabilized by digestion, or thermal reduction, or chemical treatment, prior to disposal.

Land application of stabilized sludge is an attempt to re-cycle the nutritive value in the sludge to crop production and at the same time provide an economical method of disposal for an increasing volume of waste material. The alternatives to land application are to dispose of the material in a land fill after partial removal of the water content (20% SS by weight), or to incinerate the organic fraction. Incineration still leaves the inorganic fraction for land filling disposal.

A major problem restraining the general use of agricultural re-cycling of sludge is the public opposition to spreading of wastes on land when the source is known. Since environmental and health hazards may develop from uncontrolled land disposal, regulations must be imposed on such operations and monitoring tests conducted to insure that hazardous conditions will not develop.

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Regulatory Review

The Health Department's program for sewage and wastewater regulation is authorized in the Health Laws of Virginia, 1979, Code of Virginia; 32.1, Chapter 6, Article 1. Regulation of municipal sewage sludge treatment and disposal in the Commonwealth of Virginia is administered through the Sewerage Regulations, jointly adopted by the State Health Department and the State Water Control Board in 1977. The State Health Department's Bureau of Wastewater Engineering is the technical review and advisory agency for these regulations. The Bureau's responsibilities are administered through six (6) regional "field" offices of the Division of Water Programs, which are staffed with public health engineers (B.S/M.S. Degrees in Civil, Chemical, or Environmental, Engineering/Science). The Technical Services section of the Bureau, serves to coordinate the review of the engineering documents which are submitted, as required, by the procedural regulations (Section 2.00). The review of sewage sludge management plans requires input from all other concerned agencies (Figure 1).

The Health Department's Bureau of Wastewater Engineering works directly with the State Water Control Board's Bureau of Applied Technology in processing sewage treatment and sludge disposal projects. Industrial wastewater treatment is the responsibility of the State Water Control Board. All sludge disposal operations should be permitted either by the NPDES system or a State "No-Discharge" Certificate. The Bureau of Applied Technology administers these permit programs through Regulation Six (6) and Administrative Procedural Rule Number Two (2) of the State Water Control Law, 1950, Code of Virginia, as amended, Section 62.1-44.18 through 44.19. All applications for permits are advertised in area newspapers for 30 days, requesting comments by a certain date. If a significant number of comments are received and they cannot be resolved by the regulatory staffs, a public hearing is arranged and advertised. Operations involving landfilling or burial of sewage sludge will require approval from the Health Department's Bureau of Solid Waste Management, under the State Solid Waste Disposal Regulations. The Virginia Department of Agriculture and Consumer Services provides review comments on land application projects involving agricultural land. Local health departments are also notified of all proposed land application projects.

Involvement of local government in the processing of permits for sludge disposal operations is not required by State Law, unless a local "Special-Use" ordinance or other zoning restrictions are in effect in that locality. Historically, local governments have been involved in sewage treatment planning and effluent limitations, but only a few of the larger cities and counties participated in technical reviews of treatment processes and technology. However, more recently, lightly populated counties have voiced strong objections to not being included in the review of sludge disposal permits. These permit applications often involve the disposal of sewage sludge on local lands which is not generated in that political jurisdiction, which invokes a "don't-dump-on-me" reaction. Although the disagreements are largely political in nature, technical questions concerning public health and environmental pollution are most often debated, with no positive result.

Thus, as a result of jurisdictional questions, local controversy arises in some instances. Whenever an application is received for sludge disposal involving land application within a particular locality, that local government will be notified by the state agencies, irregardless of local zoning or special use ordinances. However, a recent court decision in Fairfax County stated that local zoning could not take precedence over state regulatory permits. Local governments will be asked to give preliminary approval to permit applications, or call for a public hearing, prior to extensive processing of the application by the concerned state agencies.

Processing Sludge Management Proposals

A comprehensive land application review checklist serves to call the project reviewer's attention to important facets of the sludge management plan.

The regional office land application checklist is divided into a general section, applying to all application projects, and a section concerning repeated applications to agricultural lands. The review checklist includes lists of questions to be answered in areas of concern such as:

1. the location of sites;
2. soil profiles;
3. slope of land;
4. crop to be grown;
5. amount of nutrients required and removed by the crop;
6. time of application;
7. methods and volume of storage;
8. crop rotation;
9. annual application rate or amount applied once in 5 years;
10. soil testing both in zone of incorporation and in next six inches directly below.
11. analysis of the sludge;
12. limitations to application due to nutrient and heavy metal content of sludge and soil.
13. groundwater monitoring (nitrates); and
14. restriction to grazing of livestock.

The land application review checklist is supplemented by guidelines and additional information concerning special design features and problems associated with land application of sewage sludge to agriculture lands.

At the completion of the regional office reviews of a sludge management proposal, either preliminary of final, a formal letter report is prepared by the Regional Office engineer who has the responsibility for surveillance of sewage treatment and disposal within the planning district that the project is located (Table 1). The letter report describes the major characteristics of the proposal and states the health department's position regarding approval/disapproval of the technical adequacy of the proposal relating to public health concerns. The project may be approved conditionally provided the applicant revises specific items of design, operation, etc. If the proposal is disapproved, specific requirements for satisfactory revision of the proposal must be stated. However, all possible avenues for resolving proposal deficiencies would be pursued before a formal disapproval would be made. A series of comment letters and owner responses to Regional Office concerns will precede the submission of a letter report to the Central Office. The letter report is forwarded to the Bureau of Wastewater Enineering to be checked for completeness, compliance with the regulations and technical adequacy. If the letter report is not satisfactory, the regional Office will be asked to revise it. The State Health Commissioner has delegated the authority to approve /disapprove letter reports to the Division of Water Programs. If the letter report is satisfactory it is forwarded to the Bureau of Applied Technology with copies to all review agencies. The consultant and facility owner are also notified (Figure 2).

Final action on the permit issuance can be taken by the State Water Control Board staff through the Executive Secretary, if the project is approved by the Health Department. Projects disapproved by the Health Department must be acted upon the State Water Control Board (SWCB) Citizens Board, at a regularly scheduled public meeting. The results of specific-project public hearings are also presented at the meetings of the SWCB Citizens Board. The Citizens Board can approve or disapprove staff recommendations on permit applications.

Interaction with Agronomists:

Development of Section 25.07 of the Sewerage Regulations inolved the valuable assistance and advice of the staff of the U.S. Department of Agriculture's Research Station at Beltsville, Maryland. The expertise of staff agronomists and soil scientists with the Virginia Tech (VPI & SU) Extension Service is routinely requested and utilized during review of land application proposals. The Virginia Regulatory agencies have a good working relationship with the Extension Service agronomists and depend on input from these soil specialists during project review. An Extension Service soil scientist is directly assigned to the State Health Department under the direction of the Health Commissioner and is available upon request by division Directors to perform in-field soil evaluations for a specific project. Extension Service soil specialists have conducted extensive training courses for regulatory personnel including in-field demonstrations for Bureau Engineers. The Health Department's assigned soil specialist has compiled the information concerning evaluation of soils for land appliation suitability that is utilized by regional office engineers during project review.

The need for regulatory coordination during project review, led to the development of a technical advisory committee on land application of sewage sludge (LASS). The LASS committee is composed of representatives of Regulatory agencies, VPI & SU Agronomy Department/Extension Service, municipal and county organizations, Virginia Water Resources Research Center and the Hampton Roads Sanitation Commission staff. The committee has actively pursued means of supporting research on problems concerning land application technology. The LASS committee will also serve to evaluate research priorities and will recommend possible revisions to the existing regulations.

The LASS committee has obtained agency support for research projects in the form of time committments for both professional and clerical staff assistance. Several research projects have been recently funded in spite of federal and state reductions in research funds. The Hampton Roads Sanitation Commission, which is the largest sewerage authority in the State of Virginia, has conducted and supported several studies of land application of stabilized sewage sludge for agronomic reuse. Staff members of the regulatory agencies have worked very closely with staff members of the Hampton Roads Sanitation Commission in establishing critera for sludge farming on coastal plains soils. Current research efforts are largely directed by faculty members of the VPI & SU Agronomy Department, many of whom have conducted previous research efforts, involving disposal of wastewater in soils, for the State Health Department. The Virginia Regulatory agencies are of the opinion that the results of in-field research studies are imperative to providing specific answers to the generally speculative questions which seem to be asked at public hearings on land application of sewage sludge.

The LASS committee also worked very closely with the Education Committee of the Virginia Water Pollution Control Association (VWPCA) to develop a program for a day long seminar on land application of sewage sludge held in Richmond,

during October, 1981. A number of recognized experts in agronomic aspects of land application presented papers on research activities, in-field studies and case histories of on-going projects at the VWPCA seminar and the proceedings of that seminar are now available.

Sludge Requirements

The Virginia Sewerage Regulations defines two types of sewage sludges in Section 25.07.05 as follows:

"Prior to land application, sludge shall be evaluated in accordance with Section 25.07.03 and 25.07.04. The sludge shall be classified by its characteristics. For new projects, sludge characteristics may be approximated by data obtained from like treatment facilities receiving flow from similar waste contributors. Pilot studies for sludge characteristics may be required when deemed appropriate by the Department and the Board.

a. Class A - Class A sludge shall be suitable for land application at the approved site in accordance with the approved application conditions indefinitely under proper management. Sludge which is classified as Class A shall be stabilized and shall not contain heavy metals or other undesirable components in quantities that (1) may be harmful to the production of crops, trees or other vegetation; (2) may result in crops or vegetation containing components which may be harmful to the health of animals or humans when consumed; (3) may render the soil unsuitable for future land use; and (4) degrade existing groundwater quality. Appendix K presents standards for Class A sludge based on maximum allowable levels of certain heavy metals.

b. Class B - Class B sludge is sludge which is raw, partially stabilized, chemically or bacteriologically contaminated or contains undesirable components which makes it unfit for land application. This shall include unstabilized pumpage from septic tanks. Disposal of Class B sludge may be implemented by (1) conveyance to a sewage treatment plant having approved sludge handling facilities provided that detrimental effects to the plant shall not occur; (2) stabilization of sludge such that it shall meet the requirements of Section 25.07.05a. above; and (3) other methods which will be evaluated on a case-by case basis. Raw or partially stabilized sludge shall not be mixed with solid waste for disposal in solid waste landfills."

Analysis of sludge samples is absolutely necessary prior to processing of any sludge disposal plan involving land application.

Both anaerobic (without oxygen available) and aerobic digestion, can be used to stabilize primary and secondary sludges. Thermal reduction and chemical treatment are also used to stabilize sludges (Table 2). Stabilization is controled through adherence to accepted design and operating parameters. Sludge stabilization should eliminate any odor producing potential and significantly

reduce the numbers of pathogenic organisms which may be present in sewage sludge. Additional stabilization may be provided by composting methods in which a bulking agent is mixed with the sludge (3 or more parts bulking agent to each part of sludge) and the moisture/oxygen levels controled to provide thermophilic biological action. Adequately composted sludge should attain a temperature of 55 degrees celsius or more, for several consecutive days. An interagency committee is now developing a proposed set of regulations on compost operation and disposition.

The Class A or Class B designation is based on the degree of stabilization and chemical composition as indicated by analytical testing of sludge samples (Table 3):

1. Submission of analytical test data will be the responsibility of the owner of the facility generating sludge in Virginia or of the contractor who is applying sewage sludge.

2. Classification tests on sludge:

   a) Initial tests to be repreated in six months, if poor quality is initially detected. All extreme test values should be verified by repeat sampling and testing.

   b) Test frequency should be at least annually, with both frequency and required parameters decided on a case by case basis.

   c) Nutrient and heavy metal characteristics of sludge must be established.

3. Analytical tests conducted on sludge may include (Sewerage Regulations Section 25.07.04 and Appendix J):

   a) Percent solids, organic fraction and pH

   b) nitrogen (organic, ammonium, nitrate)

   c) total phosphorous and total potassium

   d) Heavy metals: cadmium, copper, lead, mercury, nickel, zinc, etc.

4. Due to the highly variable nature of sludge, collection of a number of samples is necessary to develop a representative sample. Samples should be stored in containers so that evaporation of moisture is prevented. A sufficient quantity, one quart or more, should be taken for representative analyses. A series of samples collected periodically over a 24 hour period should be composited according to total volume withdrawn and analyses conducted on the composite sample as soon as possible. If storage is required, samples should be refrigerated at a temperature at or below 35°F. (See Fourteenth Edition of Standard Methods and EPA Storage and Preservation Methods).

Required Soil Conditions

Adequate soil conditions ideally require 2 feet of soil as a minimum depth to groundwater, or rock, below the application site. This should include enough clay to insure some adsorption of heavy metals (CEC exceeding 5). In addition, the pH of the plow layer should be adjusted to 6.5 prior to application, unless the sludge contains a high lime content (50% $CaCO_3$ equivalent). The pH of the plow layer should not be increased above 7.0 or micro-nutrient deficiency (manganese for example) may result.

Random soil borings should be made of application areas which are to receive repeated applications, to establish the soil patterns. These should record the depth of each horizon, color (Munsell Color Chart) and texture (U.S.D.A.) of the surface soil, subsoil, and parent material and any other pronounced horizons that may occur.

In addition, random soil samples (approximately one sub-sample per acre) should be collected from each field at two depths to form two composite samples from each field. Sub-samples should be combined to form one composite sample per field or per 10 acres, whichever area is smaller. The first sample depth should be in the zone of incorporation of the sludge (plow depth) and the second sample from the 6 inch depth below the plow depth:

On-site soil samples should be obtained prior to sludge application and analysed to establish the initial soil parameters, including:

a) Soil pH/lime requirement

b) CEC

c) Organic and clay fractions

d) Nitrogen (total, Ammonia, Organic)

e) Available phosphorous and potassium

f) Selected heavy metals including cadmium, copper, lead, nickel and zinc.

The samples can be used to determine a balanced nutritive state for a specific crop and provide data on pH, CEC, and metal content. The deeper sample can show if heavy metals are held in the plow layer or move downwards in the soil. The shallower sample will also show any build up of metals after applications of sludge. The pH of the deeper sample will normally be below 6.0, but pH adjustment below the plow layer is not justified and should not be required.

All drainageways should be shown on the field maps along with hilly and steep areas because of potential runoff from these areas.

Application Controls

The rates of application of sludge in dry tons per acre could be limited by a number of sludge constituents and the method of application must be calibrated to the most limiting constituent. The application limit may be related to

nitrogen, phosphate, the heavy metal content, or the uptake by a specific crop.

Nitrate is a nutrient that is mobile in the soil and can move down to ground water and accumulate to potentially hazardous levels (10 mg/l). The rate of application of sludge is limited in part by the nitrogen level of the sludge and the ability of the crops to remove a given amount of nitrate-nitrogen. Crop removal tends to prevent a build up of nitrates eliminating movement to ground water.

Nitrogen in sewage sludge is primarily organic nitrogen or ammonia-nitrogen and is converted to nitrate by mineralization of the organic matter and nitrification of ammonia under aerobic conditions. Typical sewage sludge will contain less than one (1.0) percent ammonia-nitrogen and two to three (3) percent organic nitrogen. It is assumed that all of the ammonia-nitrogen and twenty (20) percent of the organic nitrogen is immediately available to the crop following application. Thus, each dry ton of sludge (SS) should contain at least 30 pounds of immediately available nitrate-nitrogen. The remaining organic nitrogen is mineralized to ammonium at a slower rate (about five (5) percent conversion per year).

Recommended land application loading rates for Class A sludges are listed in Appendix K of the Sewerage Regulations (Table 4). Unless it can be satisfactorily demonstrated that the nutrient uptake of the crop justifies a higher loading rate, the initial design rate should not exceed five (5) dry tons per acre, which provides approximately 150 pounds of nitrate-nitrogen during the first year following application.

The total crop uptake of nutrients is important, which makes the part of the plant that is harvested important. Nutrients are removed form the site by the part of the plant harvested (i.e., grain or silage), which may influence rates of application. Cover crops do not remove nutrients, as they only hold the nutrients in an organic form to be plowed under at a later time. Thus, grass must be removed from a land application site to control nitrate levels in the soil.

Heavy metals are also present to varying degrees in the sludge (milligrams of metal ions per kilogram of SS). The organic fraction of soil has a tendency to attract metal ions. The tendency is largely a function of the Cation Exchange Capacity (CEC) with higher CEC values (5 to 15) indicating a greater adsorption capacity. Soil pH is also a factor in heavy metal adsorption. The movement of metal ions is greatly reduced when the pH of the plow layer exceeds 6.2. The rate of application of sludge may be limited by the metal content to prevent a build up of metals in the soil. Cadmium is the most critical of metals because it can be absorbed by plants in toxic amounts and passed on to higher trophic levels (maximum sludge concentration should be less than 25 milligrams/kilogram). The other metals generally become toxic to plant growth before becoming toxic to consumers of the crop (phytotoxicity).

If the metal concentrations of sewage sludge are at normally expected levels, the sludge can be land applied at the nutrient limiting rate with no adverse impacts to the crop, to livestock, or to the public.

In a few cases, toxic organic compounds (pesticides, PCB's, etc.) may be present in sludge. Sludge should not be surface applied to land, if it is chemically contaminated, to prevent adsorption on outer layers of plant surface. Industrial waste contributions to municipal wastewaters must be carefully monitored, if the sludge is land applied.

A number of potentially pathogenic organisms can survive in significant numbers (100 to 1,000,000 per gram SS) in sludge (Table 5). Of greatest concern are the reproductive forms of worms, such as the eggs of intestinal helminths, which can survive in a natural soils environment for extended periods of time. Some types of viruses can survive for lengthy periods if moisture is present and could become attached to vegetation following surface application. Public health precautions include prohibiting sludge application to root crops, or crops to be consumed raw, limiting public access to sludge application areas and limiting livestock grazing for a period after application to pasture grass land. The time period for grazing restrictions should be related to the method of application (Table 6). A period of delay in the feeding of grass, if harvested after sludge application, is also required to increase the natural inactivation or die-off of organisms. Ground water monitoring studies have not identified problems with microbial contamination below sites in which soil characteristics and application criteria meet those recommended in the Sewerage Regulations.

The greatest concern in land application of sludge is where annual applications are to be used. A one time application of any contaminant will eventually be diluted in the soil, but continuous applications could create a build up of hazardous substances. The total life of an application site receiving repeated application will usually be established by the maximum allowable cumulative metal loadings (Table 7).

Application Site-Management Concerns

Sludge cannot be applied to the land all year round. A part of the time during an annual cycle, a crop is growing on the land, at times it may be too wet to get on the land with heavy equipment and sometimes during the winter months the soil may be frozen.

Application to frozen ground would require flat slopes (less than 5%) and sufficient crop residue to prevent run-off of contaminated precipitation.

In the spring, farmers tend to start plowing as soon as the soil is dry enough to get on the land, which limits the possible time period for sludge applications. In the fall, after crop harvest, there is more time to apply the sludge and the ground is usually drier.

The periodic timing of sludge applications requires storage of sludge or the availability of a large amount of pasture or hay land for regular application. Sludge storage should not result in surface or ground water contamination.

Removal of water from sludge increases the disposal cost, but transportation of water is also costly. Liquid sludge is generally low in solids (less than 12%SS, Section 25.07.06, Sewerage Regulations). What is termed dewatered sludge may be in the range of 12 to 30 percent solids. Dried sludge contains a solids level in excess of 30 percent. Composted sludge has most of the water

removed (exceeds 40%SS). Each type of sludge requires special equipment for hauling and land spreading.

The method of incorporation into the soil should also be site specific. Applied sludges may be plowed in, disced in, injected, or may be applied on the soil surface to hay or pasture which has been recently clipped to blade or stalk lengths of less than three (3) inches in length.

The method of incorporation of the sludge into the soil may be a factor in public approval or opposition to land disposal. Rapid incorporation or injection makes land disposal more acceptable where occasional odors may be a problem.

Runoff of sludge due to precipitation may be a problem on steeper topography and along drainageways where water concentrates. It does not make sense to remove the sludge from wastewater to prevent stream pollution and then allow it to run back into the stream with runoff water. Incorporation of the sludge into the soil is necessary in such areas.

The use of composted sludge for soil conditioner will require nutrient addition, usually as commercial fertilizer supplements.

If lime stabilized sludge is land applied, the pH of the plow layer should be closely monitored to prevent rapid rises in soil pH.

It is important that care be taken in the use of heavy equipment on the land to prevent compaction of the soil. Semi-trailors can compact wet soil when pulled into a field. Flotation tires on application equipment will normally be necessary on wet soils. Sub-surface injection on slopes steeper than eight (8) percent may be necessary to maintain traction for heavy equipment.

Site buffer zones (25 to 100 feet depending on application method and ground slope) to adjacent property are required to prevent contamination and protect the public. Buffer zones are also needed along drainageways to reduce the runoff of surface applied sludge to a stream (50 feet from defined channel boundry).

Some inclusion in the application plan for a particular site should be made concerning the fertility of the buffer zone, since this area is also farmed. Some farmers use manure in the buffer zones which creates odors that are attributed to the sludge application.

Required Monitoring

The most important phase of monitoring concerns the sludge before it is applied to the land. Composite sampling is necessary to obtain representative samples. A mixture of several random samples is needed, especially in the case of septage lagoons, where little mixing of separate sludge layers occurs.

Samples withdrawn from tank trucks, to which sludge is pumped, should be well mixed. Single samples withdrawn from pressure lines from pumps may not be representative.

The second level of monitoring involves the random composite soil samples from the zone of incorporation and 6 inches below. This will indicate any build up of hazardous material in the soil and any movement out of the zone of incorporation. Soil sampling on sites receiving a one-time application would not be necessary.

The third level of monitoring may be the crop that is harvested. This may be needed only with repeated applications of sludges that contain specific toxic materials (20 mg/kg Cadmium, 10 mg/kg PCB's).

Groundwater monitoring may also be required at sites receiving repeated applications to check the possible movement of nitrates to groundwater. The base level of groundwater quality should be established at the start of a project.

Analytical testing must be performed by a qualified laboratory. Analysis of sludges and soils for nutrients requires some agronomic testing experience. Often an unexpected high concentration of a metal, or other characteristic, reported by a laboratory, is due to improper quality control on sampling or testing methods. All unusual values of contaminant concentration reported from laboratory analysis should be verified by repeat sampling and testing.

Analytical testing of sludge samples should be performed quarterly for all parameters of significant interest. Soil testing should be conducted annually.

Current Status of Program

Agricultural utilization of stabilized sewage sludges is a viable, safe and effective method of sludge disposal when properly managed. Public opposition to land application projects normally stems from socio-political issues, but implementation of such projects are often blocked due to technical weaknesses resulting from a lack of supporting data. Complete sludge management plans are required for regulatory review under Virginia's Land Application program for agricultural re-use of stabilized sewage sludges. All sewage/sludge treatment/disposal systems located in Virginia are required to have a permit. Approved sludge disposal plans have been made a condition of approval for certificates to operate such facilities.

The Bureau of Wastewater Engineering monitors the operation of 449 sewage treatment plants in Virginia, with the majority of those facilities having a design flow of one (1.0) million gallons per day (MGD) or less. Regional surveys of the methods of sludge disposal produced the distribution of information listed in Table 8. Land application of sewage sludge is utilized by over forty (40) per cent of sewage treatment facilities in Virginia with a design flow exceeding one (1.0) million gallons per day. sludge management plans have been received from the owners of each of these larger facilities from which sewage sludge is being land applied. Review of the submitted proposals by the Bureau of Wastewater Engineering has resulted in regulatory approval of one-half of those proposals. The Bureau has established the tracked objective of obtaining approved sludge management plans from all Virginia sewage treatment plants with a design flow of 100,000 gallons per day, by the beginning of 1984. In addition, the Bureau has established a regional office goal of obtaining approved sludge management plans from all facility owners who are either currently utilizing land application of stabilized sludge, or are planning to utilize land application disposal methods in the future.

Several commercial operations for land application of sewage sludge for agricultural re-use have been approved and permitted with state "No-Discharge" certificates and several applications are under review. The amount of acreage permitted for land application of Class A sludges with the state "No-Discharge" certificate is approaching 20,000 acres and is expected to increase sharply in the near future.

The Bureau estimates that an average of approximately 200 dry tons per day of Class A sludge will be land applied in Virginia during the next year. If a one-time application method at 5 dry tons per acre is utilized for this amount of sewage sludge, approximately 40 acres per day would be required and approximately 73,000 acres should be approved for land application in a five year period before repeat applications to the initial sites could begin. Obviously, many proposals for repeat application of sewage sludge will be forthcoming from municipal generators. The Bureau may have to devote nearly 10,000 man-hours per year to review and monitor land application projects and will be ready to make this committment if necessary.

Table 1:

Processing Sludge Disposal Plans
Bureau of Wastewater Engineering

A. Regional Office

1. District Engineer reviews municipal sludge disposal plan and completes land application review checklist:

   a) If landfilling or burial to a depth exceeding one foot below ground surface is proposed, solid waste consultant must provide written comments and recommend approval/disapproval of that option,
   b) If hazardous wastes are involved, central office of the Division of Solid and Hazardous Waste Management (Bill Gilley 786-5272 or Walt Gulevich 786-1754) will handle project.
   c) If agricultural use is proposed, Department of Agriculture and Consumer Affairs (Earl Finch, 786-6911) should comment on that option,
   d) If soils analysis is involved, the Departments assigned Soil Scientist (Bill Meyer, 786-3559) should comment on that aspect. A site inspection should be made of proposed application areas with questionable soil characteristics by department soil scientist and State Water Control Board geologist,
   e) The State Water Control Board Regional Office and the Regional Health Director should be given a copy of the plan at the same time as the Departments Regional Office, and notified in advance of any meetings and/or site inspections.
   f) Local government should be informed of all applications for commercial operations.

2. The owner and or consultant should be notified as usual of any plan deficiencies. A meeting may be necessary between owner/consultant and all concerned agencies. Regional and central offices of both the Department and Board should be notified.

3. Upon receipt of the necessary comments, the District Engineer should prepare a standard letter report, copying all commenting agencies and the Local Health Department. A copy of the plan and all correspondence should be included with the central office file section.

4. Questions regarding interpretation of the Sewerage Regulations should be referred to the central office, Bureau of Wastewater Engineering (Cal Sawyer, 786-1752). Questions concerning the epidemiological impact of sludge disposal should also be referred to the Bureau of Wastewater Engineering Central Office, which will then contact the Division of Epidemiology.

B. Central Office

1. Letter report reviewed by Technical Services Chief:

   a) Insures that comments from all appropriate agencies have been received and coordinated,
   b) Cross checks with assigned soil scientist if necessary,
   c) Discusses aspects of plan with District Engineer if unsure of interpretation given to plan,
   d) Initials and recommends approval to Bureau Director.

TABLE 2

Guidelines for Interpretation
of Review Checklist for
Land Application of Sludge

A. Stabilization - Must use established methods of treatment or verify quality through extensive testing. A process which will "significantly reduce pathogens".

1. Digestion/Oxidation (25.00)

   a) Anaerobic (60 days at 20°C to 15 days at 35°C or higher)
   b) Aerobic (60 days at 15°C to 40 days at 20°C)
   c) Composting (See attached list of design factors)

2. Thermal Reduction

   a) Low Temp - high pressure (300°F to 400°F)
   b) High Temp - (400°F to 600°F)

3. Chemical Treatment - May not produce sludge suitable for land application

   a) High lime (pH $\geq$ 12, 2 hours of contact)
   b) High Chlorine (dosage $\geq$ 2,000 mg/l)

4. Additional pathogen reduction - Added treatment, such as holding, followed by long term storage of 90 days (above 0°C) or more, air drying, etc. (lagoons-Use 2 cell, alternate load-unload sequence)

TABLE 3

Guidelines for Interpretation
of Review Checklist for
Land Application of Sludge

B. Classification (See maximum metal concentrations in Sewerage Regs (Table K-1))

1. Class A

Stabilized (effective organic/pathogen reduction) and not chemically contaminated (metals, PCB's, etc.). Good quality sludge would not have undesirable levels of metals, PCB's, etc., suitable for agricultural reuse, will not degrade ground water.

2. Class B

Unstabilized and/or chemically contaminated, unfit for land application (includes septage).

Tabke K-1 Standards of Metal Content of Class A Digested Sewage Sludges for Application on Cropland

METALS	MAXIMUM CONTENT PARTS PER MILLION (Mg/kg)	DESIRALE CONTENT THAT IS REACHABLE BY MOST TREATMENT FACILITIES IN VIRGINIA
Zinc (Zn)	2,500	750
Copper (Cu)	1,000	250
Nickel (Ni)	200	50
Cadmium (Cd)	25	5
Boron (B)	100	100
Lead (Pb)	1,000	1,000
Mercury (Hg)	15	2
Cadmium/Zinc Ratio (Cd/Zn) Maxium	Cd=1.0% of Zn	0.8%

Source: Biological Waste Management and Soil Nitrogen Laboratory-Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland

TABLE 4: Recommended Land Application Rates for Agricultureal Reuse of Class A Sludges (Appendix K, Virgnia Sewerage Regulations).

The recommended loading rates are established to assure that added nitrogen will be no greater than the anticipated requirements for the crops to be removed. No crops should be removed by harvesting or grazing less than 30 days after the last application of sludge. Pasture should be clipped immediately prior to sludge application.

Table K-2 Guidelines on Maximum Loading Rates for Digested Sewage Sludge on Cropland Based on Removal of Crops When Mature or by Grazing. /3

CROP	YIELD PER ACRE	NITROGEN UPTAKE LBS/ACRE	RECOMMENDED APPLICATION PER YEAR AT 3.5% NITROGEN OF WHICH 50% IS AVAILABLE NITROGEN /T	
			DRY TONS EQUIVALENT	TONS DEWATERED AT 15% SOLIDS
Corn for grain	100 bu	135	3.9	26
	120 bu	160	4.6	30
	140 bu	180	5.1	34
Corn Silage	32 tons	240	6.9	46
Wheat /2	60 tons	140	4.0	27
	80 bu	180	5.1	34
Oats /2	100 bu	100	2.6	17
Barley /2	90 bu	135	3.9	26
Rye /2	50 bu	110	3.1	21
Grain sorghum for grain	40 CWT	80	2.3	15
Grain sorghum for silage	30 tons	225	6.4	43
Tall fescue	4 tons	160	4.6	30
Orchard grass	5 tons	200	5.1	34
Reed canary grass	4 tons	220	6.3	42
Rye grass	2 tons	80	2.3	15
Alfalfa	4 tons	225	6.4	43
Clovers	3 tons	160	4.6	30
Soybeans	40 bu	200	5.1	34

/T When Nitrogen content is higher or lower than 3.5%, multiply the recommended tons by 3.5%/%N content. (For example, the application of sludge with 2% nitrogen for 120 bu. per acre corn is (3.5%/2.0%) 4.6 tons/A=8.1tons). Available nitrogen (N) is calculated as 20% of organic (N) plus 100% of the mineral (NH4-N).

/2 If straw is removed after harvest of grain or if the crop is removed as hay.

Organisms	Disease	Reservoir(s)
I. BACTERIA		
Salmonella (Approx. 1700 types)	Typhoid Fever Salmonellosis	Man, domestic and Wild Animals and Birds
Shigellae (4 spp.)	Shigellosis	Man
Escherichia coli (enteropathogenic types)	Gastroenteritis	Man, domestic animals
Vibrio Comma	Cholera	Man
II. ENTERIC VIRUSES		
Enteroviruses	Gastroenteritis, heart anomalies, menigitis, others	Man, possibly lower animals
Polioviruses	Gastroenteritis	
Coxsackieviruses	Gastroenteritis	
Echoviruses	Gastroenteritis	
Rotavirus (Reovirus)	Gastroenteritis	Man, domestic animals
Parvovirus-like Agents (Norwalk)	Gastroenteritis	Man
Hepatitis A virus	Infectious Hepatitis	Man, other primates
Adenoviruses	Respiratory disease, conjunctivities, other	Man
III. PROTOZOAN		
Entomoeba histolytica	Amebiasis	Man
Giardia lamblia	Giardiasis	Man, Domestic and wild animals ?
IV. HELMINTHS		
Nematodes (Roundworms)		
Ascaris lumbricodies	Ascariasis	Man, Swine?
Ancylostoma duodenale	Ancylostomiasis	Man
Necator americanus	Necatoriasis	Man
Enterobius vermicularis (pinworm)	Enterobiasis	Man
Trichuris trichiura (whipworm)	Trichuriasis	Man
Cestodes (Tapeworms)		
Taenia saginata (beef tapeworm)	Taeniasis	Man
Taenia solium (pork tapeworm)	Taeniasis	Man
Hymenolepis nana (dwarf tapeworm)	Taeniasis	Man, Rat

TABLE 5: Potentially Pathogenic Organisms that may be found in Sewage Sludge

TABLE 6

Guidelines for Interpretation
of Review Checklist for
Land Application of Sludge

C. Site Management

1. Sludge surface applied to crop land should be disced into the plow layer prior to planting, and public access to the site should be restricted.

2. Pasture land should not be grazed for at least two weeks after surface application, but milk cows should not be allowed on the site within two months following surface sludge application. Time period prior to return to grazing following minimum disturbance injection followed by surface rolling should be evaluated on a site by site basis.

3. Green-chopped forage should not be fed to animals if removed within two weeks of surface application to forage and should not be fed to milk cows if removed within two months following surface application.

4. Sludge should not be applied in quantities which will result in runoff, vector or odor problems and should not be applied during periods of rain or to ground which is saturated, or covered with snow.

5. Storage at a disposal site could be provided if:

   a) no storage capacity exists at the treatment facility,
   b) public and livestock access to storage area is prevented and proper buffer maintained,
   c) runoff and percolation from the storage area is prevented or adequately treated,
   d) storage does not result in a vector or odor problem and,
   e) stored sludge is applied as soon as possible when soil and weather conditions permit surface application.

6. Runoff from application area should be minimized by soil conservation practices including, reduced tillage systems, terraces, strip cropping and retention of adequate crop residues on soil surface.

TABLE 7: Suggested Sludge Application Limits for Accumulation of Heavy Metals in Agricultural Soils (Appendix K, Virginia Sewerage Regulations

Toxic metals likely to reduce crop yields are listed in Table K-4. The capability of soils to absorb and hold toxic metals without harmful effects is limited by the cation exchange capacity of the soil. Table K-4 provides guidelines for maximum accumulations of certain metals based on cation exchange capacity.

Table K-4 Guidelines for Maximum Cumulative Application of Sludge-Borne Metals to Soils in Privately Controlled Lands. /T

	0.5 CEC		5-15 CEC		OVER 15 CEC	
METAL	kg/ha	lb/A	kg/ha	lb/A	kg/ha	lb/A
Zn	250	222	500	445	1000	890
Cu	125	111	250	222	500	445
Ni	50	44	100	89	200	178
Cd	2.5	2.22	5.0	4.45	10.0	8.9
Pb	500	445	1000	890	2000	1780

/T Such applications to be made on soils with pH adjusted to 6.5 or greater and maintained at 6.2 or greater. (These are tentative maximum levels which may be modified after further research data becomes available.

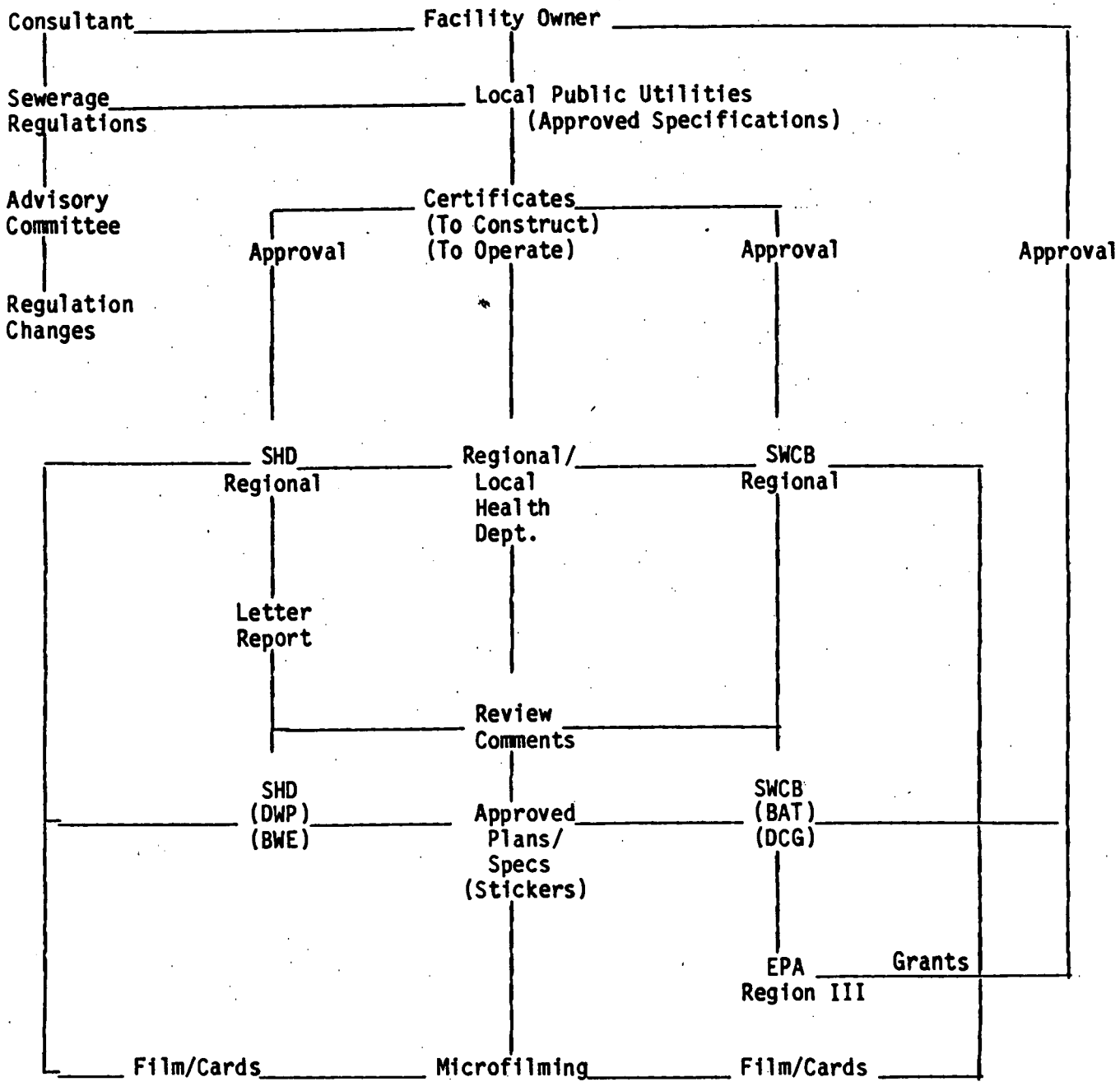
Source: Biological Waste Management and Soil Nitrogen Laboratory, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland

Sewage Treatment Plant Size Design Flow-MGD	Number Reporting Use of Land Application for Sludge Disposal	% of Total No. STP's	Sludge Disposal Plans Describing Land Application	
			Under Review	Approved
.01 - 0.1	12	5	5	1
.11 - 1.0	16	10	4	4
1.1 - 10.0	18	37*	8	10
10.1 - 50	9	53*	5	4
50.1 - 100	1	100*	1	0
.01 - 100	56		23	19

TABLE 8: Status of sludge disposal plan processing for Virginia Sewage Treatment Plants according to State Health Department, Division of Water Programs (March, 1982).

*42% of all STP's in the design flow range of 1.1 to 100 MGD report use of land application of stabilized sludge.

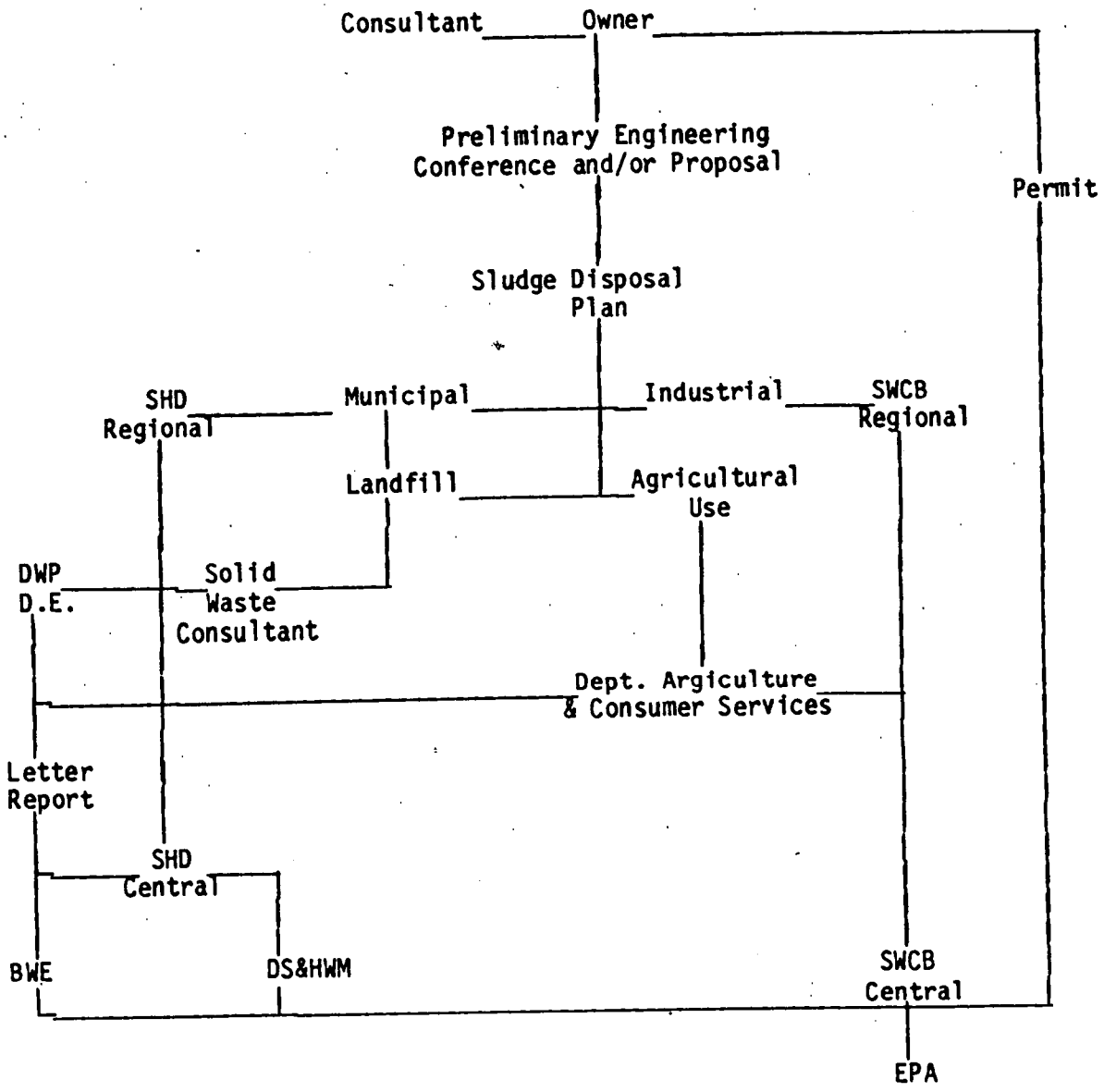
FIGURE 1:
Plans/Specs Review Flowsheet



SHD - State Health Department
DWP - Division of Water Programs
BWE - Bureau of Wastewater Engineering
SWCB- State Water Control Board
BAT - Bureau of Applied Technology
DCG - Division of Construction Grants
EPA - Environmental Protection Agency

FIGURE 2:

Sludge Disposal Plan Processing
Inter-Agency Responsibilities



SHD - State Health Department
DWP - Division of Water Programs
DS&HWM - Division of Solid and Hazardous Waste Management
BWE - Bureau of Wastewater Engineering
SWCB - State Water Control Board

Land Application of Sewage Sludge by Commercial Contractor
(or Applicant for a Virginia No-Discharge Certificate)

Recommended Permit Application Requirements

1. Must have necessary resources (equipment-personnel) to haul and uniformly apply Class A sludges (liquid-dewatered-dried) at agronomic rates. These resources must be described in the permit application.
2. Must have legal contract with generator(s) stipulating a guaranteed quantity of sludge to be handled within a specified period of time. In addition, the contract should state that the generator is responsible for providing Class A sludge for land application and the contractor is not responsible for handling any sludges not meeting Class A characteristics. Copies of the contractual agreements and written verification of agreement from generator, must be provided in the permit application. If a contractor does not have a valid contract with a generator(s) for a guaranteed quantity of sludge, a permit cannot be issued and any existing permits for land application sites permitted only for that sludge(s) would be no longer valid. A new application must be submitted to obtain a permit for use of those sites under a new contract with the generator.
3. An approved method of storage of sludge, during periods when land application is not possible, must be stipulated in the permit application, if the contract with the generator involves handling the entire quantity of generated sludge and extends through, winter month(s), planting season(s) or a period of time equal to or more than the on-site storage capacity of the generator.
4. Local governmental officials (County Administrator and Chairman of the Board of Supervisors) must be contacted and informed of the proposed land application operation prior to submittal of a permit application. A copy of an approval, or a no-objection, statement from the County Administrator should

be included with the permit application. In the absence of local government approval, the contractor must provide evidence that local zoning ordinances will not be violated by the proposed land application.

5. Must secure agreements with local farmers, and/or land owners, which indicate that land application of the Class A sludge will be allowed during a stated period of time and that permit restrictions such as, cropping rotation, grazing prohibitions, notification of operational changes, etc., will be strictly adhered to. Copies of these agreements must be provided in the permit application.
6. Must provide site specific information, such as soil characteristics, as required by the regulatory agencies, on each proposed land application site, as well as, a description of the application methodology to be utilized during the proposed land application.
7. Must provide information describing the means of record keeping necessary to control and monitor land application operations and the means of reporting required information to the regulatory agencies.
8. Must submit a request for a permit amendment describing any proposed changes in the land application operations as originally permitted. A permit amendment must be approved prior to changes in the approved land application operation and/or the addition of any application sites not originally specified in the permit application.

APPENDIX F

Roanoke Times & World-News

Times-World Corporation P.O. Box 2491, 201 West Campbell Avenue Roanoke, Virginia 24010

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Bio Gro Systems, Inc.
P. O. Box 209
Annapolis, Md. 21404

PUBLIC NOTICE

The State Water Control Board has received an application for amendment to No-Discharge Certificate from the following owner:

Name: Bio Gro Systems, Inc.
Owner Address: P.O. Box 209 Annapolis, Maryland 21404
Amendment Description: The owner proposes to add farmland in Bedford and Botetourt Counties to areas in Franklin County previously approved in No. Discharge Certificate 1W-ND-1489 for the application of sludge from the Roanoke Sewage Treatment Plant.
Location of Fields: Bedford County: Near intersection of Routes 460 and 741; near intersection of Route 460 and 690; north of Montvale between Routes697 and 695; on Route 741 approximately 1 mile north of 460.

Botetourt County: Along Blue Ridge Parkway near Coyner Springs; along Route 657 between Route 658 and Blue Ridge Parkway; along Blue Ridge Parkway about 1/4 mile north of Route 652; approximately 1/2 mile east of Route 616 and north of Route 460.

The Water Control Board will accept written comments or requests for public hearing on this application for 30 days following the first publication of this notice. The Board will hold a public hearing on the application if there is significant public interest in it and there are substantial disputed issues regarding it. All processing of this application will follow the requirements of the Board's Procedural Rules No. 1 and 2.

Additional information on this application is available from and comments and requests for hearing may be addressed to:

State Water Control Board
West Central Regional Office
P. O. Box 7017
Roanoke, Virginia 24019

(08033703)

STATE OF VIRGINIA,
CITY OF ROANOKE } Affidavit to Wit:

I, Irene W. Carr, an officer of TIMES-WORLD CORPORATION, which corporation is Publisher of the Roanoke Times & World-News, a daily newspaper published in Roanoke, in the State of Virginia, do certify that the annexed notice was published in said newspapers on .....
8/5/81 morning; 8/12/81 morning
.....
.....
.....
.....

Witness, this 17th day of August 1981

Irene W. Carr
Assistant Secretary

RHF
10/25/82

SLUDGE VALUES

Discussion at the Commission meeting of October 6, 1982 raised questions as to the equivalent fertilizer values of sludges. The attached publication by the University of Maryland's Cooperative Extension Service (May, 1980) indicates the value at $280.17 (20 dry tons/acre @ $14.00 per ton) (page 4). The attached estimates prepared by BioGro Systems (1982) of sludges values from $235.73 - $320.19 bracket the University's estimate (page 6).

Cooperative Extension Service

MARYLAND AGRI-ECONOMICS

UNIVERSITY OF MARYLAND-COLLEGE PARK — UNIVERSITY OF MARYLAND-EASTERN SHORE

May 1980

The Value and Use of Organic Wastes*

Alexander Barbarika, Daniel Colacicco and William J. Bellows **

Introduction

Rising fertilizer prices, fewer raw materials and restoring and maintaining environmental quality are some of the factors encouraging return of organic wastes to the land. For farmers the economic consequences are not clear because of imprecise current evaluations of waste materials. To make informed decisions about the use of organic wastes, reliable estimates of economic value are needed. This article first looks at the importance of organic wastes in United States and Maryland agriculture. Then it looks at some of the factors affecting the economic value and some methods of evaluating wastes.

Annual Production and Use

The organic matter and nutrients returned to the soil as organic wastes play an important role in the maintenance of soil productivity. A recent USDA study estimates that 850-million dry tons of organic wastes are generated in the United States each year, of which about 53 percent are returned to the land. At time of generation, the combined amounts of nitrogen, phosphorus and potassium in the wastes that are applied on land are roughly equal to the amounts of nutrients in commercial fertilizer used each year. Most of the materials returned to the land are agricultural wastes such as crop residues and animal manures, while those wastes not being used extensively on land are mainly urban and industrial in origin. The USDA study indicates that animal manures produced under confined conditions and sewage sludges have the greatest potential for increased land application and that the value of wastes applied to land could be increased through improved handling and storage procedures. It is estimated that as much as 4 million tons of nitrogen are lost annually from animal wastes alone due to denitrification, volatilization and leaching.

Table I shows the estimated production and land application of various organic wastes in Maryland. The quantity of nitrogen, phosphorus and potassium in the applied wastes is equivalent to 41, 24 and 32 percent, respectively, of these nutrients applied as commercial fertilizer each year. The value of the waste-supplied nutrients, however, would be lower due to the short-term unavailability of organically-bound nitrogen in waste materials. There is little potential for increased land use of crop residues and animal manures in Maryland because it is already extensively used on land or in feed. Sewage sludge use on land is expected to increase, especially on farms near urban areas. It is doubtful that fertilizer use in the state as a whole would be noticeably affected by increased land utilization of sewage sludge because of nutrient losses during handling and storage and the unsuitability of some sewage sludges for land use.

* Research on the utilization of organic wastes reported herein was partially supported by funds from the SEA, USDA.

** The authors are respectively, Graduate Research Assistant, Department of Agricultural and Resource Economics, University of Maryland; Agricultural Economist, U.S. Department of Agriculture; and Assistant Professor, Department of Agriculture and Resource Economics, University of Maryland.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914 in cooperation with the U.S. Department of Agriculture, University of Maryland and local governments. John M. Curtis, Director of Cooperative Extension Service, University of Maryland.

Table I. Organic wastes as nutrient sources in Maryland agriculture [a]

Source	Produced in MD & DC (Dry Tons/Year) Material	N	P_2O_5	K_2O	Applied on Land (Dry Tons/Year) Material	N	P_2O_5	K_2O	% of Material Applied on Land
Sewage Sludges	113,679	4,257	5,159	563	28,543	1,142	1,307	114	25
Crop Residues	1,198,818	13,240	4,255	17,656	866,187	9,629	2,943	12,326	72
Animal Manures	319,222	14,411	8,813	7,806	309,732	13,982	8,554	7,572	97
Total	1,631,719	31,908	18,227	26,025	1,204,462	24,753	12,804	20,012	74
Fertilizers						59,878	52,715	62,549	
Total						84,631	65,519	82,561	

[a] Derived from Metcalf and Eddy, Stanford Res. Inst., Larson et al., VanDyne and Gilbertson, and Maryland Crop Reporting Service.

Potential For Soil Improvement

Human, animal and plant wastes have long been used to restore and maintain the productivity of the soil. In fact, they were indispensable in this role until the introducton of inorganic fertilizers, which proved in many cases to be a cheaper, more convenient source of nutrients. However, benefits, such as increased crop yield and decreased soil erosion, may be derived from the nutrient content and soil conditioning properties of organic wastes. These wastes usually contain some of each nutrient essential for plant growth; the organic matter contained can improve soil texture, aeration and moisture retention.

Manures and sewage sludges usually contain small but appreciable amounts of nutrients. Municipal solid wastes, industrial sludges, food processing and other organic wastes may also have some nutrient content. The figures in Table II should be regarded only as representative values because nutrient contents are highly variable, and, in most cases, performing a chemical analysis of each sample is the only way to accurately estimate nutrient content. Thus, evaluation and optimum utilization of the organic waste are difficult. Some factors that can affect nutrient content of manures are diet, health and age of the animal, bedding material used and handling procedures. Factors that affect the nutrient content of sewage sludge and municipal waste are treatment method and the amount of industrial wastes relative to the amount of residential waste entering the system.

Table II. Nutrient content of some organic wastes [a]

	% Dry Weight N	P_2O_5	K_2O	Ca	S	Fe	Mg
Manures							
Dairy Cow	2.7	1.1	2.9	1.6	0.3	0.02	0.6
Broiler	3.6	3.5	3.2	2.0	0.4	0.12	0.4
Hog	2.0	1.3	1.8	2.0	0.5	0.10	0.3
Sewage Sludge	2.5	4.1	0.3	3.8	1.1	0.8	0.46
Corn Stover	1.1	0.4	1.6	0.3	0.1		0.19
Composted Refuse	1.2	0.6	0.5	1.3			0.07

[a] Derived from Kardos et al. and McCalla et al.

Organic matter is an essential component of fertile soils. Although not directly utilized by plants the way the inorganic nutrients are, the maintenance of sufficient organic matter in the soil is necessary for crop production. The practice of maintaining soil fertility through the use of animal and green manures has been replaced largely by the use of synthetic fertilizers, which do not directly increase soil organic matter. However, the amount of crop residue produced may be increased by using fertilizers, and, if left in the field, would lead to enhancement of the soil's organic-matter content. Whether this maintains sufficient organic matter levels to prevent a gradual decline in soil productivity is one of the major questions facing agriculture.

The uncertainty over the role of organic matter in crop production also results in imprecise organic waste evaluations. In large part the difficulty is in determining the value of the soil conditioning properties of organic material, which varies depending on the soil, crop and type of organic matter. Another major obstacle has been the difficulty of distinguishing the effect on yield due to the nutrients added from that due to enhanced soil structure resulting from the organic matter added. Therefore, most assessments include only the nutrient value, which may be a conservative estimate of the total value of organic waste.

Benefits derived from applying organic wastes to the land are twofold. Soil productivity is improved by enhanced soil structure, and the nutrients are used rather than disposed. While benefits accrue from the use of organic wastes on land, there are also costs associated with their use. Some of the costs are realized in the form of on-farm handling costs, but others are environmental costs which may not be directly observed.

Environmental Constraints

While organic wastes may be valuable sources of essential nutrients and organic matter, they cannot be indiscriminately applied on the land. Some may be suited only for use on nonagricultural land; others may not be suitable for use on any land. Wastes such as sewage sludges and municipal composts, if generated in areas serving extensive industry, may contain harmful levels of toxic chemicals. Heavy metals, such as cadmium, nickel, lead and zinc, can be a major problem if present and can restrict or prohibit use of waste on land.

Another factor to consider when using organic wastes on land is pathogen content of animal manure and sewage sludge. While these pathogens generally die shortly after application, it may be necessary in some cases to ensure that livestock is kept off the treated land, or that crops are not harvested within a specified period following application. Other constraints may result from the soluble salt content of the waste material. Salts can accumulate to harmful levels in the soil with repeated or excessive waste applications. Manures and sewage sludges may contain viable weed seeds and use of these wastes may require extra cultivations or herbicide applications. Some organic wastes have odors which may restrict location, method or time of application. Public attitudes concerning human and animal waste use may further restrict land application programs.

Some organic wastes can become hazardous to the environment if not used appropriately. Land application decisions must be based on environmental as well as agronomic considerations. Uses other than crop production may be more appropriate. These include use by nurseries as potting media and in turf production. They may also be used on parks, golf courses and in reclaiming disturbed lands such as strip mine spoils.

Nutrient Value

Nutrient content is commonly used to measure the value of organic wastes. This can be defined as the sum of the values of the individual nutrients available in the waste. The measure usually considers only the nitrogen, phosphorus and potassium content. Sometimes the value of micronutrients such as magnesium, boron or iron may be considered. On some soils, the micronutrient contribution can be very beneficial to crops, livestock or humans consuming the crop.

Nutrients in soil organic matter must be converted by microorganisms and other natural processes into inorganic forms before they can be used by plants; a process that occurs gradually over time. Nutrients in manure are not all available in the first year of application. The rate at which this conversion to plant-available forms takes place is termed the mineralization rate. The rate varies depending on the waste material and environmental conditions such as rainfall and temperature. A mineralization rate of 0.40, 0.25, 0.06 for cow manure means that in the first year, 40 percent of the nitrogen content is mineralized. Twenty-five percent of the nitrogen remaining after the first year is mineralized in the second year, and 6 percent of the remaining is mineralized each year thereafter.

The present value of nutrients released five years after waste application will not be worth the same per unit as the nutrients released in the first year, due to the time value of money. The present-value concept can be used to bring future streams of value to a current value. With the nitrogen mineralization rate mentioned above, and with a phosphorus mineralization 0.70, 0.10, 0.05 and all potassium immediately available, the present value of a dry ton of manure would be $15.63. If all nutrients were considered immediately available, the value obtained would have been $19.00/dry ton which would overstate the nutrient value of the manure.

Because many wastes are not applied and incorporated immediately after generation, nutrient losses often occur between the time of waste production and the time of application. The effective nutrient value is a measure that takes into account any losses due to storage, handling and application procedures. This measure is more appropriate in evaluating use of a waste in crop production than one that is based on gross contents at time of waste generation. Table III shows how handling and application can affect the quantities of nitrogen that become available over a 3-year period in cattle manure. For example, 81 percent of manure nitrogen would be available over the 3 years if the manure is incorporated the same day that it is produced. If the manure is allowed to sit on the field for 5 days before being incorporated, the 3-year availability declines to 63 percent. Usually, phosphorus and potassium are in forms more readily available to plants, and are less affected by handling procedures than nitrogen, but their availabilities and contents can be adversely affected by treatment practices as well.

Table III. Nitrogen availability in cattle manure [a]

	Percentage of Original N that becomes over the first three years
Fresh Manure	
Incorporated	
Same Day	81
1-4 Days	71
5 Days	63
Solid Manure Stack	
Same Day	62
1-4 Days	53
5 Days	42
Open-lot Storage Solid Spread	
Same Day	35

[a] From Barth et al.

Some organic wastes may have high carbon:nitrogen ratios that, after addition to the soil, can cause temporary decreases in available N. This occurs when soil microorganisms compete with plants for the available nitrogen. Nitrogen depletion may be significant if the ratio is in the range of 90 or above. This might happen when large amounts of materials, such as some crop residues, plant composts or wood products, are used. It is appropriate to reduce the estimates of the short-run availability of nitrogen in these cases.

Economic Impact on Farms

The economic value of organic wastes applied to farm soils ultimately is reflected in their impact on farm profits, brought about through changes in costs, revenues or both.

Revenues may be changed by the addition of organic wastes due to increased or decreased yields, or a change in product mix or quality which changes product price. A University of Maryland study (see Table IV) of the effects of sewage sludge on crop yields was begun in 1972. Various levels of digested sewage sludge from Washington, D.C., were applied in 1972 to test plots on Sassafras silt loam soil. The yield of corn grain, shown in Table IV, was somewhat depressed in the first year due to a late harvest. Corn was grown on the same plots each subsequent year with no additional applications of sludge. The sludge's residual effect was pronounced. The plots that received 50- and 100-dry tons per acre in 1972 gave 100+bu/acre yields in 1976, a significant increase over the yields on

Table IV. Effect of Washington, D.C., sewage sludge applied in 1972 on corn grain yields *

Sludge Applied in 1972	Fertilizer Applied Each Year			Corn Grain Yield					
	N	P_2O_3	K_2O	1972	1973	1974	1975	1976	Average
Dry/Tons Acre		lbs/acre		Bu/Acre					
0	0	0	0	40.0	33.6	10.9	25.9	1.4	22.4
25	0	0	0	88.4	109.6	103.0	86.8	61.4	89.8
50	0	0	0	106.0	163.9	109.5	106.8	107.0	118.6
100	0	0	0	97.6	172.8	122.0	110.7	110.4	122.7
0	160	80	80	54.7	81.4	91.8	79.9	76.1	76.8

* This table based on personal conversation with Dr. A. M. Decker and on articles by Decker et al.

the control plots, which received the recommended rate of fertilizer addition every year.

Revenues may also be affected by changes in the crops grown. Use of some sewage sludges might require that for several years only crops grown for grain, rather than forage or human consumption, can be planted on the affected land. In a rotation, the organic matter applied may substitute for certain crops that had been included for organic matter maintenance or erosion control.

The costs of production will change when organic wastes are substituted for commercial fertilizers because fertilizer needs will be lower, while costs of fuel and equipment for transporting and applying the waste will be higher. The net cost change may be either positive or negative. It may pay to build new or modify old manure storage facilities, or to change some waste handling procedures to conserve as much of the nutrient content as possible.

The University of Maryland study shows the value of the sludge in terms of its fertilizer equivalency. Corn yields of 77 bu/acre were obtained with nitrogen, phosphorus and potassium applied at 160, 80 and 80 lbs/acre, respectively. This represents an annual expenditure for fertilizer of $64.00/acre using prices of $500/ton N, $400/ton P_2O_5 and $200/ton K_2O. Regression analysis of the Maryland study results indicates that a one-time application of 20 dry tons/acre would give yields of 77 bu/acre each year for 5 years after application. In this case, the single application of sludge would replace 5 years of fertilizer purchases of $64.00 per year, which has a present value of $280.17. The sludge world be worth $280.17 ÷ 20 or $14.00 per dry ton to the farmer. The cost of hauling and applying the material would be deducted, if the farmer paid these costs, for a more accurate estimate of its value. However, these costs are usually borne by the sewage authority. Also it must be kept in mind that environmental constraints may prohibit application of such large amounts of sludge per acre.

Summary

Organic wastes are valuable sources of nutrients and organic matter, currently providing a significant portion of the nutrients applied to the land in the United States each year. The organic matter serves as soil conditioner and promotes conservation of nutrients, moisture and soil. In Maryland, about 75 percent of the 1.6 million dry tons of sewage sludge, animal manures and crop residues produced are returned to the land. However, competing uses, environmental concerns and costs involved are constraints to increased use on land.

Values based on nutrient content, with appropriate allowance for nutrient losses and availability, can be determined. As measures of total value these estimates are incomplete because they do not include the value of the organic matter. Also, they may evaluate nutrients that are not utilized by the crop, and they do not discount for harmful components, such as salts or heavy metals, or social unacceptability. Values based on effect on profits are usually preferable because they involve consideration of the altered production costs and farm revenues and reflect the net effect of the various components in the waste. The use of sewage sludge as a substitute for fertilizer in growing corn was evaluated using the results of 5 years of the experiment at Beltsville, Maryland. A dry ton of sludge was found to produce the same yield response as $14 of commercial fertilizer. Organic materials, which are wastes to municipalities or some producers, can be valuable inputs for agriculture.

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BIO GRO SYSTEMS

Sludge Disposal • Specializing in Land Application

SLUDGE VALUES

(Based on supplying 100 lbs. Plant Available N/Ac)

At 5 Dry Tons/Acre*(Injected)- Approximate Amounts for Land with CEC 5

Nutrients	Value
100 lbs. Plant Available N @ $0.25/lb	$ 25.00
641 lbs. Plant Available P_2O_5 @ $0.28/lb	179.48
2500 lbs. Lime ($CaCO_3$ Equiv.) @ $25/ton	31.25
Total Value	$235.73

*plus organic matter and trace elements.

According to University of Maryland's guidelines, sludge can be applied at the above rates to the same land for 18 years.

According to Federal guidelines, sludge can be applied at the above rates to the same land for 42 years.

At 7 Dry Tons/Acre* (Surface Applied)

Nutrients	Value
100 lbs. Plant Available N @ $0.25/lb	$ 25.00
898 lbs. Plant Available P_2O_5 @ $0.28/lb	251.44
3500 lbs. Lime ($CaCO_3$ Equiv.) @ $25/ton	43.75
Total Value	$320.19

*plus organic matter and trace elements.

According to University of Maryland's guidelines, sludge can be applied at the above rates to the same land for 12 years.

According to Federal guidelines, sludge can be applied at the above rates to the same land for 30 years.

Bio Gro Systems Incorporated
P.O. Box 209 Annapolis, Maryland 21404 Telephone (301) 263-2237

General Assembly of Maryland

State Department of Legislative Reference
90 State Circle . Annapolis, Maryland 21401

F. Carvel Payne
Director

Research Division
Myron H. Miller
Division Chief

November 30, 1982

MEMORANDUM

TO: Sewage Sludge Management Commission Members

FROM: Staff

SUBJECT: Liability and Bonding Requirements for Sludge Applicators

The following attachments provide examples of the liability and bonding requirements that a major applicator of sludge to agricultural land (Bio Gro Systems, Inc.) maintains:

1. An example of the insurance coverage and bonding requirements specified by a municipality in a current contract with Bio Gro.

2. The Commercial Umbrella Liability Policy Bio Gro held in 1981-1982.

3. The Comprehensive General Liability Policy Bio Gro held in 1981-1982.

4. A copy of the General Performance Bond Bio-Gro posted with the City of Akron, Ohio in 1982.

There are several levels of security that municipalities/generators require:

A. Level 1 Liability - This includes full auto and truck liability coverage; property damage liability; workmen's compensation; etc. (see attachment 1 for example).

B. Level 2 Liability - coverage for sudden and accidental incidents and general liability (attachments 2 and 3).

C. Level 3 - Performance Bonding (both payment bonds for suppliers and subcontractors, and general performance bonds - - attachment 4).

There are various ways that generators and applicators reach agreement on performance bonds; such bonds are required by municipalities/generators since (a) the generator makes an investment in

Baltimore 841-3875

Washington 858-3875

putting bid specifications together, evaluating proposals, etc. and (b) the generator is often the permittee and wants to insure completion of the work by the applicator.

The conditions which are bonded vary widely, depending on the generator's responsibility. In some cases, performance consists of removing sludge at a specified rate from the generator's premises. In others, bonded actions include the application of sludge in an approved and workmanlike manner. There are three methods used by the generators to ensure performance, depending on what their contract with an applicator calls for:

1. Retainage - of 5 to 10% of each payment (e.g., monthly), usually until a specified amount is reached which would enable the generator to hire another firm in the event of a default.

2. A Certificate of Deposit - which is held by the generator. This is the contractor's money which is remanded to him at the end of the contract period. This method is not the usual method of bonding.

3. An Irrevokable Letter of Credit - which is basically the same as a performance bond. It is issued from the contractor's bank, assuring the generator will be paid a specified amount in the event of contractor non-performance; it is essentially like a regular line of credit.

Rather than require additional bonding by the State (to our knowledge, no other states have bonding requirements unless they are acting in the capacity of a generator), one alternative is for the provision of a State Emergency Response Fund (similar to the Oil Spill Fund) for rectifying mismanaged sludge applications/ accidents involving the sludge. Such a Fund could be financed by the imposition of a per ton user fee on the generator, and would serve as another "backstop" to the liability insurance carried by applicators (which is also required by the generator).

On pages 6 and 7 of the Minutes of the Commissions October 27 meeting, Mr. Stephen Campbell, President of Bio Gro Systems, summarized pertinent aspects of liability, performance bonds, and insurance.

APPENDIX I

C. Insurance Coverage and Bonding

Bio Gro Systems will provide for the following:

1. Workman's Compensation Insurance as prescribed by State Statute.
2. Employer's Liability as required by law.
3. Comprehensive Public Liability Insurance:
   a. Bodily Injury - Each Person $100,000.
   b. Bodily Injury - Each Accident 300,000.
   c. Property Damage - Each Person 100,000.
   d. Property Damage - Each Accident 100,000.
4. Comprehensive Automobile Liability Insurance; owned, hired, and non-owned.
   a. Bodily Injury - Each Person $100,000.
   b. Bodily Injury - Each Occurrence 300,000.
   c. Property Damage - Each Accident 100,000.

Bio Gro shall also furnish an owner's protective policy with City as the named insured, issued by the same insurance company. Bio Gro shall furnish certificates of such insurance which shall provide that such insurance will not be cancelled by the insurer without the insurer first giving the City ten (10) days written notice of cancellation.

It is further agreed that Bio Gro will keep in full force and effect during the term of this Agreement insurance coverage in the amount of no less than 4.5 Million Dollars ($4,500,000.00) to protect parties against any accidental pollution and/or damages therefrom that may occur as a result of Bio Gro's performance under the contract.

NORTHEASTERN FIRE INSURANCE CO.
of Pennsylvania

KING OF PRUSSIA, PENNSYLVANIA

(A stock insurance Company, herein called the Company)

s with the insured, named in the declarations made a part hereof, in consideration of the payment of the premium and in reliance upon tha statements declarations and subject to the limits of liability, exclusions, conditions and other terms of this policy:

INSURING AGREEMENTS

I Coverage. To pay on behalf of the insured the ultimate net loss in excess of the applicable underlying (or ratained) limit hereinafter stated, which tbe insured shall become obligated to pay by reason of the liability imposed upon the insured by law or assumed by the insured under contract:

(a) PERSONAL INJURY LIABILITY. For damages, including damages for care and loss of services, because of personal injury, including death at any time resulting therefrom, sustained by eny person or persons,

(b) PROPERTY DAMAGE LIABILITY. For damages because of injury to or destruction of tangible property including consequential loss resulting therefrom,

(c) ADVERTISING LIABILITY. For damages because of libel, slander, defamation, infringement of copyright, title or slogan, piracy, unfair competition, idea misappropriation or invasion of right of privacy arising out of the named insured's advertizing activitias,

to which this insurance applies under Coverages I(a), I(b), and I(c) above, caused by an occurrence.

In jurisdictiuns whare the company may be prevented by law from carrying out the agreement to pay on behalf of the insured, the company shall indemnify the insured in accordance with this agreement.

II Defense, Settlement, Supplementary Payments. With respect to any occurrence not covered by the underlying policies listed in Schedule A hereof or any other underlying insurance collectible by the insured, but covered by the terms and conditions of this policy except for the amount of retained limit specified in Item 3(C) of the declarations, the company shall:

(a) defend any suit against the insured alleging such injury or destruction and seeking damages on account thereof, even if such suit is groundless, false or fraudulent; but the company may make such investigation, negotiation and settlement of any claim or suit as it deems expedient;

(b) pay all premiums on bonds to release attachments for an amount not in excess of the applicable limit of liability of this policy, all premiums on appeal bonds required in any such defended suit, but without any obligation to apply for or furnish any such bonds;

(c) pay all expenses incurred by the company, all costs taxed against the insured in any such defended suit and all interest accruing after entry of judgment until the company has paid or tendered or deposited in court such part of such judgment as does not exceed the limit of the company's liability thereon;

(d) reimburse the insured for all reasonable expenses, other than loss of earnings in excess of $50.00 per day, incurred at the company's request; and the amounts so incurred, except settlements of claims and suits, are payable by the company in addition to the applicable limit of liability of this policy.

In jurisdictinns where the company may be prevented by law or otherwise from carrying out this agreement, the company shall pay any expense incurred with its written consent in accordance with this agreement.

The insured shall promptly reimburse the company (excepting Defense Costs) for any amount of ultimate net loss paid on behalf of the insured within the retained limit specified in Item 3(C) of tha declarations.

III Definition of "Named Insured" and "Insured". "Named Insured", wherever used (including endorsements forming a part hereof) includes, while operating as such, any subsidiary of the named insured and any other entity coming under the named insured's control over which it assumes active management.

The unqualified word "insured", wherever used (including endorsements forming a part hereof) means the named insured and each of the following to the extent set forth below:

(a) if the named insured is designated in the declarations as a partnership or joint venture, the partnership or joint venture so designated and any partner or member thereof but only with respect to his liability as such, however, this policy does not apply to personal injury, property damage or advertising occurrences arising out of the conduct of any partnership or joint venture of which the insured is a partner or member and which is not designated in this policy as a named insured;

(b) any person, organization, trustee or estate to whom or to which the named insured is obligated by virtue of a written contract to provide insurance such as is afforded by this policy, but only with respect to operations by or in behalf of the named insured or to facilities of or used by the named insured;

(c) subject to the terms and conditions of this policy, any additiunal insured, other than the named insured, included in the underlying policies listed in Schedule A but only to the extent that insurance is provided to such additional insured thereunder;

(d) except with respect to the ownership, maintenance or use, including loading or unloading of automobiles or of aircraft, (1) any executive officer, other employee, director or stockholder thereof while acting within the scope of his duties as such; (2) any person or organization while acting as real estate manager for the named insured;

(e) any person while using an automobile or aircraft owned by or loaned to the named insured or hired for use in behalf of the named insured and any person or organization legally responsible for the use thereof, provided the actual use of the automobile or aircraft is by the named insured or with the named insured's permission, and any executive officer, director or stockholder of the named insured with respect to the use of an automobile or aircraft not owned by the named insured in the business of the named Insured. The insurance with respect to any person or organization other than the named insured does not apply under division (e) of this insuring agreement:

(1) to any person or organizatiun, to any agent or employee thereof, operating an automobile sales agency, repair shop, service station, storage garage or public parking place, with respect to any occurrence arising out of the operation thereof;

(4) mistake in advertised price; or

(5) personal injury, death or physical property damage;

(e) under Coverage I(a) and I(b), to injury, sickness, disease, death or destruction:

(1) with respect to which an insured under the policy is also an insured under a nuclear energy liability policy issued by Nuclear Energy Liability Insurance Association, Mutual Atomic Energy Liability Underwriters or Nuclear Insurance Association of Canada, or would be an insured under any such policy but for its termination upon exhaustion of its limit of liability; or

(2) resulting from the hazardous properties of nuclear material and

COMMERCIAL UMBRELLA LIABILITY POLICY PROVISIONS SECTION ONE

COMMERCIAL UMBRELLA LIABILITY POLICY

This insurance is issued by a non-admitted insurer not under the jurisdiction of the Maryland Insurance Commissioner.

NFI

NORTHEASTERN FIRE INSURANCE CO. of Pennsylvania

KING OF PRUSSIA, PENNSYLVANIA

Item 1. DECLARATIONS

PRODUCER NO	BRANCH	PREFIX	POLICY NUMBER
		CXS	66 U- 12902

NAME ASSURED & ADDRESS (Number & Street, Town, County & State)

BIO-GRO SYSTEMS, INC.
108 Old Solomons Island Rd.
Annapolis, MD

2. Policy Period (hereinafter called "this policy period") 10-15-81 To 10-1-82 ** 12:01 A.M. STANDARD TIME AT THE ADDRESS OF THE NAMED INSURED AS STATED HEREIN

[redacted]

Item 3. Limit of Liability—as insuring Agreement VI

(A) Coverage I(a) or I(b) or I(c), or all combined with respect to each occurrence $ 5,000,000.

(B) Limit in the aggregate for each annual period where applicable $ 5,000,000.

(C) Retaining Limit $ 10,000.

Item 4. Premium Computation:

Estimated Annual Rate per FLAT ANNUAL

Estimated Annual Premium $ 3,400.

Annual Minimum Premium $ 3,400.

Advance Premium $ 3,271.

In the event of cancellation by the named insured the company shall receive and retain not less than $ 1,636. as a policy minimum premium.

Item 5. During the past year no insurer has cancelled any similar insurance issued to the named insured, nor declined to issue such insurance, unless otherwise stated herein. **

** ABSENCE OF AN ENTRY MEANS "NO EXCEPTION"

Endorsements FORM 111
FORM 5214
POLLUTION EXCLUSION ENDORSEMENT

10-30-81
MD-1 jt

NORTHEASTERN FIRE INSURANCE CO. of PENNSYLVANIA

By _____
(Authorized Representative)

Form No. 5260 10/79

ORIGINAL

CONDITIONS

A. Premium. Unless otherwise provided for the premium for this policy is a flat premium and is not subject to adjustment. If this policy is subject to audit adjustment, the premium shall be based upon the rating basis as set forth in the declarations during the policy period. Upon expiration of this policy or its termination during the policy period, or at the end of each policy year, the earned premium shall be computed as thus defined. If the earned premium is more than the advance premium paid, the named insured shall pay the excess to the company; if less, the company shall return to the named insured the unearned portion, subject to the annual minimum premium stated in the declarations for each twelve months of the policy period, and subject further to the policy minimum premium as stated in the declarations

B. Inspection and Audit. The company shall be permitted but not obligated to inspect the named insured's property and operations at any time. Neither the company's right to make inspections nor the making thereof nor any report thereon shall constitute an undertaking, on behalf of or for the benefit of the named insured or others, to determine or warrant that such property or operations are safe. The company may examine and audit the named insured's books and records at any time during the policy period and extensions thereof and within three years after the final termination of this policy, as far as they relate to the subject matter of this insurance.

C. Severability of Interests. The term "insured" is used severally and not collectively except with respect to Insuring Agreement VI (Retained Limit-Limit of Liability) and Condition I (Other Insurance). The inclusion in this policy of more than one insured shall not operate to increase the company's total liability for all insureds covered by this policy beyond the limits set forth in item 3(A) and 3(B) of the declarations.

D. Notice of Occurrence. Whenever the Insured has information from which the Insured may reasonable conclude that an occurrence covered hereunder involves injuries or damages which in the event that the insured should be liable, are likely to involve this policy notice shall be sent to the company as soon as practicable; provided, however, that failure to give notice of any occurrence which at the timo of its happening did not appear to involve this policy but which, at a later date, would appear to give rise to claims hereunder, shall net prejudice such claims. Such notice shall contain particulars sufficient to identify the insured and reasonably obtainable information concerning the time, place and circumstances of the occurrence and all pertinent details. The insured shall give like notice of any claim or suit on account of such occurrence and shall immediately forward to the company every demand, notice summons or other process received by him or his representative together with copies of reports of investigation made by the insured with respect to such claim or suit.

E. Assistance and Cooperation. Except as provided in Insuring Agreement II (Defense, Settlement Supplementary Payments) or in Insuring Agreement VI (Retained Limit-Limit of Liability) with respect to the exhaustion of the aggregate limits of underlying policies listed in Schedule A and in Condition J, the company shall not be called upon to assume charge of the settlement or defense of any claim made or proceeding instituted against the insured, but the company shall have the right and opportunity to associate with the insured in the defense and control of any claim or proceeding reasonably likely to involve the company; in such event the insured and the company shall cooperate fully.

F. Appeals. In the event the insured or the insured's underlying insurer elects not to appeal a judgment in excess of the retained limit, the company may elect to do so at its own expense, and shall be liable for the taxable costs, disbursemonts and interest incidental thereto, but in no event shall the liability of the company for ultimate net loss exceed the amount set forth in Insuring Agreement VI for any one occurrence plus taxable costs, disbursements and interast incidental to such appeal.

G. Loss Payable. Liability of the company with respect to any one occurrence shall not attach unless and until the insured, the company in behalf of the insured, or the insured's underlying insurer, has paid the amount of retained limit. The insured shall make a definite claim for any loss for which the company may be liable within twelve (12) months after the insured shall have paid an amount of ultimate net loss in excess of the retained limit or after the insured's liability shall have been made certain by final judgment against the insured after actual trial, or by written agreement of the insured, the claimant and the company. If any subsequent payments are made by the insured on account of the same occurrence, additional claims shall be made similarly from time to time and shall be payable within thirty (30) days after proof in conformity with this policy.

H. Bankruptcy or Insolvency. Bankruptcy or insolvency of the insured shall not relieve the company of any of its obligations hereunder.

I. Other Insurance. If other collectible insurance with any other insurer is available to the insured covering a loss also covered hereunder [illegible] purchased to apply in excess of the sum of the retained limit and the limit of liability hereunder) the insurance hereunder shall be excess of, and not contribute with, such other insurance. If the insured carries other insurance with the company covering a loss also covered by the policy (other than underlying insurance of which the insurance afforded by this policy is in excess) the insured must elect which policy shall apply and the company shall be liable under the policy so elected and shall not be liable under any other policy.

J. Underlying Insurance. If underlying insurance is exhausted by any occurrence the company shall be obligated to assume charge of the settlement or defense of any claim or proceeding against the insured resulting from the same occurrence but only where this policy applies immediately in excess of such underlying insurance, without the intervention of excess insurance of another insurer.

K. Subrogation. The company shall be subrogated to the extent of any payment hereunder to all the insured's rights of recovery therefor, and the insured shall do everything necessary to secure such rights. Any amount so recovered shall be apportioned as follows:

Any interest (including the insured's) having paid an amount in excess of the retained limit plus the limit of liability hereunder shall be reimbursed first to the extent of actual payment. The company shall be reimbursed next to the extent of its actual payment hereunder. If any balance then remains unpaid, it shall be applied to reimburse the insured or any underlying insurer, as their interest may appear. The expenses of all such recovery proceedings shall be apportioned in the ratio of respective recoveries. If there is no recovery in proceedings conducted solely by the company it shall bear the expenses thereof.

L. Changes. Notice to or knowledge of any agent or other person shall not effect a waiver or change in any part of this policy nor stop the company from asserting any right under it nor shall the terms of this policy be waived or changed except by endorsement issued to form part of this policy.

M. Assignment. Assignment of interest under this policy shall not bind the company until its consent is endorsed hereon; if, however, the named insured shall die, such insurance as is afforded by this policy shall apply (1) to the named insured's legal representative, as the named insured, but only while acting within the scope of his duties as such, and (2) with respect to the property of the named insured, to the person having proper temporary custody thereof, as insured, but only until the appointment and qualification of the legal representative.

N. Cancellation. This policy may be cancelled [illegible] surrender thereof to the company or any of its authorized agents or by mailing to the company or any of its authorized agents written notice stating when thereafter such cancellation shall be effective. The policy may be cancelled by the company by mailing to the named insured at the address shown in this policy written notice stating when not less than thirty (30) days thereafter such cancellation shall be effective. The mailing of notice as aforesaid shall be sufficient proof of notice. The time of surrender or the effective date and hour of cancellation stated in the notice shall become the end of the policy period. Delivery of such written notice either by the namod insured or by the company shall be equivalent to mailing. If the named insured cancels, earned premium shall be computed in accordance with customary short rate table and procedure. If the company cancels, earned premium shall be computed pro rata. In the event of cancellation, the earned premium shall in no case be less than the annual minimum premium stated in the declarations, subject to the policy minimum premium also stated in the declarations.

Premium adjustment may be made at the time cancellation is effected or as soon as practicable thereafter. The check of the company or its representative mailed or delivered, shall be sufficient tender of any refund due the named insured.

If this policy insures more than one named insured, cancellation may be effected by first of such named insureds for the account of all insureds, and notice of cancellation by the company to such first named insured shall be notice to all insureds. Payment of any unearned premium to such first named insured shall be for the account of all interests in such payment.

O. Maintenance of Underlying Insurance. It is warranted by the insured that the underlying policies listed in Schedule A, or renewals or replacements thereof not more restricted, shall be maintained in force during the currency of this policy, except for any reduction of the aggregate limits therein solely by payment of claims with respect to occurrences happening during the period of this policy. In the event of failure by the insured so to maintain such policies in force or to meet all conditions and warranties subsequent to loss under such policies, the insurance afforded by this policy shall apply in the same manner it would have been applied had such policies been so maintained in force.

In witness whereof, the company has caused this policy to be signed by its president and a secretary at King of Prussia, Pennsylvania, but the policy shall not become valid until countersigned on the declarations page by a duly authorized representative of the company.

NORTHEASTERN FIRE INSURANCE CO.
of Pennsylvania
KING OF PRUSSIA, PENNSYLVANIA

Helen V. McKenna
Secretary

Wm. J. Vaughn
President

INSURED [illegible]

INSURED BY NORTHEASTERN FIRE INSURANCE COMPANY OF PENNSYLVANIA

EFFECTIVE ON AND AFTER October 15th, 1981, 12:01 A.M. STANDARD TIME

THIS SCHEDULE FORMS PART OF POLICY NUMBER CXS 66 U 12902

CARRIER, POLICY NUMBER & PERIDD	TYPE DF POLICY	APPLICABLE LIMITS
(a) AETNA C & S TBA 10-1-81 to 10-1-82	**Standard Workmen's Compensation & Employers' Liability**	**Coverage B — Employers' Liability** $ 100,000. one occurrence aggregate

(b) AETNA C & S
TBA
10-1-81 to 10-1-82
	General Liability including
	☒ comprehensive form
	☐ schedule form
	☐ storekeeper's form
	☒ contractual liability
	☒ completed operations
	☒ products liability
	☒ personal injury liability
	☒ B F P D
	☐
	☐
	☐
	☐
		Bodily Injury Liability
		$ each person
		$ each occurrence
		$ aggregate products
		$ aggregate completed operations
		Property Damage Liability
		$ each occurrence
		$ aggregate premises/operations
		$ aggregate protective
		$ aggregate products
		$ aggregate contractual
		$ aggregate completed operations
		Bodily Injury/Property Damage Liability
		$ 500,000. each occurrence—combined single limit
		aggregate—combined single limit

(c) AETNA C & S
TBA
10-1-81 to 10-1-82
	Automobile Liability including
	☒ owned automobiles
	☒ non-owned automobiles
	☒ hired automobiles
	☐
	☐
		Bodily Injury Liability
		$ each person
		$ each occurrence
		Property Damage Liability
		$ each occurrence
		Bodily Injury/Property Damage Liability
		$ 500,000. each occurrence—combined single limit

(d)		
(e)		
(f)		

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An "X" marked in the box provided indicates these broadening or optional coverages are provided in the Underlying Policies.

Form 111 (Rev. 11/80)

CASUALTY ENDORSEMENTS
LIMITATIONS AND EXCLUSIONS

This endorsement is affective 10-15-81 and forms a part of policy number CXS 66 U 12902

issued to Bio-Gro Systems, Inc.

in consideration of covarage provided by the policy of which this is a part, it is agreed and understood that the sections of this endorsemant which are marked by an X below amand and limit tha policy of which this is a part.

( ) Cross Suits Exclusion Endorsement

This policy does not epply to personal injury or property damage causad by an Insurad covarad by this policy to any othar Insured under this policy

( ) Individual As Named Insured

It is understood and agreed that this Insuranca does not apply to:

(1) any Individual who is named in Itam I of the Declarations or who may be defined es a Namad Insurad of tha policy except:
   (a) an individual operating in tha conduct of a businass of which he is tha sole proprietor;
   (b) a partner or member of eny partnership or joint venture named in tha Declerations whila acting in tha scope of his duties as such;
   (c) an executive officer, director, stockholder or employee of any employee of any corporation named in tha Declarations whila acting within tha scope of his duties as such.

(2) this endorsement does not apply to the ownership, maintenanca or use, loading or unloading of any automobila.

(X) Personel Injury Following Form Endorsement

Except insofar as coverage is availabla to the Insured in tha underlying policies as set forth in the Schedula of Underlying Insurance, this policy does not epply to personal injury arising out of the following offanses:

(a) falsa arrast, detention or imprisonment, or malicious prosecution;
(b) the publication or uttarance of a libel or slander or of other dafamatory or disparaging matarial, or a publication or uttarance in voilation of an individual's right of privacy including publications or uttarances in tha course of or related to advertising, broadcasting or telecasting activities conducted by or on behalf of tha Insurad;
(c) wrongful antry or aviction, or othar invasion of the right of private occupancy;
(d) discrimination, humiliation and mental anguish.
(e) disability, shock or mental injury.

( ) Contractual Liability Following Form Endorsement

Except insofar as coverage is availabla to tha Insured in the underlying policies as set forth in tha Schadula of Underlying Insuranca, this policy does not apply to personal injury, property damage or advertising liability arising out of liebility assumed by tha Insurad under any contract or agreement.

( ) Liquor Law Liability — Following Form

It is hereby agreed that except as set forth in tha Schedula of Underlying Insurance, this policy shall not apply to liability for bodily injury or property damaga for which tha insurad or his indamnitae may be held liable by reason of the selling, serving or giving of any alcoholic beverage under tha following circumstances:

(1) in violation of any statute, ordinance or regulation
(2) to a minor
(3) to a person under the influence of alcohol
(4) to a person causing or contributing to his intoxication

(X) Contractor's Endorsemant

It is agreed that this policy does not apply, excapt insofar as coverege is available to tha Insured in the underlying policies as sat forth in tha Schedule of Underlying Insurence, to:

(1) Property Damage included within:
   (a) the Explosion Hazard,
   (b) tha Collapse Hazard,
   (c) the Underground Property Damage Hezard.
(2) Liability assumed by tha Insured under any contract or agreement.

It is further agraed that this insurance does not apply undar any circumstances to:

(1) Personal injury or property damege arising out of any partnership or joint ventura of which tha Insurad is a partner or mamber and which is not designated in tha Declarations as the Namad Insured;
(2) Any liability arising out of any project insured under a "wrap-up" or eny similer reting plan;
(3) Property Damage to work performed by or on behelf of the Insured arising out of the work or any portion thereof, or out of meterials, parts or equipment furnished in connection therewith;
(4) Property Damage to:
   (a) property owned or occupied by or rentad to the Insured,
   (b) property used by the Insured, or
   (c) property in the cara, custody or control of the Insured or as to which tha Insurad is for any purpose exercising physical control; but parts (b) and (c) of this exclusion do not apply with respect to liability under a writtan sidetrack agreement and part (c) of this exclusion does not apply with raspect to property damege (othar than to elevators) arising out of tha usa of an alavator at pramises owned by, rantad to or controllad by the Insured.
(5) Any liability for personal injury or property damaga arisIng out of faulty design, maps, plans and specifications or any other arror, omission or mistaka of a profassional natura committed or alleged to hava been committed by or on behalf of tha Insured in tha conduct of the Insurad's businass or occupation.

Definitions — Whan usad in this endorsement:

"Collapsa Hazard" includes "structural property damage" as dafined harein and property damage to any othar property at any tima resulting therefrom. "Structural Property Damage" means tha collapsa of or structural injury to any building or structura dua to (1) grading of land, excavating, burrowing, filling, back-filling, tunnelling, pila driving, coffer-dam work or caisson work or (2) moving, shoring, underpinning, raising or demolition of any building or structura or ramoval or rebuilding of any structural support thareof. Tha Collapsa Hazard does not include property damage included within tha Complatad Operations Hazard or Underground Property Damage Hazard.

"Explosion Hazard" includes proparty damage arising out of blesting or explosion. The Explosion Hazard does not include property damage (1) to prima movers, machinery or power transmitting equipment, or (2) included within the Complated Operations Hazard or Underground Property Damage Hazard.

"Underground Property Damage Hazard" includes underground property damage as defined herein and property damage to any other property at any time resulting therefrom. "Underground Property Damage" means property damage to wiras, conduits, pipes, mains, sewers, tanks, tunnels, any similar property and any apparatus in connection therewith, beneeth the surface of tha ground or weter, ceused by and occurring during the use of machanical equipment for tha purposa of grading land, paving, excavating, drilling, burrowing, filling, back-filling or pile driving. The Underground Property Damage Hazard does not include property damage included with the Completed Operations Hazard.

X) Pollution Exclusion Endorsement

This policy does not apply to personel injury or property damege arising out of the discharge, dispersal, release, escape or seepage of oil, petroleum substances or derivetives (including any oil refuse or oil mixed with wastes), smoke, vepors, soot, fumes, acids, alkalis, toxic chemicals, liquids or gases, weste materiel or other irritents, conteminents or pollutents into or upon:

(a) land or the atmosphere, but this exclusion shell not apply if such discharge, dispersel, release or escape is sudden end accidental;

(b) eny watercourse, body of water, bog, marsh, swemp or wetland, whether or not such discherge, dispersal, releese or escape was sudden accidental.

:) Unimpaired Aggregate Endoresment

In consideretion of the premium charged it is understood and agreed that the underlying aggregate limits, where applicable, shall be unimpaired et the ettachment date of this policy end for the purpose of this insurance, only occurrences teking place during the term of this policy shall be considered in determining the extent of eny exhaustion of the underlying aggregete limits.

:) Care, Custody or Control Exclusion Endorsement

This policy does not apply to property damege:

(a) to property occupied by or leased to the Insured; or

(b) except with respect to liebility under sidetreck agreements, property used by the Insured; or

(c) except with respect to liability under sidetrack egreements, or the use of elevetors or escaletors et premises owned by, rented to or controlled by the Insured, property in the care, custody or control of the Insured or property over which the Insured for any purpose is exercising physical control.

.) E.R.I.S.A. Exclusion

In consideration of the premium cherged, such insurance as efforded by this policy shall not apply with respect to eny claim or claims brought about es e result of eny violation of eny responsibilities, obligetions, or duties imposed upon fiduciaries by the Employee Retirement end Insurance Security Act of 1974 or amendments thereto.

) No-Fault Exclusion

This policy does not apply:

To any obligation, whether direct or assumed by the Insured under contract, for which the Insured or eny of its insurers may be held liable under any Automobile No-Fault Reparetions Law for Personel Injury Protections, however, Titled or Styled.

) Uninsured end/or Underinsured Motorist Exclusion

In consideretion of the premium cherged it is agreed this policy does not apply to liability for eutomobile liebility bodily injury and/or property damage arising out of claims under eny uninsured and/or underinsured motorist ect, law or coverege.

) Service of Suit Clause

Service of Suit: It is agreed thet in the event of the failure of the Company hereon to pay eny emount claimed to be due hereunder, the Comp. hereon, at the request of the Named Insured will submit to the jurisdiction of any court of competent jurisdiction within the United States and will comply with ell requirements necessary to give such court jurisdiction and all matters arising hereunder shell be determined in eccordence with the law end practice of such court. It is further agreed that service of process in such suit may be made upon WILLIAM H. VAUGHAN & COMPANY, INC., Gulph Road Corporate Canter, 367 South Gulph Road, King of Prussia, Pennsylvania 19406, and that in any suit instituted against them upon this contract, the Company will abide by the finel decision of such court or of any eppellete court in the event of an appeal.

The above named are authorizad and diractad to accept service of process on behalf of the Compeny in any suit and/or upon the request of the Named Insurad that thay will antar e general appearance upon the Company's behalf in the event such e suit shall be instituted.

Furthar, pursuent to eny statute of any state, territory, or district of the United States which makes provision therefor, tha Company hereon designates the Superintendent, Commissioner or Director of Insurance or othar officer specifiad for that purpose in the statute, or his successor or successors in office, es their true end lewful attorney, upon whom may be servad any lawful process in any ection, suit or proceeding instituted by or on behalf of tha Named Insured or eny beneficiary hereunder erising out of this contract of insurence, end hereby designates the ebove nemed as the person to whom the said officer is euthorized to meil such process or to a true copy thereof.

(The Attaching Clause need be completed only when this endorsement is issued subsequent to preparation of the policy.)

ENDORSEMENT

GU 207
(Ed. 6-78)

This endorsement, effective on 10-15-81 at 12:01 A.M. standard time, forms a part of

Policy No. CXS 66 U 12902 of the NORTHEASTERN FIRE INSURANCE CO. OF PA.
(NAME OF INSURANCE COMPANY)

Issued to Bio-Gro Systems, Inc.

By NORTHEASTERN FIRE INSURANCE COMPANY OF PENNSYLVANIA

Authorized Representative

POLLUTION EXCLUSION ENDORSEMENT

This policy does not apply to personal injury or property damage arising out of the discharge, dispersal, release, escape or seepage of oil, petroleum substances or derivatives (including any oil refuse or oil mixed with wastes), smoke, vapors, soot, fumes, acids, alkalis, toxic chemicals, liquids or gases, waste material or other irritants, contaminants or pollutants into or upon:

a) land or the atmosphere, but this exclusion shall not apply if such discharge, dispersal, release or escape is sudden and accidental;

b) any watercourse, body of water, bog, marsh, swamp or wetland, whether or not such discharge, dispersal, release or escape was sudden and accidental.

It is further understood and agreed that as respects Automobile Liability coverage only, Part (b) of the Pollution Exclusion Endorsement is deleted and replaced with the following:
"any watercourse, body of water, bog, marsh, swamp or wetland, if such discharge, dispersal, release or escape is sudden and accidental."

STATEMENT CONCERNING SURPLUS LINES
PLACEMENT IN THE STATE OF MARYLAND

As your policy indicates: "THIS INSURANCE IS ISSUED BY A NON-ADMITTED INSURER NOT UNDER THE JURISDICTION OF THE MARYLAND INSURANCE COMMISSIONER."

We point out that, although the Maryland Insurance Commissioner does not have jurisdiction over rates and forms used on this coverage, this insurance company has qualified with the Department of Licensing and Regulations as an acceptable Surplus Lines Carrier in the State of Maryland. Qualification is done yearly and in order to maintain its status as an acceptable Surplus Lines Carrier, your insurance company must file and have its financial data approved by the Department of Licensing and Regulations, and as well, must appoint the Maryland Insurance Commissioner as agent for purposes of receiving suit papers in the event of lawsuit.

YOUR INSURANCE COMPANY HAS QUALIFIED IN MARYLAND AS AN ACCEPTABLE SURPLUS LINES CARRIER.

sudden & accidental

(2) with respect to eny automobile or aircraft hired by or loaned to the named insured, to the owner or lessee thereof other than the nemed insured, or to any agent or employee of such owner or lessee;

(3) to any manufacturer of eircraft, aircraft engines or aviation accessories, or any aviation sales or service or repair organization or eirport or hengar operator or their respective employees or egents, with respect to any occurrence arising out of the operation thereof.

IV Other Oefinitions. When used in this policy (including endorsements forming a part hereof):

(a) "Personal injury" meens (1) bodily injury, sickness, disease, disability, shock, fright, mental enguish end mentel injury; (2) false arrest, false imprisonment, wrongful eviction, wrongful detention, malicious prosecution or humiliation; (3) libel, slander, defamation of charecter or invasion of right of privacy, unless erising out of any edvertising activities; and (4) assault and battery not committed by or at the direction of the insured, unless committed for the purpose of preventing or eliminating danger in the operation of aircraft or for the purpose of protecting the property of the insured or the person or property of others;

(b) "Ultimate net loss" means the totel of the following sums with respect to eech occurrence:

(1) ell sums which thc insured, or any carrier es his insurer, or both, become legelly obligeted to pay as dameges, whether by reason of edjudication or settlement, because of personal injury, property damege or edvertising occurrences to which this policy epplies, end

(2) ell expenses incurred by the insured in the investigation, negotietion, settlement and defense of any claim or suit seeking such demages, excluding only the salaries of the insured's regular employees, provided ultimate net loss shall not include any demege or expense beceuse of liability excluded by this policy (including endorsements forming a part hereof).

This policy shall not epply to defense, investigation, settlement or legal expenses covered by underlying insurance;

(c) The term "nemed insured's products" means goods or products manufactured, sold, hendled or distributed by the named insured or by others trading under his name, including eny container thereof (other than a vehicle), but the "named insured's products" shall not include a vending machine or eny other property other than such conteiner, rented to or located for use by others but not sold;

(d) The term "completed operations hazard" means personal injury or property damage arising out of operations or reliance upon a representation or warranty made at any time with respect thereto, but only if the occurrence happens after such operations have been completed or abandoned and occurs eway from premises owned by or rented to the named insured. "Operations" include materials, parts or equipment furnished in connection therewith. Operations shall be deemed completed at the earliest of the following times:

(1) when all operations to be performed by or on behalf of the named insured under the contract have been completed;

(2) when all operations to be performed by or on behalf of the named insured at the site of the operations have been completed; or

(3) when the portion of the work out of which the injury or damage arises has been put to its intended use by any person or organization other then another contractor or subcontractor engaged in performing operations for a principal as a part of the same project.

Operations which may require further service or maintenance work, or correction, repair or replacement because of any defect or deficiency, but which are otherwise complete, shall be deemed completed.

The completed operations hazerd does not include personal injury or property damage arising out of:

(i) operations in connection with the transportation of property, unless the personal injury or property damage erises out of a condition in or on a vehicle created by the loading or unloading thereof;

(ii) the existence of tools, uninstalled equipment or ebandoned or unused materials; or

(iii) operations for which the classification stated in the underlying insurance specifies "including completed operations."

(e) "Occurrence." With respect to Coverage I(a) and I(b) occurrence shall mean an accident, including injurious exposure to conditions, which results, during the policy period, in personal injury or property damage neither expected nor intended from the standpoint of the insured. For the purpose of determining the limit of the company's liability, all personal injury and property damage arising out of continuous or repeated exposure to substantially the same general conditions shell be considered as arising out of one occurrence.

With respect to Coverage I(c), all damages involving the same injurious material or act, regardless of the frequency of repetition thereof, the number or kind of media used, and the number of claimants shall be deemed to arise out of one occurrence.

V Policy Period, Territory. This policy applies only to personal injury, property damage or advertising occurrences which happen anywhere during the policy period.

VI Limits. With respect to Coverage I(a), I(b) or I(c) or any combination thereof, the company's liability shall be only for the ultimate net loss in excess of the insured's underlying or retained limit which shall be:

(a) Underlying Limit—the total of the applicable limits of the underlying policies listed in Schedule A thereof, and the applicable limits of any other underlying insurance collectible by the insured; or

(b) Retained Limit—an amount as stated in Item 3(C) of the declarations as the result of any one occurrence not covered by said policies or insurance;

and then up to an amount not exceeding the amount as stated in Item 3(A) of the declarations as the result of any one occurrence.

There is no limit to the number of occurrences during the policy period for which claims may be made, except that the liability of the company arising out of the named insured's products or the completed operations hazard, or both combined, on account of all occurrences during each consecutive policy year shall not exceed the aggregate amount stated in Item 3(B) of the declarations.

In the event of the reduction or exhaustion of the aggregate limits of liability of the underlying policies listed in Schedule A by reason of losses paid thereunder, this policy, subject to the above limitations, (1) in the event of reduction, shall pay the excess of the reduced underlying limits; or (2) in the event of exhaustion, shall continue in force as underlying insurance. The inclusion or addition hereunder of more than one insured shall not operate to increase the company's limit of liability.

EXCLUSIONS

This policy does not apply:

(a) under Coverage I(a), to any obligation for which the insured or any of its insurers may be held liable under any workmen's compensation, unemployment compensation, disability benefits law, or under any similar law, provided, however, that this exclusion does not apply to liability of others assumed by the named Insured under contract;

(b) under Coverage I(a) and I(b), to liability for:

(1) personal injury or property damage resulting from the failure of the named insured's products or work completed by or for the named insured to perform the function or serve the purpose intended by the named insured, if such failure is due to a mistake or deficiency in any design, formula, plan, specifications, advertising material or printed instructions prepared or developed by any insured; but this exclusion does not apply to personal injury or property damage resulting from the active malfunctioning of such products or work;

(2) property damage to the named insured's products arising out of such products or any part of such products;

(3) property damage to work performed by or on behalf of the named insured arising out of the work or any portion thereof, or out of material, parts or equipment furnished in connection therewith;

(4) damages claimed for the withdrawal, inspection, repair, replacement or loss of use of the named insured's products or work completed by or for the named insured or of any property of which such products or work form a part, if such product, work or property are withdrawn from the market or from use because of any known or suspected defect or deficiency therein;

(c) under Coverage I(b), to injury to or destruction of:

(1) property owned by the insured;

(2) property rented to, occupied or used by or in the care, custody or control of the insured to the extent the insured is under contract to provide insurance therefor;

(d) under Coverage I(c), to liability for:

(1) failure of performance of written contract;

(2) infringement of registered trade mark, service mark or trade name by use thereof as the registered trade mark, service mark or trade name of goods or service sold, offered for sale or advertised, but this shall not relate to titles or slogans;

(3) incorrect description of any article or commodity;

(4) mistaka in advertised price; or

(5) personal injury, death or physical property damage;

(e) under Coverage I(a) and I(b), to injury, sickness, disease, death or destruction:

(1) with respect to which an insured under the policy is also an insured under a nuclear energy liability policy issued by Nuclear Energy Liability Insurance Association, Mutual Atomic Energy Liability Underwriters or Nuclear Insurance Association of Canada, or would be an insured under any such policy but for its termination upon exhaustion of its limit of liability; or

(2) resulting from the hazardous properties of nuclear material and with respect to which (a) any person or organization is required to maintain financial protection pursuant to the Atomic Energy Act of 1954, or any law amendatory thereof, or (b) the insured is, or had this policy not been issued would be, entitled to indemnity from the United States of America, or any agency thereof, under any agreement entered into by the United States of America, or any agency thereof, with any person or organization.

(f) under Coverage I(a) and I(b), to injury, sickness, disease, death or destruction resulting from the hazardous properties of nuclear material, if:

(1) the nuclear material (a) is at any nuclear facility owned by, or operated by or on behalf of, an insured or (b) has been discharged or dispersed therefrom;

(2) the nuclear material is contained in spent fuel or waste at any time possessed, handled, used, processed, stored, transported or disposed of by or on behalf of an insured; or

(3) the injury, sickness, disease, death or destruction arises out of the furnishing by an insured of services, materials, parts or equipment in connection with the planning, construction, maintenance, operation or use of any nuclear facility, but if such facility is located within the United States of America, its territories or possessions, or Canada, this exclusion (3) applies only to injury to or destruction of property at such nuclear facility;

as used in this policy:

"hazardous properties" include radioactive, toxic or explosive properties;

"nuclear material" means source material, special nuclear material or byproduct material;

"source material", "special nuclear material", and "byproduct material" have the meanings given them in the Atomic Energy Act of 1954 or in any law amendatory thereof;

"spent fuel" means any fuel element or fuel component, solid or liquid, which has been used or exposed to radiation in a nuclear reactor;

"waste" means any waste material (1) containing byproduct material and (2) resulting from the operation by any person or organization of any nuclear facility included within the definition of nuclear facility under paragraph (1) or (2) thereof;

"nuclear facility" means

(1) any nuclear reactor,

(2) any equipment or device designed or used for (a) separating the isotopes of uranium or plutonium, (b) processing or utilizing spent fuel, or (c) handling, processing or packaging waste,

(3) any equipment or device used for processing, fabricating or alloying of special nuclear material if at any time the total amount of such material in the custody of the insured at the premises where such equipment or device is located consists of or contains more than 25 grams of plutonium or uranium 233 or any combination thereof, or more than 250 grams of uranium 235,

(4) any structure, basin, excavation, premises or place prepared or used for the storage or disposal of waste;

and includes the site on which any of the foregoing is located, all operations conducted on such site and all premises used for such operations;

"nuclear reactor" means any apparatus designed or used to sustain nuclear fission in self-supporting chain reaction or to contain a critical mass of fissionable material;

With respect to injury or to destruction of property, the words "injury" or "destruction" include all forms of radioactive contamination of property;

(g) under Coverage I(a) and I(b), except with respect to occurrences taking place in the United States of America, its territories or possessions, or Canada, to any liability of the insured directly or indirectly occasioned by, happening through or in consequence of war, invasion, acts of foreign enemies, hostilities (whether war be declared or not), civil war, rebellion, revolution, insurrection, military or usurped power or confiscation or nationalization or requisition or destruction of or damage to property by or under the order of any government or public or local authority;

(h) except insofar as coverage is available to the insured in the underlying insurance as set out in Schedule A of the policy, this policy shall not apply under Coverage I(a) and I(b), to liability arising out of the ownership, maintenance, operation, use, loading or unloading of aircraft owned by the insured or chartered on behalf of the insured without crew, but this exclusion shall not apply to liability for personal injury to any employee of the insured arising out of and in the course of his employment by the insured.

Attachment 3.

$500,000 general liability

suelty and Surety Company
nnecticut 06156

13

UMBER

98 GL 299635 CCA

COMPREHENSIVE GENERAL LIABILITY POLICY
For

1. NAMED INSURED ▶ BIO GRO SYSTEMS, INC.
108 OLD SOLOMON ISLAND RD
ANNAPOLIS, MARYLAND 21403

(Show Number and Street or RFD, City, County, State and Zip Code)

Y PERIOD From 10-1-81 to 10-1-82 12:01 A
Standard Time at the address of the named insured as stat herein.

AUDIT PERIOD
Annual, unless otherwise stated:

THE NAMED INSURED IS ☐ Individual ☐ Pertnership ☐ Corporation ☐ Joint Ventura ☐ Other:

BUSINESS OF NAMED INSURED
WASTE DISPOSAL (LIQUID SLUDGE)

3. The insurance afforded is only with respect to such of the following Parts and Coverages as are indicated by specific premium charge or cherges. Tha limit of tha Company's liability against each such Coveraga shell ba as stated herein, subject to all the terms of this policy having referenca thereto.

COMPREHENSIVE GENERAL LIABILITY INSURANCE (Except Automobile)

PART	COVERAGES	LIMITS OF LIABILITY		ADVANCE PREMIUM
		Each Occurrence	Aggregate	
CGL	Bodily Injury Liability	$ SEE ,000	$ SEE ,000	$ 4350.-
	Property Damage Liability	$ CC324 ,000	$ CC324 ,000	$ 7650.-

ENDORSEMENTS MADE PART OF THE POLICY (designated by [X] or Endorsement number) $

K ☐ Contractual Liability
MP ☐ Premises Medical Payments GL0111 GL0019 GL0404 GL2011
I ☐ Personal Injury Liability
☐ Broad Form Comprehensive General Liability Insurance

4. The declarations are completed on the attached General Liability Schedule.

This policy has been individually assembled for your convenience. All the provisions contained herein form the complete contract. Read it carefully.

THE PROVISIONS ARE ARRANGED IN THE FOLLOWING ORDER:

1. Daclarations indicating coverages afforded and any necessary Schedules of Hazards.
2. Insuranca Coveraga Parts describing coverages and limitations thereon.
3. Endorsaments affording coverage or modifying coverage afforded as required by law, by the company's manual or by your specifications.
4. General Provisions for Liability Policies:
   a. Dafinitions of terms in general use throughout the policy (defined terms appear in bold print.)
   b. Supplementary Payments provided in connection with Liability Coverage.
   c. Nuclaar Exclusion generally applicable to all Liability Coverages.
   d. Conditions applicable to the Coverage Parts.

Endorsements issued to form a part of the policy during its term should be placed in the policy.

PAYMENT METHOD		
	1 Year Policy Total Advance Premium	$ 12,000.
	Deposit Premium	$
	3 Year Prepaid Total Advance Premium	$
	3 Year Policy Installments Total Advance Premium	$
	Installments: 1st Anniversary	$
	2nd Anniversary	$

"TBD" means To Be Determined.

RECEIVED JAN 22 1982

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MD. INS. MGT. SER., INC.

Countersigned by

-5370-11 ED. 8-77

AGENT'S COPY 4

AGENCY BROKER ➤	5400	MIMS					TYPE	BUSINESS	A P	POLICY EFF. DATE	DATE A INITI
COUNTERSIGNING CODES ➤		C/S OFFICE	C/S CODE	C/S COM.			E			10-1-81	
										POLICY EXPIRY DATE 10-1-82	1-26

STAT. PLAN	TERRITORY STATE	TERRITORY RATE	LIMITS OF LIABILITY BI	LIMITS OF LIABILITY PD	LIMITS OF LIABILITY MED.	DR. REC.	LINE DESIG.	FORM OR CLASS	COMP.	COLL.	DISC.	PREMIUM	EXPOSURE	BILL. ID	ACCOUNT NUMBER
	19														14
															END'T FORM

IT IS AGREED THAT ENDORSEMENT CG324 A IS ATTACHED TO THE POLICY.

218

This endorsement, issued by one of the below named companies, forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein.

(The information below is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective 10-1-81

Named Insured Bio Gro Systems Inc.

Additional Premium $

Policy No. 98 GL 2926350CA Endorsement No. 1

Return Premium $

	BI	PD
In Advance $	$	
1st Anniv. $	$	
2nd Anniv. $	$	

The Ætna Casualty and Surety Company
The Standard Fire Insurance Company
Hartford, Connecticut

Countersigned by _____
(Authorized Representative)

15

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

ALL LIABILITY INSURANCE, OTHER THAN COMPREHENSIVE PERSONAL AND FARMER'S COMPREHENSIVE PERSONAL INSURANCE

SINGLE LIMIT

It is agreed that with respect to the insurance indicated below by [X]:

1. The total limit of the company's liability for all damages as the result of any one occurrence is the amount stated below as applicable to "each occurrence." Insuring Agreement III, Limits of Liability is amended accordingly.

2. Any aggregate limit of liability, the amount of which is specifically stated below or in the declarations, shall nevertheless continue to apply in accordance with all the terms of the policy applicable thereto.

COVERAGES	LIMITS OF LIABILITY
[ ] All Liability Insurance	$ 500,000. each occurrence
	$ 500,000. aggregate
[ ] Comprehensive Automobile Liability Insurance	
[X] Comprehensive General Liability Insurance	

219

This endorsement, issued by one of the below named companies, forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein.

(The information below is required only when this endorsement is issued subsequent to preparation of the policy.)

Endorsement effective | Policy No. | Endorsement No.

Named Insured

Additional Premium $ | Return Premium $ | In Adv. $ $ | 1st Anniv. $ $ | 2nd Anniv. $ $

The Ætna Casualty and Surety Company
The Standard Fire Insurance Company
Hartford, Connecticut

Countersigned by _____
(Authorized Representative)

ICC 324 AI 1-72

CAT. 446076
PRINTED IN U.S.A.

Aetna Life & Casualty

GENERAL LIABILITY SCHEDULE

(Code–Symbol–Serial No.–Suffix) 16

Policy No. 98 GL 299635 CCA Page No. 1

Description of Hazards (First Column) – including

1. Location of all premises owned, rented, or controlled by the named insured. 2. Interest of named insured in such premises (O. General Lessee or Tenant). 3. Part occupied by the named insured. The absence of any typewritten entry relating to Hazard (A (B), (C), (D), (E), or (F) indicates no known exposure thereunder.

The rating classifications stated herein, except as specifically provided elsewhere in this policy, do not modify any of the other provisions of this policy.

A. PREMISES–OPERATIONS
B. ESCALATORS
C. INDEPENDENT CONTRACTORS
–LET OR SUBLET WORK
D. COMPLETED OPERATIONS
E. PRODUCTS
F. CONTRACTUAL

If location same as address in Item 1 of the declarations, check ☐

Double space between entries to allow for coding.

			LINE DESIG	CODE NUMBERS	PREMIUM BASES†		RATES BI	RATES PD	ADVANCE PREMI BI	ADVANCE PREMI PD
					1. Area sq. ft.		Per 100 sq. ft.			
					2. Frontage		Per linear ft.			
					3. Payroll		Per $100			
					4. Flat charge				"M" DESIGNATES MINIMUM PREMIUM	
					5. Units		Per each			
					6. Receipts		Per $100			
					7. Number		Per landing			
					8. Cost		Per $100			
					9. Receipt		Per $1000			
					10. Sales		Per $1000			
					11.					
					12.					
							223	2.88		
A	.850	19 999 FERILIZER LIQUID APPLICATION 38.M BI 20.M PD	M	07316	3	750,000.	.190	.071	356.DEP	133.D
							.110	.045		
		ADDL: INSURED	M	11111					36. DEP	13.D
		37 013 AUTOMOABILE GARGES:	O	41122	1	3,600.	1.73	.034	62.M	46.M
		1421 3RD AVENUE DUNKINSVILLE PA 16635								
		19 999 CONSTRUCTION OPERATION CONTRACTORS 35.M BI 23.M PD	I	16291	8	TBD	.040	.016	35.M	23.M
		19 999 FERTILIZER LIQUID APPLICATION 157.M BI 319M PD	P	07290S	9	2,000,000.	(a) 1.57	(a) 3.19	3140.	6380.
		BFCGL 15% DIV A,C,D, 10.M BI 5.M PD	I	96015					721.	1055.
									220	✓

Increased Limits Basic Charges

*Designates location to which Landlord's Protective Liability Endorsement applies. †As described

GL 04 04
(Ed. 07 76)

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein.
(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective Policy No. Endorsement No.

Named Insured

Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

COMPREHENSIVE GENERAL LIABILITY INSURANCE

BROAD FORM COMPREHENSIVE GENERAL LIABILITY ENDORSEMENT

Schedule

Personal Injury and Advertising Injury Liability
Aggregate Limit shall be the per occurrence bodily injury liability limit unless otherwise indicated herein:
Limit of Liability $_____ Aggregate.

Limit of Liability—Premises Medical Payments Coverage: $1,000 each person unless otherwise indicated herein:
$_____ each person.

Limit of Liability—Fire Legal Liability Coverage: $50,000 per occurrence unless otherwise indicated herein:
$_____ per occurrence.

Premium Basis	Advance Premium
15 % of the Total Comprehensive General Liability Bodily Injury and Property Damage Premium as Otherwise Determined.	$ INC.
MINIMUM PREMIUM $ 15.	

I. CONTRACTUAL LIABILITY COVERAGE

(A) The definition of incidental contract is extended to include any contract or agreement relating to the conduct of the named insured's business.

(B) The insurance afforded with respect to liability assumed under an incidental contract is subject to the following additional exclusions:

(1) to bodily injury or property damage for which the insured has assumed liability under any incidental contract, if such injury or damage occurred prior to the execution of the incidental contract;

(2) if the insured is an architect, engineer or surveyor, to bodily injury or property damage arising out of the rendering of or the failure to render professional services by such insured, including

(a) the preparation or approval of maps, drawings, opinions, reports, surveys, change orders, designs or specifications, and

(b) supervisory, inspection or engineering services;

(3) if the indemnitee of the insured is an architect, engineer or surveyor, to the liability of the indemnitee, his agents or employees, arising out of

(a) the preparation or approval of or the failure to prepare or approve maps, drawings, opinions, reports, surveys, change orders, designs or specifications, or

(b) the giving of or the failure to give directions or instructions by the indemnitee, his agents or employees, provided such giving or failure to give is the primary cause of the bodily injury or property damage;

(4) to any obligation for which the insured may be held liable in an action on a contract by a third party beneficiary for bodily injury or property damage arising out of a project for a public authority; but this exclusion does not apply to an action by the public authority or any other person or organization engaged in the project;

(5) to bodily injury or property damage arising out of operations, within 50 feet of any railroad property, affecting any railroad bridge or trestle, tracks, road beds, tunnel, underpass or crossing; but this exclusion does not apply to sidetrack agreements.

(C) The following exclusions applicable to Coverages A (Bodily Injury) and B (Property Damage) do not apply to this Contractual Liability Coverage: (b), (c) (2), (d) and (e).

(D) The following additional condition applies:

Arbitration

The company shall be entitled to exercise all of the insured's rights in the choice of arbitrators and in the conduct of any arbitration proceeding.

II. PERSONAL INJURY AND ADVERTISING INJURY LIABILITY COVERAGE

(A) The company will pay on behalf of the insured all sums which the insured shall become legally obligated to pay as damages because of personal injury or advertising injury to which this insurance applies, sustained by any person or organization and arising out of the conduct of the named insured's business, within the policy territory, and the company shall have the right and duty to defend any suit against the insured seeking damages on account of such injury, even if any of the allegations of the suit are groundless, false or fraudulent, and may make such investigation and settlement of any claim or suit as it deems expedient, but the company shall not be obligated to pay any claim or judgment or to defend any suit after the applicable limit of the company's liability has been exhausted by payment of judgments or settlements.

(B) This insurance does not apply:

(1) to liability assumed by the insured under any contract or agreement;

(2) to personal injury or advertising injury arising out of the wilful violation of a penal statute or ordinance committed by or with the knowledge or consent of the insured;

(3) to personal injury or advertising injury arising out of a publication or utterance of a libel or slander, or a publication or utterance in violation of an individual's right of privacy, if the first injurious publication or utterance of the same or similar material by or on behalf of the named insured was made prior to the effective date of this insurance;

(4) to personal injury or advertising injury arising out of libel or slander or the publication or utterance of defamatory or disparaging material concerning any person or organization or goods, products or services, or in violation of an individual's right of privacy, made by or at the direction of the insured with knowledge of the falsity thereof;

(5) to personal injury or advertising injury arising out of the conduct of any partnership or joint venture of which the insured is a partner or member and which is not designated in the declarations of the policy as a named insured;

(6) to advertising injury arising out of

(a) failure of performance of contract, but this exclusion does not apply to the unauthorized appropriation of ideas based upon alleged breach of implied contract, or

(b) infringement of trademark, service mark or trade name, other than titles or slogans, by use thereof on or in connection with goods, products or services sold, offered for sale or advertised, or

(c) incorrect description or mistake in advertised price of goods, products or services sold, offered for sale or advertised;

(7) with respect to advertising injury

(a) to any insured in the business of advertising, broadcasting, publishing or telecasting, or

(b) to any injury arising out of any act committed by the insured with actual malice.

(C) Limits of Liability

Regardless of the number of (1) insureds hereunder, (2) persons or organizations who sustain injury or damage, or (3) claims made or suits brought on account of personal injury or advertising injury, the total limit of the company's liability under this coverage for all damages shall not exceed the limit of liability stated in this endorsement as "aggregate".

(D) Additional Definitions

"Advertising Injury" means injury arising out of an offense committed during the policy period occurring in the course of the named insured's advertising activities, if such injury arises out of libel, slander, defamation, violation of right of privacy, piracy, unfair competition, or infringement of copyright, title or slogan.

"Personal Injury" means injury arising out of one or more of the following offenses committed during the policy period:

(1) false arrest, detention, imprisonment, or malicious prosecution;

(2) wrongful entry or eviction or other invasion of the right of private occupancy;

(3) a publication or utterance

(a) of a libel or slander or other defamatory or disparaging material, or

(b) in violation of an individual's right of privacy; except publications or utterances in the course of or related to advertising, broadcasting, publishing or telecasting activities conducted by or on behalf of the named insured shall not be deemed personal injury.

III. PREMISES MEDICAL PAYMENTS COVERAGE

The company will pay to or for each person who sustains bodily injury caused by accident all reasonable medical expense incurred within one year from the date of the accident on account of such bodily injury, provided such bodily injury arises out of (a) a condition in the insured premises, or (b) operations with respect to which the named insured is afforded coverage for bodily injury liability under the policy.

This insurance does not apply:

(A) to bodily injury

(1) arising out of the ownership, maintenance, operation, use, loading or unloading of

(a) any automobile or aircraft owned or operated by or rented or loaned to any insured, or

(b) any other automobile or aircraft operated by any person in the course of his employment by any insured;

but this exclusion does not apply to the parking of an automobile on the insured premises, if such automobile is not owned by or rented or loaned to any insured;

(2) arising out of

(a) the ownership, maintenance, operation, use, loading or unloading of any mobile equipment while being used in any prearranged or organized racing, speed or demolition contest or in any stunting activity or in practice or preparation for any such contest or activity, or

(b) the operation or use of any snowmobile or trailer designed for use therewith;

(3) arising out of the ownership, maintenance, operation, use, loading or unloading of

(a) any watercraft owned or operated by or rented or loaned to any insured, or

(b) any other watercraft operated by any person in the course of his employment by any insured;

but this exclusion does not apply to watercraft while ashore on the insured premises;

(4) arising out of and in the course of the transportation of mobile equipment by an automobile owned or operated by or rented or loaned to the named insured;

(B) to bodily injury

(1) included within the completed operations hazard or the products hazard,

(2) arising out of operations performed for the named insured by independent contractors other than

(a) maintenance and repair of the insured premises, or

(b) structural alterations at such premises which do not involve changing the size of or moving buildings or other structures;

(3) resulting from the selling, serving or giving of any alcoholic beverage

(a) in violation of any statute, ordinance or regulation,

(b) to a minor,

(c) to a person under the influence of alcohol, or

(d) which causes or contributes to the intoxication of any person

if the named insured is a person or organization engaged in the business of manufacturing, distributing, selling or serving al-

coholic beverages, or if not so engaged, is an owner or lessor of premises used for such purposes, but only part (a) of this exclusion (B) (3) applies when the named insured is such an owner or lessor;

(4) due to war, whether or not declared, civil war, insurrection, rebellion or revolution, or to any act or condition incident to any of the foregoing;

(C) to bodily injury

(1) to the named insured, any partner thereof, any tenant or other person regularly residing on the insured premises or any employee of any of the foregoing if the bodily injury arises out of and in the course of his employment therewith;

(2) to any other tenant if the bodily injury occurs on that part of the insured premises rented from the named insured or to any employee of such a tenant if the bodily injury occurs on the tenant's part of the insured premises and arises out of and in the course of his employment for the tenant;

(3) to any person while engaged in maintenance and repair of the insured premises or alteration, demolition or new construction at such premises;

(4) to any person if any benefits for such bodily injury are payable or required to be provided under any workmen's compensation, unemployment compensation or disability benefits law, or under any similar law;

(5) to any person practicing, instructing or participating in any physical training, sport, athletic activity or contest whether on a formal or informal basis;

(6) if the named insured is a club, to any member of the named insured;

(7) if the named insured is a hotel, motel, or tourist court, to any guest of the named insured;

(D) to any medical expense for services by the named insured, any employee thereof or any person or organization under contract to the named insured to provide such services.

LIMITS OF LIABILITY

The limit of liability for Premises Medical Payments Coverage is $1,000 each person unless otherwise stated in the schedule of this endorsement. The limit of liability applicable to "each person" is the limit of the company's liability for all medical expense for bodily injury to any one person as the result of any one accident; but subject to the above provision respecting "each person", the total liability of the company under Premises Medical Payments Coverage for all medical expense for bodily injury to two or more persons as the result of any one accident shall not exceed the limit of bodily injury liability stated in the policy as applicable to "each occurrence".

When more than one medical payments coverage afforded by the policy applies to the loss, the company shall not be liable for more than the amount of the highest applicable limit of liability.

ADDITIONAL DEFINITIONS

When used herein:

"insured premises" means all premises owned by or rented to the named insured with respect to which the named insured is afforded coverage for bodily injury liability under this policy, and includes the ways immediately adjoining on land;

"medical expense" means expenses for necessary medical, surgical, x-ray and dental services, including prosthetic devices, and necessary ambulance, hospital, professional nursing and funeral services.

ADDITIONAL CONDITION

Medical Reports; Proof and Payment of Claim

As soon as practicable the injured person or someone on his behalf shall give to the company written proof of claim, under oath if required, and shall, after each request from the company, execute authorization to enable the company to obtain medical reports and copies of records. The injured person shall submit to physical examination by physicians selected by the company when and as often as the company may reasonably require. The company may pay the injured person or any person or organization rendering the services and the payment shall reduce the amount payable hereunder for such injury. Payment hereunder shall not constitute an admission of liability of any person or, except hereunder, of the company.

IV. HOST LIQUOR LAW LIABILITY COVERAGE

Exclusion (h) does not apply with respect to liability of the insured or his indemnitee arising out of the giving or serving of alcoholic beverages at functions incidental to the named insured's business, provided the named insured is not engaged in the business of manufacturing, distributing, selling or serving of alcoholic beverages.

V. FIRE LEGAL LIABILITY COVERAGE—REAL PROPERTY

With respect to property damage to structures or portions thereof rented to or leased to the named insured, including fixtures permanently attached thereto, if such property damage arises out of fire

(A) All of the exclusions of the policy, other than the Nuclear Energy Liability Exclusion (Broad Form), are deleted and replaced by the following:

This insurance does not apply to liability assumed by the insured under any contract or agreement.

(B) The limit of property damage liability as respects this Fire Legal Liability Coverage—Real Property is $50,000 each occurrence unless otherwise stated in the schedule of this endorsement.

(C) The Fire Legal Liability Coverage—Real Property shall be excess insurance over any valid and collectible property insurance (including any deductible portion thereof), available to the insured, such as, but not limited to, Fire, Extended Coverage, Builder's Risk Coverage or Installation Risk Coverage, and the Other Insurance Condition of the policy is amended accordingly.

VI. BROAD FORM PROPERTY DAMAGE LIABILITY COVERAGE (Including Completed Operations)

The insurance for property damage liability applies, subject to the following additional provisions:

(A) Exclusions (k) and (o) are replaced by the following:

(1) to property owned or occupied by or rented to the insured, or, except with respect to the use of elevators, to property held by the insured for sale or entrusted to the insured for storage or safekeeping;

(2) except with respect to liability under a written sidetrack agreement or the use of elevators

(a) to property while on premises owned by or rented to the insured for the purpose of having operations performed on such property by or on behalf of the insured,

(b) to tools or equipment while being used by the insured in performing his operations,

(c) to property in the custody of the insured which is to be installed, erected or used in construction by the insured,

(d) to that particular part of any property, not on premises owned by or rented to the insured,

(i) upon which operations are being performed by or on behalf of the insured at the time of the property damage arising out of such operations, or

(ii) out of which any property damage arises, or

(iii) the restoration, repair or replacement of which has been made or is necessary by reason of faulty workmanship thereon by or on behalf of the insured;

(3) with respect to the completed operations hazard and with respect to any classification stated in the policy or in the company's manual as "including completed operations", to property damage to work performed by the named insured arising out of such work or any portion thereof, or out of such materials, parts or equipment furnished in connection therewith.

(B) The Broad Form Property Damage Liability Coverage shall be excess insurance over any valid and collectible property insurance (including any deductible portion thereof) available to the insured, such as, but not limited to, Fire, Extended Coverage, Builder's Risk Coverage or Installation Risk Coverage, and the Other Insurance Condition of the policy is amended accordingly.

VII. INCIDENTAL MEDICAL MALPRACTICE LIABILITY COVERAGE

The definition of bodily injury is amended to include Incidental Medical Malpractice Injury.

Incidental Medical Malpractice Injury means injury arising out of the rendering of or failure to render, during the policy period, the following services:

(A) medical, surgical, dental, x-ray or nursing service or treatment or the furnishing of food or beverages in connection therewith; or

(B) the furnishing or dispensing of drugs or medical, dental or surgical supplies or appliances.

This coverage does not apply to:

(1) expenses incurred by the insured for first-aid to others at the time of an accident and the "Supplementary Payments" provision and the "Insured's Duties in the Event of Occurrence, Claim or Suit" Condition are amended accordingly.

(2) any insured engaged in the business or occupation of providing any of the services described under VII (A) and (B) above;

(3) injury caused by any indemnitee if such indemnitee is engaged in the business or occupation of providing any of the services described under VII (A) and (B) above.

VIII. NON-OWNED WATERCRAFT LIABILITY COVERAGE (under 26 feet in length)

Exclusion (e) does not apply to any watercraft under 26 feet in length provided such watercraft is neither owned by the named insured nor being used to carry persons or property for a charge.

Where the insured is, irrespective of this coverage, covered or protected against any loss or claim which would otherwise have been paid by the company under this endorsement, there shall be no contribution or participation by this company on the basis of excess, contributing, deficiency, concurrent, or double insurance or otherwise.

IX. LIMITED WORLDWIDE LIABILITY COVERAGE

The definition of policy territory is amended to include the following:

(4) Anywhere in the world with respect to bodily injury, property damage, personal injury or advertising injury arising out of the activities of any insured permanently domiciled in the United States of America though temporarily outside the United States of America, its territories and possessions or Canada, provided the original suit for damages because of any such injury or damage is brought within the United States of America, its territories or possessions or Canada.

Such insurance as is afforded by paragraph (4) above shall not apply:

(a) to bodily injury or property damage included within the completed operations hazard or the products hazard,

(b) to Premises Medical Payments Coverage.

X. ADDITIONAL PERSONS INSURED

As respects bodily injury, property damage and personal injury and advertising injury coverages, under the provision "Persons Insured", the following are added as insureds:

(A) Spouse—Partnership—If the named insured is a partnership, the spouse of a partner but only with respect to the conduct of the business of the named insured;

(B) Employee—Any employee of the named insured while acting within the scope of his duties as such, but the insurance afforded to such employee does not apply:

(1) to bodily injury or personal injury to another employee of the named insured arising out of or in the course of his employment;

(2) to personal injury or advertising injury to the named insured or, if the named insured is a partnership or joint venture, any partner or member thereof, or the spouse of any of the foregoing;

(3) to property damage to property owned, occupied or used by, rented to, in the care, custody or control of or over which physical control is being exercised for any purpose by another employee of the named insured, or by the named insured or, if the named insured is a partnership or joint venture, by any partner or member thereof or by the spouse of any of the foregoing.

XI. EXTENDED BODILY INJURY COVERAGE

The definition of occurrence includes "any intentional act by or at the direction of the insured which results in bodily injury, if such injury arises solely from the use of reasonable force for the purpose of protecting persons or property."

XII. AUTOMATIC COVERAGE—NEWLY ACQUIRED ORGANIZATIONS (90 DAYS)

The word insured shall include as named insured any organization which is acquired or formed by the named insured and over which the named insured maintains ownership or majority interest, other than a joint venture, provided this insurance does not apply to bodily injury, property damage, personal injury or advertising injury with respect to which such new organization under this policy is also an insured under any other similar liability or indemnity policy or would be an insured under any such policy but for exhaustion of its limits of liability. The insurance afforded hereby shall terminate 90 days from the date any such organization is acquired or formed by the named insured.

GL 20 11
(Ed. 07 66)

21

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein

(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective Policy No Endorsement No

Named Insured

Additional Premium $ _____ Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

COMPREHENSIVE GENERAL LIABILITY INSURANCE
MANUFACTURERS AND CONTRACTORS LIABILITY INSURANCE
OWNERS, LANDLORDS AND TENANTS LIABILITY INSURANCE
SMP LIABILITY INSURANCE
STOREKEEPERS INSURANCE

ADDITIONAL INSURED
(Premises Leased to the Named Insured)

It is agreed that the "Persons Insured" provision is amended to include as an insured the person or organization designated below, but only with respect to liability arising out of the ownership, maintenance or use of that part of the premises designated below leased to the named insured, and subject to the following additional exclusions:

The insurance does not apply:

1. to any occurrence which takes place after the named insured ceases to be a tenant in said premises;
2. to structural alterations, new construction or demolition operations performed by or on behalf of the person or organization designated below.

SCHEDULE

Designation of Premises (Part Leased to Named Insured)	Name of Person or Organization (Additional Insured)	Annual Premiums: Bodily Injury Liability	Annual Premiums: Property Damage Liability
108 OLD SOLOMON ISLAND RD. ANNAPOLIS, MARYLAND 21403	NATIONAL CAR RENTAL SYSTEMS, INC. P.O. BOX 35805 MINNIAPOLIS, MN ATTN. MR. ELDRIDGE	INC.	INC.

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GL 20 11
(Ed. 07 66)

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein 22

(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective Policy No. Endorsement No.

Named Insured

Additional Premium $ _____ Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

COMPREHENSIVE GENERAL LIABILITY INSURANCE
MANUFACTURERS AND CONTRACTORS LIABILITY INSURANCE
OWNERS, LANDLORDS AND TENANTS LIABILITY INSURANCE
SMP LIABILITY INSURANCE
STOREKEEPERS INSURANCE

ADDITIONAL INSURED
(Premises Leased to the Named Insured)

It is agreed that the "Persons Insured" provision is amended to include as an insured the person or organization designated below, but only with respect to liability arising out of the ownership, maintenance or use of that part of the premises designated below leased to the named insured, and subject to the following additional exclusions:

The insurance does not apply:

1. to any occurrence which takes place after the named insured ceases to be a tenant in said premises;
2. to structural alterations, new construction or demolition operations performed by or on behalf of the person or organization designated below.

SCHEDULE

Designation of Premises (Part Leased to Named Insured)	Name of Person or Organization (Additional Insured)	Annual Premiums Bodily Injury Liability	Annual Premiums Property Damage Liability
108 OLD SOLOMON ISLAND RD. ANNAPOLIS, MARYLAND 21403	COMMERCIAL CAPITAL, INC. EXECUTIVE PLAZA IV HUNT VALLEY, MARYLAND 21031	INC.	INC.

226

GL 20 11
(Ed. 07 66)

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein 23

(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective Policy No. Endorsement No.

Named Insured

Additional Premium $ _____ Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

COMPREHENSIVE GENERAL LIABILITY INSURANCE
MANUFACTURERS AND CONTRACTORS LIABILITY INSURANCE
OWNERS, LANDLORDS AND TENANTS LIABILITY INSURANCE
SMP LIABILITY INSURANCE
STOREKEEPERS INSURANCE

ADDITIONAL INSURED
(Premises Leased to the Named Insured)

It is agreed that the "Persons Insured" provision is amended to include as an insured the person or organization designated below, but only with respect to liability arising out of the ownership, maintenance or use of that part of the premises designated below leased to the named insured, and subject to the following additional exclusions:

The insurance does not apply:

1. to any occurrence which takes place after the named insured ceases to be a tenant in said premises;
2. to structural alterations, new construction or demolition operations performed by or on behalf of the person or organization designated below.

SCHEDULE

Designation of Premises (Part Leased to Named Insured)	Name of Person or Organization (Additional Insured)	Annual Premiums: Bodily Injury Liability	Annual Premiums: Property Damage Liability
108 OLD SOLOMON ISLAND RD. ANNAPOLIS, MARYLAND 21403	BIO GRO SYSTEMS, INC. EMPLOYEES	INC.	INC.

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GL 01 11
(Ed. 01 73)

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein. 24

(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

Endorsement effective Policy No. Endorsement No.

Named Insured

Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

COMPREHENSIVE GENERAL LIABILITY INSURANCE
COMPLETED OPERATIONS AND PRODUCTS LIABILITY INSURANCE
CONTRACTUAL LIABILITY INSURANCE
FARMERS COMPREHENSIVE PERSONAL INSURANCE
MANUFACTURERS AND CONTRACTORS LIABILITY INSURANCE
OWNERS AND CONTRACTORS PROTECTIVE LIABILITY INSURANCE
OWNERS, LANDLORDS AND TENANTS LIABILITY INSURANCE
STOREKEEPERS INSURANCE

CONTAMINATION OR POLLUTION

(Maryland, New Hampshire and Vermont)

It is agreed that the exclusion relating to the discharge, dispersal, release or escape of smoke, vapors, soot, fumes, acids, alkalis, toxic chemicals, liquids or gases, waste materials or other irritants, contaminants or pollutants is deleted.

228

GL 01 11 01 73

covers everything

This endorsement forms a part of the policy to which attached, effective on the inception date of the policy unless otherwise stated herein.
(The following information is required only when this endorsement is issued subsequent to preparation of policy.)

25

Endorsement Effective Policy No. Endorsement No.

Named Insured

Countersigned by _____
(Authorized Representative)

This endorsement modifies such insurance as is afforded by the provisions of the policy relating to the following:

GENERAL LIABILITY INSURANCE

SMP LIABILITY INSURANCE

BUSINESSOWNERS POLICY

AMENDATORY ENDORSEMENT—ADDITIONAL DEFINITION

It is agreed that the following definition is added:

"loading or unloading", with respect to an automobile, means the handling of property after it is moved from the place where it is accepted for movement into or onto an automobile or while it is in or on an automobile or while it is being moved from an automobile to the place where it is finally delivered, but "loading or unloading" does not include the movement of property by means of a mechanical device (other than a hand truck) not attached to the automobile.

GENERAL PERFORMANCE BOND

Attachment 4

26

NORTHWESTERN NATIONAL INSURANCE COMPANY
OF MILWAUKEE, WISCONSIN
A STOCK COMPANY

POWER OF ATTORNEY

KNOW ALL MEN BY THESE PRESENTS, That NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN, a Wisconsin corporation, does hereby make, constitute and appoint

- - - - - - - - - - Eugene A. Cushing, of Baltimore, Maryland - - - - - - - - - - - -

its true and lawful Attorney(s)-in-Fact, with full power and authority for and on behalf of the company as surety, to execute and deliver and affix the seal of the company thereto if a seal is required, bonds, undertakings, recognizances or other written obligations in the nature thereof, as follows:

- - - - - - - - - - Any and all bonds, undertakings, recognizances or other written obligations in the nature thereof - - - - - - - - - - - - -

and to bind NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN thereby, and all of the acts of said Attorneys-in-Fact, pursuant to these presents, are hereby ratified and confirmed. This appointment is made under and by authority of the following provisions of the By-Laws of the company, which are now in full force and effect:

Article II, Section 1. The business and property of the company shall be managed and controlled by the board of directors.

Article III, Section 1. ...The board of directors may appoint additional officers and agents to perform such duties as may be assigned by the board of directors.

This Power of Attorney is signed and sealed by facsimile under and by the authority of the following resolutions adopted by the board of directors of the NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN at a meeting duly held on May 14, 1963.

RESOLVED that the president, any vice-president or assistant vice-president, in conjunction with the secretary or any assistant secretary, may appoint attorneys-in-fact or agents with authority as defined or limited in the instrument evidencing the appointment in each case, for and on behalf of the company to execute and deliver and affix the seal of the company to bonds, undertakings, recognizances, and suretyship obligations of all kinds; and said officers may remove any such attorney-in-fact or agent and revoke any power of attorney previously granted to such person.

RESOLVED FURTHER that any bond, undertaking, recognizance, or suretyship obligation shall be valid and binding upon the company

(i) when signed by the president, any vice-president or assistant vice-president, and attested and sealed (if a seal be required) by any secretary or assistant secretary; or

(ii) when signed by the president, any vice-president or assistant vice-president, secretary or assistant secretary, and countersigned and sealed (if a seal be required) by a duly authorized attorney-in-fact or agent; or

(iii) when duly executed and sealed (if a seal be required) by one or more attorneys-in-fact or agents pursuant to and within the limits of the authority evidenced by the power of attorney issued by the company to such person or persons.

RESOLVED FURTHER that the signature of any authorized officer and the seal of the company may be affixed by facsimile to any power of attorney or certification thereof authorizing the execution and delivery of any bond, undertaking, recognizance, or other suretyship obligations of the company; and such signature and seal when so used shall have the same force and effect as though manually affixed.

IN WITNESS WHEREOF, NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN has caused these presents to be signed by its proper officer, and its corporate seal to be hereunto affixed this 20th day of June 19 72

NORTHWESTERN NATIONAL INSURANCE COMPANY
OF MILWAUKEE, WISCONSIN

Asst. Vice President

Secretary

STATE OF WISCONSIN, COUNTY OF MILWAUKEE--ss

On this 20th day of June A.D., 19 72, personally came before me, Bruce W. Seeds and Robert P. Falat, to me known to be the individuals and officers of the NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN, who executed the above instrument, and they each acknowledged the execution of the same, and being by me duly sworn, did severally depose and say: that they are the said officers of the corporation aforesaid, and that the seal affixed to the above instrument is the seal of the corporation, and that said corporate seal and their signatures as such officers were duly affixed and subscribed to the said instrument by the authority of the board of directors of said corporation.

Patricia A. Mortag
Notary Public
My Commission Expires December 23, 1978

STATE OF WISCONSIN, COUNTY OF MILWAUKEE--ss

CERTIFICATE

I, the undersigned, assistant secretary of the NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN, a Wisconsin corporation, DO HEREBY CERTIFY that the foregoing and attached Power of Attorney remains in full force and has not been revoked; and furthermore, that the provisions of the By-Laws of the company and the Resolutions of the board of directors set forth in the Power of Attorney, are now in force.

Signed and sealed at the City of Milwaukee this 6th day of July 19 82

Assistant Secretary

Gerald F. Williquette

11108 (12-70)

ECN 870863

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BOND

KNOW ALL MEN BY THESE PRESENTS:

THAT WE, the undersigned BIO GRO SYSTEMS INC as Principal CONTRACTOR and [redacted] as Sureties are hereby held and firmly bound unto the CITY OF AKRON in the penal sum of SIX HUNDRED THOUSAND & 00/100 Dollars ($600,000.00), for payment of which, well and truly to be made, we hereby jointly and severally bind ourselves, our heirs, executors, administrators, successors and assigns.

Signed this 6th day of July 1982

THE CONDITION OF THE ABOVE OBLIGATION IS SUCH, That whereas the above named Principal did on the 6th day of July 1982 enter into a contract with THE CITY OF AKRON, which said contract is made a part of this bond, the same as though set forth herein.

NOW, if the said BIO GRO SYSTEMS INC shall well and faithfully do an perform the things agreed by THEM to be done and performed according to the terms of said contract, and to maintain said improvement in accordance with Section 143 and 144, Division I, of the General Specifications, and shall pay all lawful claims of sub-contractors, material men and laborers for labor performed and materials furnished in carrying forward, performing or completing of said contract; we agreeing and assenting that this undertaking shall be for the benefit of any material man or laborer having a just claim, as well as for the obligee herein, then this obligation shall be void, otherwise the same shall remain in full force and effect; it being expressly understood and agreed that the liability of the surety for any and all claims hereunder shall in no event exceed the penal amount of this obligation as herein stated.

The said surety hereby stipulates and agrees that no modifications, omissions or additions in or to the terms of said contract or in or to the plans or specifications therefore shall in any wise affect the obligation of said surety on its bond.

Signed, sealed and acknowledged in the the presence of

James R Hart
Witness

John Cavallaro
Witness

Bio Gro Systems, Inc.

Stephen R Cahill
Contractor

NORTHWESTERN NATIONAL INSURANCE COMPANY OF MILWAUKEE, WISCONSIN

Eugene A Cushing
Eugene A. Cushing Attorney in-fact
Surety