MARK WILLIAM KITZMILLER. A Comparative Analysis Of Hazardous Waste Management On Three University Campuses. (Under the direction of ALVIS G. TURNER, Jr.)

ABSTRACT

Research and teaching laboratories at universities and university hospitals produce a wide variety of RCRA hazardous waste streams. This analysis will compare hazardous waste management programs on three North Carolina university campuses, the University of North Carolina at Chapel Hill, Duke University in Durham, and North Carolina State University in Raleigh. This analysis examines the administrative infrastructure and costs of hazardous waste management and operations on each campus; will attempt to identify major research, teaching and medical activities which contribute to the generation of hazardous waste; and will assess the internal policies, regulatory compliance and effectiveness of each program. The volume of RCRA listed hazardous waste a university generates is a function of the types of research practiced and the presence or absence of a medical center. Costs and liability considerations shape program policies, operations and training functions. The university must decide whether it will take total responsibility for managing its hazardous waste including the operation of a TSDF or use a full time contractor to provide these services. These factors need to be considered in planning a hazardous waste management program.

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LIST OF ABBREVIATIONS

BTU	British Thermal Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CESQG	Conditionally Exempt Small Quantity Generator
CHYDARU	Chapel Hill Youth Detention and Release Unit
CFR	Code of Federal Regulations
DOT	Department of Transportation
EPA	United States Environmental Protection Agency
FTE	Full Time Employees
GM	Waste Generation and Management
HMF	Hazardous Material Facility
HSO	Health and Safety Office
HSWA	Hazardous and Solid Waste Amendments
IDLH	Immediately Dangerous to Life or Health
LABP	Labpack
LQG	Large Quantity Generator
MSDS	Material Safety Data Sheet
NCSU	North Carolina State University
NPL	National Priorities List
OSHA	Occupational Safety and Health Administration

PI	Principal Investigator
PPE	Personal Protective Equipment
PS	Waste Treatment, Disposal, or Recycling Process Systems
PTE	Part Time Employees
RCRA	Resource Conservation and Recovery Act
SCBA	Self-Contained Breathing Apparatus
SQG	Small Quantity Generator
TSD	Treatment, Storage, and Disposal
TSDF	Treatment, Storage, and Disposal Facility
UNC-CH	The University of North Carolina at Chapel Hill
WR	Waste Received from Off Site

LIST OF SYMBOLS

$\geq$	Greater Than or Equal To
$\leq$	Less Than or Equal To
$>$	Greater Than
$<$	Less Than
#	Number
°C	Degrees Celcius
°F	Degrees Fahrenheit

I. INTRODUCTION

The Resource Conservation and Recovery Act (RCRA), 1976, an amendment to the Solid Waste Disposal Act of 1965, creates a framework for the safe management of hazardous and nonhazardous solid wastes. In Subtitle C of this Act, Congress directs the U.S. Environmental Protection Agency (EPA) to establish a national program to manage hazardous waste in a manner that protects human health and the environment.

The hazardous waste regulations promulgated by EPA under RCRA became effective on November 19, 1980. The major elements of these regulations include a definition of regulated hazardous waste; the creation of a manifest and permitting system; the establishment of standards for generators, transporters, and treatment, storage, and disposal facilities (TSDF); and a provision for states to manage their own hazardous waste programs.

Research and teaching laboratories at universities and university hospitals produce a wide variety of RCRA hazardous waste streams. This analysis will compare hazardous waste management programs on three North Carolina university campuses, the University of North Carolina at Chapel Hill, Duke University in Durham, and North Carolina State University in Raleigh. This analysis will examine the administrative infrastructure and costs of hazardous waste management and operations on each campus; will attempt to identify major research, teaching and medical activities which contribute to the generation of hazardous waste; and will assess the internal policies, regulatory compliance and effectiveness of each program.

The purpose of this analysis is to provide an operational model hazardous waste management program for university campuses which will encourage waste minimization, manage cost effectively, and improve operations.

II. THE RCRA HAZARDOUS WASTE SYSTEM

The first federal solid waste law, the Solid Waste and Disposal Act, was passed by Congress in 1965. This Act required the states or local government to improve the handling and disposal of solid waste in the United States and its provinces. The Act was first amended by the Resource Recovery Act of 1970 and in greater detail by the Resource Conservation and Recovery Act of 1976; however, the hazardous waste regulations did not become effective until 1980. An important amendment to this Act was the Hazardous and Solid Waste Amendments (HSWA) which was enacted on November 8, 1984. HSWA created major changes in RCRA and the regulatory requirements.

Resource Conservation and Recovery Act

A solid waste is regulated as a hazardous waste if it:

- was not specifically excluded by Congress in the Resource Conservation and Recovery Act or specifically exempted under the EPA RCRA rules;
- exhibits anyone of four characteristics: ignitability, corrositivity, reactivity, EP (extraction procedure) toxicity;
- is listed in the RCRA rules;
- is mixed with a regulated hazardous waste;
- is a residual waste obtained from the treatment, storage, or disposal of a listed waste; or
- has not been delisted.

Resource Conservation and Recovery Act Regulations

Generators of Hazardous Waste

A generator may be a facility owner, operator, or any person who first produces a hazardous waste stream. A generator can also be a person who first causes the waste to be regulated by RCRA under Subtitle C. There are three types of Generators: Large Quantity Generators (LQG), Small Quantity Generators (SQG), and Conditionally Exempt Small Quantity Generators (CESQG). Large Quantity Generators and SQGs are regulated under RCRA (40 CFR Part 262). Generators must determine if their waste streams are hazardous or nonhazardous and they are liable for their hazardous waste from cradle-to-grave.

Large Quantity Generator

- facilities that generate over 1,000 kilograms per month of hazardous waste; or
- facilities that generate over 1 kilogram of acutely hazardous waste per month.

Small Quantity Generator

- produces greater than 100 but less than 1,000 kilograms of hazardous waste at a site per month (and accumulates less than 6,000 kilograms at any one time).
- produces less than 1 kilogram of acutely hazardous waste per month (and accumulates less than 1 kilogram at any one time).

Conditionally Exempt Small Quantity Generators

- Identify the waste to determine whether it is a hazardous waste.
- Not accumulate more than 1,000 kilograms of hazardous waste at any time.

- Treats or disposes of the waste on site, or ensures that the waste is sent to a: Permitted or interim status TSDF, or; Permitted municipal or industrial solid waste facility, or; Recycling facility.

Accumulation of wastes on site differs for each type of generator, particularly for LQGs. A LQG may accumulate any amount of waste on site $\leq$ 90 days for a more cost effective program if there is proper storage, an emergency response plan and personnel training. Proper storage containers must be marked with the words "Hazardous Waste" and the date accumulation begins. A contingency plan is required only for LQGs in case an emergency occurs. Personnel must be trained in the proper handling of hazardous waste in an established training program for LQGs. If waste is stored for $>$ 90 days then the LQG must obtain a RCRA storage permit. There are also regulations governing satellite accumulation areas for LQGs. Waste can only be accumulated at the satellite if $\leq$ 55 gallons of nonacute hazardous waste is being stored and $\leq$ 1 quart of acutely hazardous waste. There is a 90 day storage limit once the LQG exceeds the satellite accumulation limits.

The SQG can store hazardous waste for $\leq$ 180 days as long as 6,000 kilograms is never exceeded along with other requirements. SQGs who transport their waste $>$ 200 miles to an off-site TSDF can accumulate waste on-site up to 270 days without a storage permit or interim status. Generators must obtain a RCRA permit if they treat or dispose of hazardous waste or exceed storage limitations.

CESQG must guarantee the waste is sent to a RCRA permitted TSDF, a permitted municipal or industrial solid waste facility, or a recycling facility. If a CESQG exceeds these limits, it is considered to be a SQG. Conditionally Exempt Small Quantity Generators are exempt from RCRA regulations.

Transporters

In the U.S. Department of Transportation (DOT) system of classification of hazardous materials, hazardous wastes are ORM-E (Other Regulated Material,

Class E). ORM-E materials are not subject to DOT labeling and packaging requirements but are accompanied instead by a hazardous waste manifest. EPA does require generators to mark all hazardous waste containers with a capacity of 110 gallons or less with a statement indicating that federal law prohibits improper disposal of such wastes.

All transporters of RCRA hazardous wastes must have an EPA identification number, comply with the manifest system and take immediate action in the event of a discharge. This action includes notification of appropriate authorities, cleaning up the discharge, and submitting an incident report.

Treatment, Storage, and Disposal Facilities

Treatment, storage, and disposal facilities are the last stage in the cradle-to-grave system. Treatment, storage and disposal facilities must obtain an operating RCRA permit (40 CFR part 270) and follow strict regulations in order to legally operate such a facility. Part B of the permit application must be filed for permanent status and Part A for interim status. Prior to November 8, 1980, TSDFs operated under an interim permit, which was issued by EPA or an authorized state. Interim status was allowed for those owners and operators who were in existence before November 19, 1980. Interim facilities had to file a final permit application by November 1988 (November 1986 for incinerators). If they did not apply, they lost their interim status in November 1992 (November 1989 for incinerators and November 1985 for land disposal facilities if they did not apply by the same month and year). There were no requirements for interim status permits except good housekeeping and properly managing hazardous waste. After November 8, 1980 all new facilities were required to have a RCRA permit before ground breaking. Permits ensure that owners or operators who treat, store, or dispose of hazardous waste adhere to Subtitle C regulations of RCRA. If there are changes in the facility's structure, processes or new laws are enacted, then the permit must be modified. Permits are valid up to 10 years.

40 CFR 260.10 - TSDF Definition

- Treatment: Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize it, or render it non-hazardous or less hazardous, or to recover it, make it safer for transportation, storage, or disposal of , or amenable for recovery, storage or volume reduction.

- Storage: The holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed, or stored elsewhere.

- Disposal: The discharge, deposit, injection, dumping, spilling, leaking, or placing of and solid waste into or on any land or water so that the waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground wastes.

There are two types of requirements for interim and permitted facilities. The first type is administrative and nontechnical and the second type is technical and unit-specific. Administrative and nontechnical requirements mandate that owners and operators establish procedures to properly operate a facility and a plan of action in case of an emergency or accident. Technical requirements mandate that owners and operators operate a TSDF in an appropriate manner to reduce risk to human health and the environment.

Manifests

Manifests and records are a key function in managing hazardous waste. The Uniform Hazardous Waste Manifest form is designed to insure proper management of hazardous waste from cradle-to-grave. Through this process generators are able to track their waste from generation to the final destination called the designated facility (TSDF). The RCRA manifest must contain the following: generator's name and EPA ID#; transporter(s) name and EPA ID#; TSDF name and EPA ID#; DOT description of the waste, quantity of the waste, and the address of the designated facility (TSDF). The HSWA requires that the

manifest also contain a certification that the generator has a waste reduction program in place and that the treatment, storage, and disposal (TSD) method used will decrease possible health risks. The manifest is used to track the handling of all wastes. Once the waste is picked up by the transporter, the generator has 35 days to receive a copy of the manifest from the designated TSDF. If 35 days pass without the generator receiving the manifest he must determine what happened to the hazardous waste. If 45 days pass without receipt of the manifest, the generator must complete an exception report. These manifests are sometimes called Hazardous Material Transfer Forms or Request for Disposal Form at educational institutions. Manifests must be kept on file for three years by the generator, transporter, and designated TSDF. Documentation is satisfied once the forms are complete.

Reports and Record Keeping

Record keeping and reports are used to track the quantities and movement of hazardous waste. Each hazardous waste generator must prepare biennial reports, exception reports, and retain all manifests, records and reports for at least three years. The designated TSDF must also retain the manifest for three years. The generator must also maintain records of their waste analysis for three years once the waste is shipped on or off-site, The EPA Administrator may extend the retention of the records if there are any problems associated with the waste. Biennial reports must be submitted by March 1st of even years to the regional EPA Administrator (North Carolina is in region IV) to account for all the generators activities from the preceding or odd year. Biennial reporting is also required by LQGs that transport waste off-site and generators with TSDFs. Exception reports must be filed if the manifest form is not returned to the generator, thus notifying the regional EPA Administrator. LQG must receive the manifest within 45 days from the initial transport of the waste; however, SQGs have 60 days before the exception report must be filed. This report must document attempts which were made to locate the waste and the outcome of

the generators efforts in finding the waste. Reports and record keeping are a significant part of the tracking process.

III. HAZARDOUS WASTE MANAGEMENT ON UNIVERSITY CAMPUSES

Many hazardous waste management practices at colleges and universities are not allowed under current regulations and some of them are not aware of the liability costs of chemical waste mismanagement. The key to safe management of hazardous wastes at these institutions is to increase the awareness of administrators, faculty members, students, researchers and maintenance personnel in the proper handling, packaging and storage of chemical wastes, recordkeeping and waste reduction strategies. Institutions must also commit sufficient funds and staff to solve their hazardous waste management problems.

Nearly 3,400 colleges and universities in the United States are classified as hazardous waste generators [6, 9]. The primary sources of hazardous waste in the university community are research laboratories, university hospitals, academic (teaching) laboratories, art, vocational and maintenance departments. Unlike industrial generators who often produce large volumes of a few hazardous wastestreams, university operations usually produce small quantities of many different wastestreams.

There are a variety of factors which determine the volume and types of hazardous wastes generated on a university campus. These include such characteristics as the types of scientific and medical research being conducted; the presence of a teaching hospital; the size of graduate programs (particularly those in chemistry and environmental, chemical and industrial engineering); and the number and types of maintenance shops and activities found on campus. The University of Wisconsin in Madison reported that it generated 105,000 kilograms of hazardous waste in 1980 whereas the University of Illinois at

Urbana-Champaign reported 37,000 kilograms generated in 1985 [9]. The volume of hazardous wastes generated on both of these campuses has increased from year to year.

The types and quantities of wastes generated by universities also directly influences the technical and economic feasibility of using certain treatment, storage and disposal methods. Research laboratories on university campuses are usually independently managed and operated by one or more faculty members. These laboratories receive research grant funding from many sources. Although indirect costs included in some of these grants may pay some of the costs, they seldom cover the total cost of hazardous waste treatment and disposal. These services are usually provided by the university administration who find it difficult to develop and adequately fund waste management programs considering their budgetary and management constraints. The U.S. Environmental Protection Agency's Office of Solid Waste pointed out in a *Report to Congress: Management of Hazardous Waste from Educational Institutions* in 1989 that "Most problems in hazardous waste management at educational institutions arise from the institutions' lack of awareness about hazardous wastes and the applicable regulations; the transient nature of student populations; the highly variable waste streams generated, which contain multiple constituents; the insufficient resources available for hazardous waste management programs; the high cost and location of off-site treatment, storage, and disposal; and the difficulties in complying with the hazardous waste regulations."

A typical educational institution manages hazardous waste by first assembling wastes at one or more locations, segregating wastes by type and, if necessary, labeling the wastes. Off-site transportation of hazardous waste to a permitted treatment, storage or disposal facility can be costly to universities and colleges. To lower costs, a school may store its waste on-site for long periods of time (a storage permit is required if wastes are stored longer than 180 days by a small generator) or arrange with other institutions to have their

waste transported simultaneously. Off-site transportation by a licensed transporter is usually arranged through a continuing or one-time contract, however, some transporters are reluctant to serve a university because the amounts of wastes shipped are generally very small.

Educational institutions that dispose of hazardous waste may be legally liable for the cleanup of those wastes if they are mismanaged. There are several hazardous waste sites at universities which are on the National Priorities List (NPL) for Superfund cleanup. One of these is on an off-campus site at North Carolina State University where containers of waste chemicals were buried between 1969 and 1970. It is not clear who is liable under these circumstances: the university administration, laboratory director(s), or waste removal service.

IV. ADMINISTRATIVE INFRASTRUCTURE

The administrative infrastructure for hazardous waste management at the three universities includes: the University of North Carolina at Chapel Hill's (UNC-CH) Health and Safety Office, Duke University's Occupational and Environmental Safety Office, and North Carolina State University's Environmental Health and Safety Center. The operation and management of these offices will be contrasted to show how they diverge from one another. A flow chart of each organization is provided to show the office structure (*see Appendix A*). An analysis of the effectiveness of these hazardous waste management programs is included.

Organizational Structure

University hazardous waste business organizations differ significantly in waste management functions and operations. Each of these universities has its own procedure for controlling how hazardous waste is handled and in defining employee job classifications and duties. Contractors are selected based upon several key factors. The administrative staff is a crucial component in managing any environmental, occupational, health and safety program.

Office Sections

The Health & Safety Office in the UNC-CH organization consists of a director, an administrative staff, and four sections (*see Appendix A*). The Hazardous Waste Management Division is responsible for collecting and disposing of hazardous materials on the University campus and the North Carolina Memorial Hospital. The waste is then transported to the University's TSDF. UNC-CH was the only University in North Carolina with a permitted TSDF until NCSU was permitted in July 1993. The University's Industrial

Hygiene and Biological Safety Division recognizes, evaluates, controls and anticipates employee, student or visitor exposures to chemical, physical and biological hazards. The Radiation Safety Division is responsible for all radioactive sources and ensures proper management and handling of isotopes on campus. The Fire Safety Division enforces North Carolina building and fire codes on the university campus. The Health and Safety Office has approximately thirty full time employees to administer the University's guidelines and provide a safe work environment.

Duke University's Occupational and Environmental Safety Office consists of a director, an administrative director, a technical director, an administrative staff, and six sections (*see Appendix A*). The Environmental Programs Division is responsible for picking up and disposing of hazardous materials on the University campus and the University Medical Center where hazardous waste is generated. The Environmental Programs Division manages chemical and low-level radioactive waste, and monitors storm and ground water discharge to the sanitary sewer and potential air toxins. The Occupational Health and Safety Division which includes industrial hygiene is responsible for the recognition, evaluation, control and anticipation of harmful exposures by chemicals and physical hazards to university employees, students, or visitors. The Biological Safety Division is charged with preventing exposures to etiologic agents, bloodborne pathogens and medical waste. The University Safety Office handles fire safety for the main campus and residential housing. The University Medical Center's Fire and Safety Office is responsible for safety in research and patient care buildings at the medical facility. The Radiation Safety Office Division manages the handling of isotopes at the University. The Occupational and Environmental Safety Office has forty-two full time employees to administer the University's guidelines and provide a safe work environment.

NCSU's Environmental Health and Safety Center's organization includes a director, two service branches, and an administrative staff (*see Appendix A*). Life Safety Services implements laws and policies for the University community

and informs the University populace of these regulations. Three divisions in Life Safety Services, Hazardous Waste Management, Industrial Hygiene, and Occupational Health and Safety are responsible for these activities. The Hazardous Waste Management division contracts out and oversees the handling of hazardous waste on campus. The Industrial Hygiene Division's primary function is similar to UNC-CH and Duke's program in recognizing, evaluating, controlling and anticipating chemical, physical, and biological hazard exposures to University employees, students, or visitors. The Occupational Safety and Health Division inspects and investigates University property for compliance. It also consults and trains University employees. The Radiation Protection Services is responsible for all radioactive sources, including ionizing-radiation-producing devices such as the nuclear reactor. The Radiation Protection Services ensures proper management and handling of isotopes on campus and extension sites. Life Safety Services encompasses a large area of responsibility, including the Hazardous Waste Management program that helps to protect the University community and the environment against harmful consequences. The Environmental Health and Safety Center has twenty-three full time employees to administer the University's guidelines and provide a safe work environment.

Hazardous Waste Management Personnel

Hazardous waste employees at UNC-CH and Duke University are responsible for collecting hazardous waste generated in all laboratory facilities, including UNC-CH's University hospital and Duke Medical Center. These laboratory facilities are usually not charged for waste pick-up except UNC-CH imposes a surcharge on its hospital pickups. NCSU has an outside contractor who picks-up and handles wastes generated in their laboratory facilities.

University of North Carolina at Chapel Hill

There are seven employees who work in the Hazardous Waste section

at UNC-CH. A Hazardous Waste Manager coordinates operations and employee job functions. There are two Hazardous Materials Technicians: one is responsible for hazardous waste; and the other is responsible for radioactive waste. Two Hazardous Waste Chemists play an important role in managing hazardous waste before it is transported off-site to a TSDF. Two student assistants support the Hazardous Materials Technicians.

The Hazardous Waste Manager is responsible for the management, treatment and disposal of hazardous and low-level radioactive wastes generated by the University and University hospital. The Hazardous Waste Manager is also responsible for operating an effective waste minimization program by reducing the volumes of waste generated in laboratory facilities, encouraging recycling or reuse of unused chemicals, and overseeing the treatment of selected hazardous waste in order to reduce the toxicity and/or eliminate the hazardous component. Supervision is the key to effectively operating a hazardous waste program. The manager supervises the Hazardous Materials Technicians who collect and transport hazardous and low-level radioactive wastes on campus and the Hazardous Waste Chemists who classify, segregate and prepare hazardous materials for proper storage and disposal.

The four principal functions of the Hazardous Materials Technician are: (1) picks up chemical wastes for transport to the UNC-CH Hazardous Materials Facility (HMF), (2) collects and prepares radioactive wastes for transport to the appropriate University facility (HMF or CHYDARU), (3) enters all wastes into the UNC-CH paper tracking system, (4) and prepares a weekly activity report covering waste volumes, problems encountered, and special situations.

The job of the two Hazardous Waste Chemists is to: (1) segregate chemicals delivered by the Hazardous Materials Technician and (2) package and document the waste for transportation. The Hazardous Waste Chemists also segregate chemicals for reuse and treat chemicals by neutralization or by bulking and blending solvents according to compatibility and reactivity. They are also responsible for maintaining all personal protective equipment,

housekeeping of the facility, and maintaining accurate records of all activities related to transportation, receiving, storage, and treatment. They are also available to answer questions from the University community by explaining proper segregation, packaging, and labeling procedures for laboratory waste. The University complies with all state, federal and UNC-CH safety regulations, policies and procedures.

Duke University

Three employees work in the Environmental Programs Division at Duke. The Chemical Waste Manager oversees the operations of this Division. The manager focuses on waste minimization and volume reduction while the Environmental Safety Specialist supports and oversees waste collection and prepares the waste for disposal. This Technician collects all the hazardous waste on campus, and bulks and segregates the chemicals according to chemical compatibility at the campus storage facility. The Environmental Programs Division assists the main campus and medical center in managing hazardous waste on campus.

North Carolina State University

NCSU has a different approach for the management of hazardous waste. Prior to August 1992, NCSU collected all hazardous wastes from laboratories and shops and transported the waste to either the main waste storage facility or the Veterinary School central storage facility. As of January 1, 1993, NCSU contracted for a full-service contractor, Advanced Environmental Technology Corporation, to remove its hazardous waste. The Hazardous Waste Management division oversees the pick-up and disposal of hazardous waste by this contractor. NCSU has three full-time employees who work in the Hazardous Waste Management Division. The Hazardous Materials Manager identifies, collects, treats, stores and disposes or recycles chemical waste. The manager is responsible for emergency planning and response and providing technical

assistance and information. NCSU also employs two Chemistry Technicians-II, who provide information and technical support in hazardous waste and assist in emergency planning and response. They inform the manager of daily waste activities at the University and assist the contractor in waste collection, identification, treatment, storage, disposal or recycling of assorted chemical waste streams. Scheduling and information-management of chemical waste is dealt with by a clerk typist who maintains a schedule for waste pick-up and a database file of the hazardous waste at NCSU.

The Hazardous Materials Manager must have a thorough knowledge of RCRA to effectively operate the hazardous waste management program. The manager oversees and is in daily communication with the contractor, managing the chemical technicians and clerk typist in NCSU's hazardous waste collection program. Working side by side with the contractor helps to ensure compliance under RCRA. Providing guidance and assistance in waste minimization, spill prevention, developing contingency plans, and providing technical support is a significant part of the duties of the hazardous materials manager. Hazardous areas are identified for emergency planning and risk assessments. The manager provides the chemical technicians with technical assistance during an emergency response to a chemical spill; keeps and maintains an inventory of emergency response equipment; provides technical assistance to hazardous waste generators and advises them of their responsibilities for hazardous waste management; and ensures that staff employees are educated and trained in the areas pertinent to their job specifications.

The Chemical Technician's have four areas of responsibility. They inform and assist people who use or store hazardous materials. They accomplish this goal by notifying hazardous waste generators of their responsibility and provide educational and technical training to the PIs and their workers. Responding to incidents which involve chemical releases is the second function of the technicians. They also identify possible areas for emergency and spill response. The third function of the technicians is to observe daily activities of the

contractor or university generators in their management of hazardous waste. Finally, the technicians must be familiar with the overall hazardous waste management program. They must know how to schedule collections, collect waste and surplus chemicals, store chemicals safely, treat chemicals and dispose of chemical waste.

Effective January 1, 1993 there are two to three contract employees on-site at all times during regular university work hours. The contractor must assign qualified personnel for the handling of hazardous waste, however the University has the option of requesting new personnel if job performance or professional courtesy is inadequate. The contractor's employees must be certified in hazardous waste handling for workers and transportation of hazardous waste according to OSHA (29 CFR 1910.120) and RCRA (40 CFR 264.15). Equipment, uniforms, PPE, transportation, material handling and personal monitoring devices are the contractor's responsibility.

Contractors

Each university has its own philosophy for selecting affiliates to package, transport, treat, store and disposal of hazardous waste. Liability appears to be the primary factor in choosing a transporter and a TSDF. Contractors play distinctive roles depending on what the university needs or requires. Hazardous waste generators take numerous risks in choosing contractors to handle their waste, especially liability risks. The university selects a contractor according to the reputation and violation history of the company and the role they are to play in handling hazardous waste.

The University of North Carolina at Chapel Hill chooses its contractors through a bidding procedure. UNC-CH compiles a list of chemical hazardous waste and sends it to potential vendors who can pick up and dispose of the waste. The vendors bid on the list and appraise the costs of managing the University's hazardous chemicals. The University looks for the best deal which conforms to its requirements in managing hazardous waste. The best service

and lowest price are the final elements in the University's choice of one TSDF that can transport and dispose of the hazardous waste rather than choosing two different companies.

Before a vendor is chosen, the University obtains compliance records for each of the vendors from the state agency which manages environmental affairs. To protect the University's interest, the University assesses each vendor's limitations on waste disposal. The University is investing in the contractor to protect against liability and assure proper delivery and disposal costs. It is also important for the University to consider whether a vendor is a broker or an actual TSDF. Brokers typically provide certified transport (truck drivers) and haul hazardous waste to a TSDF that accepts a particular waste stream. Ideally, however, the University prefers to use a TSDFs that transports and disposes of waste using the company's own disposal facilities.

UNC-CH is planning to initiate hazardous waste TSDF site-visits in the near future. A vendor's compliance record will be obtained and the University will contact the vendor to set up an appointment for a facility inspection. The University will not engage in a business relationship with any company that refuses an on-site visit to the TSDF. The University inspects the vendor's insurance claim records to gauge the liability risk. Finally the University conducts a visual inspection of the waste facility to assess potential liability.

The vendor's only function at UNC-CH is to transport hazardous waste from HMF to a permitted TSDF. It should be noted that UNC-CH packages all of its hazardous waste (labpacks, bulked waste, etc.) before the contractor transports it off-site. The University wants to deal with only one company in handling the hazardous waste from transportation to the disposal site. The hazardous waste is almost always incinerated and seldom buried at a hazardous waste landfill. The waste is segregated and packed for the optimum BTU value before the waste is incinerated as a fuel substitute. The purpose in segregating hazardous waste is to obtain the optimum BTU value to reduce disposal costs and encourage energy recovery by using waste as a fuel substitute.

Duke University, a private institution, has its own particular approach for choosing contractors. The University first talks with customers that have their hazardous waste managed by a specific contractor. Then Duke researches the background of the contractor before the contractor's facility is accepted. Duke uses a "Liability Check List" where several factors are taken into consideration. Prior to accepting the TSDF as a contractor to handle the University's waste, two people from Duke will inspect the facility, which takes three to five days. The facility is inspected every 85 to 90 days to safeguard against any potential problems.

Duke employs a three-phase approach in evaluating potential contractors. Phase I consists of an assessment of the contractor's insurance policy for liability coverage for both the transporter and TSDF. Information on the company's past environmental compliance is gathered on the landfill where the contractor disposes of his/her waste. Duke communicates with the company's Compliance Manager Officer to evaluate how the organization operates its business. Duke also looks at the annual reports from the TSDF before it accepts the company as a contractor.

Phase II involves communication with the appropriate State Environmental Management Office, which verifies whether the contractor is in compliance and if the contractor had any past citations. Any actions against the company, such as closure, by a current or past generator, is explored. Reviewing critical parts of the closure plan, such as ground waste monitoring, is necessary to protect the University's interest.

Phase III consists of a visual walk-through inspection of the TSDF and observation of the employees' work practices and the physical condition of the plant. The University also examines the packaging dates on containers where hazardous waste is stored to make sure the dates do not exceed one or more years. The University will not employ a contractor if the date on the hazardous waste container exceeds one year. A visual inspection of the facility and property is conducted to assess that the facility is an appropriate risk, and to

check on surrounding conditions. The main element considered is whether storm water is managed properly and is in compliance with surface water and storm water regulations.

The contractor's role at Duke is similar to that at UNC-CH. Both universities use a contractor to transport and dispose of hazardous waste. Before hazardous waste is transported off-site, Duke bulks and segregates its hazardous waste; however, Duke's contractor is responsible for labpacking chemical waste streams. The hazardous waste is picked up by the contractor at Duke's waste facility and transported to a permitted TSDF. There, the waste is placed in a hazardous waste landfill or burned in incinerators as a fuel substitute.

NCSU has a method similar to UNC-CH for choosing its contractors since both are state institutions. NCSU's bidding process usually involves as many as 15 interested parties. The companies submitting bids are reviewed by NCSU's Environmental Health and Safety Center and NCSU's State Purchasing Office. Several items are reviewed such as the contractor's labor and disposal costs before a contractor is selected. NCSU also considers legal liability. The University thoroughly examines the contractor's history and determines if the company is capable of managing its chemical waste streams and its recycling and reuse programs. NCSU communicates with other generators that have dealt with a particular contractor to safeguard against poor waste management. A contract is signed once the University and State Purchasing Office is satisfied that the contractor is capable of safely managing hazardous waste.

At NCSU the contractor plays a much larger role in waste collection than at UNC-CH and Duke. The contractor is required to have personnel trained in waste disposal. The contractor at NCSU identifies, collects, treats, stores, and disposes of or recycles chemical waste. Chemical wastes includes both hazardous and low-level radioactive waste. Before the waste is collected from laboratories and other facilities where it is generated, the contractor reviews the generator's documents to confirm that the information is in agreement with

the laboratory's manifest. The waste is then transported to NCSU's designated TSDF. NCSU also checks the manifest to confirm that the information is accurate before the waste is shipped off-site for incineration, treatment, or disposal, and that the waste can be tracked back to the generator.

The contractor has multiple job functions at NCSU. At the start of each working day the contract requires a daily facility inspection (Monday through Friday, except University holidays) and a weekly inspection of the storage facility to safeguard against non-compliance with EPA regulations. Chemical wastes are collected according to a schedule established by the Environmental Health and Safety Center. The contractor must provide all the necessary equipment for the proper handling of hazardous waste. The contractor's waste-handling procedures vary according to the waste's composition and is segregated according to chemical compatibility. The contractor decides if the waste should be treated, stored or packaged for disposal and an inventory of these wastes is maintained. Waste is treated at the University by the contractor only for the purpose of off-site recycling or recovery. NCSU's hazardous materials manager inspects the work of the contractor to ensure that waste storage and handling are in accordance with NCSU's operating procedures. Waste chemicals are required to be packaged in an efficient and cost-effective method. Finally, the contractor provides a plan for off-site treatment and disposal. Reporting and record keeping is conveyed to the University's Hazardous Materials Manager. The contractor assumes responsibility for any spill or release of hazardous materials while it is in his/her custody. Nevertheless they are not involved in emergency response to a chemical spill or other crisis. This responsibility is assumed by the University's chemical technicians. All waste containers and documentation are inspected prior to waste removal. Liability transfers to the contractor once the waste is accumulated and properly disposed of at the appropriate on-site facility.

Hazardous Waste Operating Procedures

Typically on all three campuses, chemical waste is collected in four-liter glass bottles, preferably empty carcinogen containers; however, often unused, deteriorated, or old chemicals in their original containers are discarded as hazardous waste. Laboratory personnel are usually required to label the bottle with the volume of each waste stream being disposed of in that particular container. Chemicals that are picked up by UNC-CH, Duke, or NCSU must be sealed, the bottle must be free from exterior contamination, and it must be stored according to the University's policy. Chemicals which have never been used and are in their original containers can often be recycled to other laboratories. The PI is the person solely responsible for identifying, labeling and handling of hazardous waste generated in his/her laboratory facility.

Waste Stored on Campus

Hazardous waste is temporarily stored in the laboratory where the waste streams are first generated. Hazardous waste cannot be picked up from the laboratory facility until proper documentation and record keeping is completed by the PI. Waste is then picked-up by the designated chemical waste technician for transport to the appropriate collection point on campus. Each university must be aware of its responsibility in managing hazardous waste and antiquated chemicals, and must assure that the hazardous waste is properly manifested before the waste is shipped off-site to an appropriate TSDF.

Hazardous Waste Transportation

Manifests and record keeping are required before transporting hazardous wastes on public roads. At UNC-CH the Hazardous Material Technician who picks up and transports hazardous waste must take special precautions because this University has to use public access roads to transport its waste. At Duke, the Environmental Programs Division personnel pick up and transport hazardous waste. Duke University does not have to use public roads, therefore it is not

required to manifest its hazardous waste until the waste is ready to be transported off-campus. Duke does not have to adhere to the strict transportation guidelines established by RCRA and DOT. A contractor at NCSU picks up and transports the hazardous wastes off-site. Like UNC-CH, NCSU also has to follow rigid guidelines in the transport of hazardous waste across public access roads. Transporters must have an EPA identification number, comply with the manifest system, and take immediate action in case of discharge.

Manifests, Reports and Records

Manifests, reporting and record keeping enable the generator to track his/her waste from the point of generation to final disposal (TSDF), which is known as a cradle-to-grave system. The manifest is used to document waste reduction and the treatment, storage, and disposal techniques used to manage the wastes. Manifests, reports, and records of waste analysis must be retained for three years.

The hazardous waste manifest form or data log sheet is used to identify chemical waste streams. Waste streams must be logged by percent or by volume as the container is being filled. Once the hazardous waste containers are full, the information on the label must be transferred to the University's hazardous waste manifest form. The Health and Safety Office at UNC-CH uses a hazardous material transfer form, Form 510, which is attached to the hazardous waste bottle. A carbon copy of the manifest is then sent to the hazardous waste office before the container is picked up from the laboratory facility. The Occupational and Environmental Safety Office at Duke University either picks up waste after receiving a chemical pick-up card, phoning in to the hazardous waste office for the waste to be picked up, or answering a questionnaire on the computer network. The Environmental Health and Safety Center at NCSU did not have a hazardous waste manifest form until January 1992. NCSU uses a chemical identification form which has the same function and is identical to UNC-CH's hazardous material transfer form (HSO Form 510).

A carbon copy of the manifest is then sent to the hazardous waste division before the container is picked up from the laboratory facility. Prior to January 1992, laboratory personnel who generated hazardous waste were required to keep a log of each chemical waste being disposed of in that particular container. Usually the PI or laboratory supervisor signs the hazardous waste manifest form to verify the contents of that particular waste container.

The hazardous materials transfer form (HSO Form 510) is used at UNC-CH to collect a significant amount of information: (1) the name and telephone number of the PI or designee, (2) his/her mailing address, (3) location of the waste, (4) container size, and (5) weight of the hazardous materials in the container. An important part on the manifest is the principal constituents section which lists the waste(s) description by volume. If the laboratory personnel do not know the specifics of each chemical being disposed, they are required to list all the waste ingredients in the container by percentage or in parts per million. The director or the hazardous waste manager at the Health and Safety Office will then determine which RCRA code and waste characteristic will be used on the off-site transport manifest. The waste characteristic determines what types of hazardous waste are being disposed: ignitable/flammable (flash point $\leq$ 140 °F), corrosive (pH $\leq$ 2.0 or $\geq$ 12.5), reactive (to air, water, heat), extraction procedure toxicity (extractable metals), toxicity characteristics, poison (non-RCRA, but unsuitable for disposal to sewer or sanitary landfill), oil (motor, vacuum pump, etc.), and asbestos-containing materials. There is a stipulation on the Hazardous Material Transfer Form stating that waste must not contain infectious, biohazardous, radioactive, highly toxic or reactive material and that the PI must certify, under penalty of law, that the information on the form is correct. Finally, the form must be signed and dated by the PI or designee and mailed to the UNC Health and Safety Office before the hazardous waste is picked up.

There are three ways chemical waste can be picked up at Duke. A chemical pick-up card must be filled out properly and mailed to the Occupation-

al and Environmental Safety Office. Once the card is received, an arrangement is made by the office to pick-up the chemical waste. Certain information is required before the waste can be picked up and transported to the Environmental Safety Building for treatment and disposal: PI's name, PI's phone number, and the building and room number where the waste is stored. It is the responsibility of the PI to guarantee the information is accurate. To make a request to pick up waste by telephone, the PI or laboratory employee must call the chemical hotline on Tuesdays or Thursdays from 10:30 am to 2:30 pm. Before calling the hotline, the chemical waste pick-up card must be filled out as stated above. Requests can also be made through the computer by dialing the chemical waste pick-up questionnaire.

The chemical identification form used at NCSU requests the same information as UNC-CH's HSO Form 510. The form must be signed and dated by the PI and sent to the Environmental Health and Safety Center before the hazardous waste is picked up for disposal. Prior to January 1992, NCSU used a slightly different method for picking up hazardous wastes from the University research laboratories. All containers of hazardous waste must be labeled "Waste" or "Hazardous Waste" and must be documented by keeping a running log of each material placed in the waste container. The person who discards the chemical must list the waste composition and volume. Each person must record the date and put his/her initial on the hazardous waste-stream log sheet. The EPA code for each listed hazardous waste is also logged on the sheet. The hazardous waste division must be notified for pick up or a prearranged date is set for regular chemical waste pick up. NCSU does not have a structured manifest form like those used at UNC-CH and Duke. Each University has its own procedure for documenting hazardous waste, collections, transport and treatment/disposal.

V. GENERATION OF RCRA LISTED HAZARDOUS WASTE

Hazardous Waste Generation

These universities differ in the types of research, teaching and medical activities which contribute to the generation of hazardous waste. Hazardous waste streams generated in laboratories are the responsibility of PIs while hazardous waste streams from non-laboratory facilities are the responsibility of supervisors. These chemical waste streams are regulated under RCRA and must be handled in a manner which will protect human health and the environment.

Firstline Responsibility

PIs and Supervisors are associated with a department, research center, or other program at the university or university hospital. The PI and supervisor are responsible for identifying, labeling and managing hazardous waste in their work zone. Supervisors are usually associated with non-research activities, for example, the individual responsible for used aviation fuel (D001) from the hospital's helicopter. Only a small percentage of university waste is generated in non-research activities. PIs and supervisors are held accountable for the hazardous waste generated in their work areas until the waste is picked up for disposal by the university.

EPA ID Number

By law, all generators, transporters and TSDFs must have an EPA identification numbers. The status of university generators (CESQG, SQG, LQG) is determined by the amount of hazardous waste generated. EPA has provided identification numbers for all UNC-CH, Duke, and NCSU handlers of hazardous waste.

University of North Carolina at Chapel Hill

EPA has divided the UNC-CH campus into five hazardous waste zones, plus the University's Hazardous Material Facility (HMF) and the Chapel Hill Youth Detention and Release Unit (CHYDARU). HMF is a permitted TSDF which treats, stores, and prepares hazardous waste for transport before it is incinerated or sent to a secure landfill. CHYDARU is a SQG and an interim status treatment, storage, and disposal facility. CHYDARU stores all mixed waste (low level radioactive mixed with hazardous waste) for at least ten half lives to allow low level radioactive isotopes ($\leq$ 165 days) to decay. Once the isotopes decay, the waste is treated as hazardous waste and not mixed waste. Most of the mixed waste managed at CHYDARU is toluene or xylene containing radioactive isotopes. After the decay period, the waste is transported to the HMF and disposed of as hazardous waste. CHYDARU is also a RCRA transporter of hazardous waste. The hazardous waste zones and facilities on the UNC-CH campus are:

Zone 1	EPA ID# NCD 982 114 985 Small Quantity Generator Buildings: FLOB, Lineberger
Zone 2	EPA ID# NCD 982 114 860 Small Quantity Generator Buildings: School of Pharmacy: Beard
Zone 3	EPA ID# NCD 982 114 982 Small Quantity Generator Buildings: School of Medicine: Berryhill, Brinkhous-Bullitt, MacNider, Medical Sciences Research Building, Old Clinic Building (Histology)
Zone 4	EPA ID# NCD 980 515 308 Large Quantity Generator Buildings: Chemistry Department: Kenan, Morehead, and Venable

Zone 5 Conditionally Exempt Small Quantity Generator
Any building not listed in Zones 1 - 4
Buildings: Baity, Brauer, McGavran-Greenberg, Peabody, Phillips, Rosenau, Sitterson, UNC Hospital (NCMH), etc.

HMF EPA ID# NCD 982 093 783
Treatment, Storage, and Disposal Facility
HSWA Permit No. NCD 982 093 783
Building: UNC-CH Hazardous Material Facility

CHYDARU EPA ID# NCD 003 203 213
Interim Status Small Quantity Generator and Interim Status Treatment, Storage, and Disposal Facility
Building: CHYDARU

The UNC-CH HMF applied for a RCRA Part A and Part B permit on August 22, 1989 and the Part B permit became effective on June 25, 1990 and expires June 25, 2000. CHYDARU is an interim status mixed waste facility whose RCRA permit was due to expire on May 28, 1992. CHYDARU was not able to close down as planned, so EPA granted an 180 day extension period. CHYDARU no longer handles low level radioactive mixed waste, only low-level radioactive waste.

Duke University

EPA divided the Duke University campus into five zones. The main campus and the University Medical Center (hospital) are in one zone. During 1990 - 1992, Duke had a small quantity generator in Beafort, NC but this site was closed in 1992. Duke also has three CESQG's satellite facilities which generate minute quantities of hazardous waste. The hazardous waste generated at the SQG and CESQGs sites is picked up by the University contractor. These sites are each in different zones. The waste from Duke's main campus and medical center is transported to one of two storage buildings behind the Occupational and Environmental Safety Office (3,500 square feet)

or the Gross Chemistry building (1,000 square feet). Two new buildings (500 square feet each) are going to be used as temporary storage site within the next 18 months. Zones for Duke University are:

Zone	EPA ID# NCD 000 813 519 Large Quantity Generator Location: Main Campus and Medical Center
Zone	Small Quantity Generator (1990 & 1991) Location: Marine Lab; Beaufort, NC
Zone	Conditionally Exempt Small Quantity Generator Location: Duke Farm; Guess Rd.
Zone	Conditionally Exempt Small Quantity Generator Location: Clinical Labs I; University Park
Zone	Conditionally Exempt Small Quantity Generator Location: Clinical Labs II; University Park

North Carolina State University

EPA has divided NCSU into two generating zones and 11 conditionally exempt zones; however, NCSU has obtained an EPA identification number for each of these CESQG's because these sites may generate more hazardous waste than is allowed for a CESQG. The main university campus is the primary zone. The veterinary school which is located away from the campus is considered a separate zone and is the second largest zone generating hazardous waste. The waste from both of these zones is transported, by a contractor, to the University's interim status treatment and storage facility. NCSU received a RCRA TSDF permit in July 1993. Hazardous waste is packaged at the storage facility and is then transported to an incinerator or secure landfill by the contractor. The EPA identification number for the main campus (LQG) also covers the permitted TSD facility and transporter status. Zones for NCSU are:

Zone — EPA ID# NCD 000 830 737
Large Quantity Generator
Location: Main Campus

Zone — EPA ID# NCD 982 156 614
Small Quantity Generator
Location: Veterinary School

Zone — EPA ID# NCD 986 228 328
Conditionally Exempt Small Quantity Generator
Location: Centennial Campus

Zone — EPA ID# NCD 986 228 344
Conditionally Exempt Small Quantity Generator
Location: Method Road Greenhouses

Zone — EPA ID# NCD 982 166 225
Conditionally Exempt Small Quantity Generator
Location: Pesticide Residual Lab

Zone — EPA ID# NCD 986 228 369
Conditionally Exempt Small Quantity Generator
Location: Pylon Research Labs

Zone — EPA ID# NCD 986 228 302
Conditionally Exempt Small Quantity Generator
Location: * Research Unit 1A

Zone — EPA ID# NCD 986 228 377
Conditionally Exempt Small Quantity Generator
Location: Research Unit 1B

Zone — EPA ID# NCD 986 228 294
Conditionally Exempt Small Quantity Generator
Location: Research Unit 1C

Zone — EPA ID# NCD 986 228 385
Conditionally Exempt Small Quantity Generator
Location: Research Unit 2A

Zone — EPA ID# NCD 986 228 310
Conditionally Exempt Small Quantity Generator
Location: Research Unit 2B

Zone EPA ID# NCD 986 228 369
Conditionally Exempt Small Quantity Generator
Location: Research Unit 4

Zone EPA ID# NCD 986 228 336
Conditionally Exempt Small Quantity Generator
Location: Turf Grass Research

* Research Unit 1A normally does not generate hazardous wastes. However, 8 ounces of unused P-listed pesticide was accidently added to a 55 gallon drum of non-regulated rinsates, resulting in the site becoming a LQG in 1992.

Sources of Hazardous Waste Information

Determining which individuals are responsible for the sites where hazardous waste is generated at these educational institutions is difficult. There was limited information on the PIs, the PIs department and how much waste was generated. UNC-CH's HSO Form 501 lists the PIs name and the type of hazardous waste generated; however, Duke and NCSU did not have current information on who the PIs were or the department from which waste was collected. UNC-CH had the best data for the three years analyzed; however, none of the universities were able to differentiate whether researchers, teaching facilities or the university medical activities contributed to the waste generated.

UNC-CH has data on specific waste generation sites. The HSO (Health and Safety Office) Form 501 is used to document the shipment of hazardous waste. This data source is very useful in obtaining information on chemical waste generation. Because the PI's name is required on HSO Form 501, the PI's department was acquired through the University's campus telephone directories and the Health and Safety Office's PI files. The following information is also available on this form: (1) the zone in which the waste was picked up, (2) the EPA hazardous waste code(s), (3) the date the waste was logged, and (4) the amount of waste in kilograms. The University also has a computer

database which is constructed from the information on these forms.

Two survey forms were sent to the business managers of the 55 departments at UNC-CH who generate hazardous waste. The first survey solicited information on the total number of PIs and laboratory personnel working for the PIs in their department and the total number of PIs and his/her laboratory personnel who generated hazardous waste in their laboratory. Most of the business managers responded that the information on laboratory personnel would not be accurate because of the transient nature of such laboratory personnel or that information was not attainable. Therefore, a second survey form was sent to business managers to determine just the number of PIs in each department and the number of PIs who generated hazardous waste. There were only 35 responses to the surveys, thus it was not possible to estimate the number of individuals who might be exposed to hazardous waste on the job.

Duke University and NCSU did not have data identifying PIs in laboratories where hazardous waste is generated. Duke has a database which lists the buildings and rooms from which hazardous waste was collected, but it does not list the PI's name or department in which the waste was generated. Identifying the PIs and the department at Duke University where the waste was generated was not possible.

NCSU records only reveal whether the hazardous waste was generated on the main campus or the Veterinary School. Prior to May 1992 when a database was initiated at NCSU, there was no information on where hazardous waste was picked up. This database now contains the department, the PI, the building and room number and other information pertaining to waste pickups. Information is still not available on the PI, the PI's department and what type and how much hazardous waste was generated.

Statistical Analysis

Hazardous waste information from these universities was collected from

many different documents. At UNC-CH, hazardous waste data was gathered from the Health and Safety Office's form 501. Hazardous waste information was obtained from the annual RCRA hazardous waste reports at Duke and NCSU. At UNC-CH, when the Health and Safety Office receives the generator's manifest (HSO Form 510), the information is entered into a database. The following information was obtained from HSO Form 501: (1) the zone from which the waste was picked up, (2) date the EPA hazardous waste code was logged on the manifest prior to shipment or treatment, (3) EPA waste code(s), (4) department in which the waste was picked-up, and (5) total waste generated in kilograms. For 1991 and 1992, information on the total amount of waste shipped off-site in kilograms and the total waste which was treated, disposed, or recycled was obtained from UNC-CH's 1991 and 1992 hazardous waste annual report.

Frequently several different types of hazardous waste (different EPA waste codes) were placed in the same container by laboratory personnel. This practice increased during the years 1990 through 1992. In order to determine the principal-type of waste in the container, a percent was computed and this was applied to the other waste streams in the same container. This percentage was determined from the combined waste streams by taking the total number of combined waste codes (denoted by the union symbol $\cup$), dividing by the total sum of one single entry waste code and multiplying by 100. Once the percentage from the single waste code was calculated, the original combined waste codes were multiplied by the waste code percentage in order to estimate the amount of each waste in the container.

For Example:

1^{st} step $[\ (D001 \cup F003) \div D001\ ] \times 100 = \%\ D001$

2^{nd} step $[\ (D001 \cup F003) \times \%\ D001\ ] = \mathbf{D001}$

3^{rd} step $(D001 \cup F003) - \mathbf{D001} = \mathbf{F003}$

The bold **D001** and **F003** denotes the estimated values based upon the original combined wastes (D001 $\cup$ F003) from the sum of the single D001 listed waste streams.

The data from Duke and NCSU was obtained from their 1990, 1991, and 1992 annual reports. The reports were acquired from each University and also from the State of North Carolina's Department of Environmental, Health, and Natural Resources, Division of Solid Waste Management's Hazardous Waste Section. The 1990 annual hazardous waste report's from Duke and NCSU were in a different format than the 1991 and 1992 reports. The following information was obtained from these annual reports: (1) general area where the waste was picked up (1990 only), (2) total waste generated in kilograms, (3) total waste which was shipped off-site in kilograms, (4) total waste treated, disposed, or recycled (1991 and 1992 only), and (5) a description of each waste.

In addition to the annual reports, EPA forms IC, GM, WP, and PS were used to obtain information on hazardous waste generated at NCSU and Duke. Form IC is the identification and certification of the LQG or SQG which all sites must submit. Form GM is the waste generation and management which all sites must submit only if the site generated or shipped any quantity of RCRA listed hazardous waste. Form WR is the waste received from off-site only if the university received waste from off-site. Form PS is the on-site waste treatment, disposal, or recycling process system which must be completed if the university had a waste treatment, disposal, or recycling facility. These forms become an integral part of the annual report.

Tables *5.1, 5.2, 5.3* list the major hazardous waste streams generated at UNC-CH, Duke and NCSU during 1990, 1991, and 1992. A detailed listing by EPA's hazardous waste code number and their description is provided in *Appendix B*. *Appendix C* contains the total quantity of all RCRA listed hazardous waste generated by EPA waste code number for each year, 1990 - 1992.

Table 5.1 Major RCRA Hazardous Wastes Generated by Three Universities 1990 (kilograms)

Waste #	UNC-CH	Duke	NCSU
D001 Ignitable	7,997.9	38,882.8	9,446.7
D002 Corrosive	1,246.0	884.6	2,854.3
F002 Halogenated	1,613.0	1,499.1	2,852.3
F003 Non-Halogenated	12,753.1	12,753.1	14,384.3
F005 Non-Halo / Toxic	1,850.6	136.7	138.7
Total	**25,460.6**	**54,156.3**	**29,676.3**
Percent of Total Waste Generated	**94.3 %**	**96.2 %**	**91.9 %**

Table 5.2 Major RCRA Hazardous Wastes Generated by Three Universities 1991 (kilograms)

Waste #	UNC-CH	Duke	NCSU
D001 Ignitable	47,518.3	26,470.6	17,266.4
D002 Corrosive	1,008.5	3,206.8	734.0
F002 Halogenated	3,957.8	0.0	362.8
F003 Non-Halogenated	3,376.6	18,541.8	7,025.4
F005 Non-Halo / Toxic	2,723.1	0.0	3,254.1
Total	**28,584.3**	**48,219.2**	**28,642.7**
Percent of Total Waste Generated	**94.1 %**	**96.2 %**	**52.7 %**

Table 5.3 Major RCRA Hazardous Wastes Generated by Three Universities 1992 (kilograms)

Waste #	UNC-CH	Duke	NCSU
D001 Ignitable	20,846.1	17,830.0	11,059.7
D002 Corrosive	605.7	73.4	3,991.3
F002 Halogenated	4,972.7	17,756.6	1,186.2
F003 Non-Halogenated	842.0	0.0	4,319.7
F005 Non-Halo / Toxic	3,033.9	0.0	0.0
Total	**30,300.4**	**35,660.0**	**20,556.9**
Percent of Total Waste Generated	**95.1 %**	**83.5 %**	**42.3 %**

Note that, in the three years examined, five types (waste codes) of hazardous waste account for more than ninety-four percent (94 %) of all hazardous waste generated at the University of North Carolina at Chapel Hill. This consistency is not seen at Duke and North Carolina State University. More RCRA waste is generated annually at Duke than at the other two universities. The reason for this is not clear since UNC-CH and NCSU enroll twice the number of students as Duke which should result in many more basic science laboratory sections at these universities. The large medical complex at Duke may account for this disparity. While ignitable waste, code D001, usually constitutes the largest waste stream generated on each campus each year, other types of hazardous waste often vary significantly from year to year even on the same campus.

The amount and types of hazardous waste generated by each department on the UNC-CH campus were analyzed (*see Appendix D*). The results of this analysis is shown in *Table 5.4*.

Table 5.4 Types and Amounts of RCRA Wastes Generated by Selected Academic Departments on the UNC-CH Campus, 1990 -1992 (kilograms)

UNC-CH Department	Waste Code Number	1990	1991	1992
CHEMISTRY	D001	1,285.5	4,823.7	4,895.2
	D002	462.2	433.1	173.0
	F002	1,338.6	2,233.3	1,803.7
	F003	6,172.2	1,107.1	306.8
	F005	281.3	685.0	1,090.7
	Total	**9,539.8**	**9,282.2**	**8,269.4**
HISTOLOGY	D001	2,890.0	3,697.4	3,877.0
	D002	1.0	6.4	0.5
	F002	0.0	0.0	0.0
	F003	1,602.6	401.3	23.0
	F005	698.2	1,118.7	1,407.0
	Total	**5,191.8**	**5,223.8**	**5,307.5**
SCHOOL OF PHARMACY	D001	431.3	1,473.5	1,651.8
	D002	72.4	16.9	21.9
	F002	35.6	1,061.0	2,167.2
	F003	1,778.1	902.0	102.6
	F005	151.0	202.6	180.7
	Total	**2,468.4**	**3,657.0**	**4,124.2**
MICROBIOLOGY & IMMUNOLOGY	D001	483.8	1,054.8	1,483.1
	D002	39.1	50.1	31.1
	F002	129.0	396.0	266.0
	F003	329.3	142.5	21.5
	F005	123.3	120.5	63.7
	Total	**1,104.5**	**1,763.9**	**1,865.4**

The three departments and one school on the UNC-CH campus which

generated the largest amounts of hazardous waste were the Chemistry, Histology, Microbiology and Immunology departments and the School of Pharmacy. While ignitable waste (D001) is generally the waste stream most frequently generated in each of these departments, the amounts of individual wastes do vary from year to year in the same department. There was a 13% overall decrease in the generation of these five types of hazardous waste in the Chemistry department over the three year period but the amount increased in the other two departments and the Pharmacy school, 55% in the School of Pharmacy and 68% in the Department of Microbiology and Immunology. The School of Pharmacy's chemical waste increased 55% from 1990 to 1992 due to a chemical storage room clean out which had accumulated chemicals for over 25 years. It is not known whether the increase in Microbiology and Immunology are real or are due to better management and reporting.

The total quantity of hazardous waste generated annually on-site at UNC-CH, Duke and NCSU is listed in *Table 5.5*. The hazardous wastes, by waste codes, that were generated during 1990, 1991 and 1992 were D, F, P, and U listed wastes. There were no K listed wastes streams generated during the three years the universities were examined.

Table 5.5 Total Quantity of Hazardous Waste Generated On-Site by the Three Universities, 1990 - 1992 (kilograms)

RCRA Waste	UNC-CH	Duke	NCSU
1990	26,998	56,273	32,290 *
1991	30,358	50,145	54,301 *
1992	31,877	42,701	48,544
Mean	**29,744**	**49,706**	**45,045**
Total three year period	**89,260**	**150,131**	**135,135**

* Only the chemical waste was weighed and not the secondary container or the packaging material.

The total amounts of hazardous waste generated and the amounts shipped off-site for treatment or disposal can vary considerably each year. At the years end, hazardous waste can also be carried over to the next year for shipment. The data shown in *Table 5.6* covers only 1991 and 1992 , this information was not available for 1990. The total quantity of waste shipped off-site may be more (carried over) or less (in storage) than the total quantity of waste generated on-site.

Table 5.6 Total Quantity of Hazardous Waste Shipped Off-site by the Three Universities, 1991 - 1992 * (kilograms)

RCRA Waste	UNC-CH	Duke	NCSU
1991	101,755	47,457	51,062
1992	26,721	41,797	49,551
Total	**128,476**	**89,254**	**100,613**

* Shipped for treatment or disposal.

UNC-CH closed down CHYDARU during 1991 and there were large quantities of scintillation vials which needed to be disposed. The crushed scintillation vials were transported from CHYDARU to HMF and were shipped off-site for disposal. This accounts for the large amount of hazardous waste shipped off-site from the UNC-CH campus in 1991.

Each university has implemented a waste treatment, disposal, or recycling system(s) and this information was recorded on Form PS of the annual report. These data, shown in *Table 5.7* were obtained from the 1991 and 1992 annual hazardous waste reports.

Table 5.7 Amount of Hazardous Waste Treated, Disposed of, or Recycled On-site by the Three Universities, 1991 - 1992 (kilograms)

RCRA Waste	UNC-CH	Duke	NCSU
1991	2,731	2,821	2,001
1992	327	908	3,190
Total	**3,058**	**3,729**	**5,191**

Assignment of EPA Waste Codes

Documenting the amount of RCRA listed hazardous wastes generated at these universities is consistent, but determining the amount of waste in a specific RCRA waste code is virtually impossible. The difficulty in assigning a wastestream to a hazardous waste code results from changes in research projects. Experimental procedures may change due to better means of waste management or the PI may replace a particularly dangerous chemical with a less hazardous chemical. These changes may either eliminate a RCRA waste stream or produce a wastestream which is cheaper to dispose.

Cost Analysis

Costs are always an important factor in operating a hazardous waste management program. Hazardous waste programs are not profitable for companies or universities, yet a vast amount of money is required to operate them. Budgeting funds for a reliable contractor is worth while because of liability considerations. The costs to operate a hazardous waste management program depends upon how much waste is generated, the number of hazardous waste workers, and the fees for the contractors. The costs of operating a university hazardous waste program is shown in *Table 5.8*.

Table 5.8 Approximate 1992 Operating Costs to Manage Hazardous Waste at the Three Universities

Costs	UNC-CH	DUKE	NCSU
Office Labor	160,000 / 5	60,000 / 2	65,000 / 2.5
Contractor Labor	NONE	60,000 / 2	153,800 / 2-3
Non-Halogenated	1.84 / gal	5.70 / gal	4.00 / gal
Halogenated	2.00 / gal	15.35 / gal	10.00 / gal
Labpack	Varies	37.00 / gal	Varies
Disposal Cost	54,526	130,000	437,800
Training	500 / person	1,000 / person	1,000 / person
Total Cost	175,000	250,000	658,600

The operating costs in U.S currency are approximate values for 1992.

The UNC-CH operating costs for hazardous waste management are separated into seven categories. Office labor accounts for five hazardous waste employees with a $160,000 budget, but actual costs were about $120,000 due to vacancies. There is no contractor labor at UNC-CH since the Hazardous Material Technician picks-up and packs the hazardous waste; however, some vendors charge on-site labor fees as part of their pricing or a fixed rate for certain waste streams. The disposal cost accounts for the disposal of non-halogenated, halogenated, and labpacking RCRA listed hazardous waste. The budget for waste disposal was $54,526 for 1992. Non-halogenated waste disposal costs are $1.84 per gallon which does not include labor costs, only includes disposal fees. Non-halogenated waste usually costs $1.00 per gallon including occasional surcharges. The costs of disposing of halogenated waste depends upon the BTU content and how the waste is packed into each drum. Halogenated wastes costs were $2.00 per gallon in 1992 and are now $4.00 per gallon. Halogenated waste can be inexpensive

or costly depending upon certain factors. The higher the BTU value of the waste, the cheaper it is to dispose of, if the waste contains < 2% chlorine and a low percentage of water, it is more attractive to TSDFs. Packing hazardous waste streams into labpacks can vary and this will affect the cost of disposal. Ensco charged the University $1.60 per pound, while Rollins charged $285.00 per 30 gallons, plus $1,000 lower threshold limit and on-site labor during 1992. The disposal costs are low due to bulking chromerge, inorganic liquid mercury compounds, mercury contaminated glass and chromatography wastes. Bulking these wastes has reduced the costs compared to labpacking costs. The university spends approximately $500 per person for training. Total costs consists of labor, RCRA listed waste disposal costs, training, facility equipment, and depreciation.

Duke University's operating costs are based upon this same type of cost structure. The office and contractor labor is the cost per unit of disposal, labor, and overhead. The $60,000 office and contractor's labor covers two employees who work at Duke and two employees who work for the contractor. Information on the managers labor costs was not available from Duke. Disposal costs cover the disposal of non-halogenated, halogenated, and labpacking RCRA listed hazardous waste. Bulked non-halogenated and halogenated wastes are placed inside 55 gallon drums. Bulked non-halogenated solvent waste is often used as a fuel substitute. Bulked halogenated solvent waste has a low BTU factor and the costs are three times that of non-halogenated wastes. Most lab packs are transported to the hazardous waste landfill for disposal. Annual training of hazardous waste personnel costs an average of $1,000 per employee. The total costs consists of labor, RCRA listed waste disposal costs, training, facility equipment, and depreciation.

NCSU's operating costs are based on $65,000 for office labor of two and a half annual person hours. The contractor's labor is $153,000 for two or three employees. The disposal cost includes the disposal of non-halogenated, halogenated, and packing RCRA listed hazardous waste into labpacks. The

cost of disposing of non-halogenated waste is $4.00 per gallon which includes shipping, handling, and the cost of the drum. Disposal of halogenated waste is averages $10.00 per gallon. Like UNC-CH, the cost of packaging hazardous waste varies too much to give an exact figure. The costs of packaging laboratory chemicals depends on how much waste is being packed, the size of the waste container, and what type of waste is being placed in the waste container. Annual training at NCSU is also $1,000 per person. The NCSU total costs consists of labor, RCRA listed waste disposal costs, training, facility equipment, and depreciation.

VI. HAZARDOUS WASTE MANAGEMENT PROGRAMS

Management Practices

University campuses must manage their chemical wastes streams in accordance with federal laws and internal university policies. Each university is unique in the way they manage hazardous waste. The structure of a waste management program depends which direction the university takes in waste collection, segregation, minimization, disposal and the role of contractors.

UNC-CH, Duke and NCSU hazardous waste sections review regulations, implement waste minimization practices and respond to chemical emergencies. OSHA requires that material safety data sheets (MSDSs) be made available for personnel who handle chemicals on campus. MSDSs provide general information on product identification, chemical components, physical, fire and explosion data, health hazards, reactivity data, spill and leak procedures, chemical safety, how to handle and properly store chemicals, and the use of personal protective equipment (PPE). All Personnel handling or coming into contact with chemicals must be trained.

Communication and Training Requirements

Communication, education and training are keys to successful hazardous waste management. UNC-CH, Duke and NCSU all have training programs for hazardous waste personnel. All hazardous material personnel must receive a 40 hour emergency response course on hazardous material incidents which meets OSHA's 29 CFR 1910.120(q) training requirements for hazardous material technicians. The 40 hour hazardous waste site worker course meets OSHA's 29 CFR 1910.120 training requirements for hazardous waste operations and emergency response. Either a 24 hour or 8 hour refresher course is required annually for hazardous waste site workers at TSDFs. Either

of these courses will fulfill OSHA's 29 CFR 1910.120. Training hazardous waste site workers to wear Self-Contained Breathing Apparatus (SCBAs) is required for individuals who may work in IDLH (immediately dangerous to life or health) conditions during an emergency response.

UNC-CH and Duke communicate the proper handling of hazardous waste through written policies, newsletters, or through meetings with hazardous waste personnel. UNC-CH has monthly training sessions for new employees on the laboratory environment, waste management, OSHA Laboratory Standard and the Bloodborne Pathogen Standard. The hazardous and chemical waste managers, chemists, technicians, and specialists all respond and answer questions from the university community concerning the management and handling of hazardous waste.

NCSU educates, communicates and trains University and laboratory personnel somewhat differently from UNC-CH or Duke. The department chair or PI provide all waste management training. PIs and generators are responsible for training employees in using and handling hazardous materials and equipment in the work environment. The Environmental Health and Safety Center provides a training manual for departmental chairs and PIs covering the management of hazardous materials and wastes, but there is no formal training available for PIs or generators. The Environmental Health and Safety Center does train its own hazardous waste employees in the use of PPE, the understanding of the Hazard Communication Standard and their job requirements concerning emergency response procedures. The contractors at NCSU are required to train their personnel in 29 CFR 1910.120 and corporate policies. The Environmental Health and Safety Center trains the contractors in the University's facility safety plan, contingency plan, and policies and procedures.

Manifests and Record Keeping

Each University also has its own system for collecting information which can be used for reports, program evaluation, and regulatory requirements.

Universities, like any other hazardous waste generator, must properly manifest any waste shipped off-site, record internal inspections, and prepare biennial reports (annual in North Carolina). Annual hazardous waste reports are required by North Carolina. The format for these reports was standardized in 1991. Universities whose status is LQG or SQG are required to complete an annual report by the end of March for waste generated during the preceding year.

UNC-CH uses the Health and Safety Office Form 510 to track hazardous waste from the point of generation to the point of segregation. This manifest lists each waste, by percent or by volume, being disposed of in each container. The original of HSO Form 510 is mailed by the PI or supervisor to the Health and Safety Office to request pick-up, and the information from this form is logged into a database file for future reference. A Hazardous Waste Chemist transfers the RCRA waste number(s) from form 510 to HSO Form 501 before the waste is either recycled or shipped off-site. HSO Form 501 denotes the zone from which the waste was collected, types and amounts of hazardous wastes, the generator, and the off-site shipping date.

Duke's recordkeeping procedures are very similar to that of UNC-CH. The Chemical Waste Manager maintains manifests and records for all hazardous waste generated from pick-up to disposal at a TSDF. The Occupational and Environmental Safety Offices' chemical pick up card is used as a manifest to track hazardous waste. Each label on each waste container must document each waste by volume being disposed of in that container. The pick-up card is sent to the Occupational and Environmental Safety Office for scheduling pick-up. Duke also uses a computer system to schedule waste collection, or generator employees can telephone the Occupational and Environmental Safety Office to establish a time for waste pick-up. Duke logs all information into a database for future reference. The database contains detailed information on who generated the waste, where the waste was generated, when the waste was collected, how much waste was generated, and other information which Duke deems important.

NCSU's Hazardous Materials Manager keeps track of hazardous waste shipments to and from the primary waste facility. A clerk follows each waste container from the point of generation to the facility and to its final destination. The Environmental Health and Safety Center does not have a specific form for documenting waste collections. A running log of each material listed on the waste container is usually written down by the generator's laboratory personnel. Regardless, the contractor must report and record all waste activities, inspection logs, waste receipts, inventory reports, treatment records, discrepancies, spills, and manifests to the Hazardous Materials Manager daily. NCSU implemented a detailed database covering individual waste containers during May 1992. The information available in the database includes the generator's name, location and department, waste type and quantity, and management and disposal facility.

Waste Minimization

Minimizing the generation of hazardous waste, while required by regulation, is an accepted practice in most programs. A PI cannot treat hazardous waste without a permit unless the treatment is the last step in the written laboratory procedure. All other hazardous wastes must be picked up for off-site disposal. Source reduction and recycling are two fundamental methods for decreasing the volume of hazardous waste. Source reduction is the elimination or reduction of waste at the source or point of generation. Methods of source reduction include process modification, material substitutions, product modifications, improved operating practices or housekeeping, inventory control, spill prevention, and recycling within a process.[3] Recycling a material before it becomes a hazardous waste is also a useful alternative. Neutralization or other means to render waste non-hazardous is encouraged as the final stage in the PI's experimental protocol. Researchers are encouraged to practice waste minimization, such as neutralization. However, a generator is not allowed to treat hazardous waste without a permit. Treatment of

hazardous waste can be done only by a permitted TSDF.

There are several criteria used by the universities in deciding whether a particular waste minimization process is feasible. The primary concern is cost. Cost is a vital concern for any hazardous waste program since the generation of hazardous waste is not a beneficial or profitable endeavor. Source reduction or recycling waste is an integral part of any hazardous waste program. The university must determine if a waste minimization process is practical, and as cost effective as shipping waste off-site. UNC-CH and Duke University have cost effective waste minimization programs, however, NCSU, at this time, does not have a cost effective waste minimization plan. *Figure 6.1* indicates a hierarchy for managing hazardous wastes.

Figure 6.1 Hierarchy of Hazardous Waste Alternatives

UNC-CH's waste minimization program plays a significant role in reducing hazardous waste streams. Based on UNC-CH's 1991 Hazardous Waste Report, they treated, disposed, and recycled some hazardous waste on-site while meeting RCRA requirements. They are not considered RCRA-exempt for the treatment, disposal, or recycling of hazardous waste. The Health and Safety Office advises PI's to encourage their employees to reduce the amount of hazardous waste generated. University generators are urged to recycle, reuse,

or reclaim unused chemicals before the material is discarded as hazardous waste. This final step in all research experiments should be either decontamination, detoxification, neutralization, or rendering the waste non-hazardous. PIs and laboratory employees are encouraged to suggest ways to reduce, recycle, decontaminate or redesign experiments to reduce chemical waste streams.

Duke University's waste minimization program is similar to that at UNC-CH. Waste is first segregated by hazard class and then by treatment or disposal alternatives. Duke does not have an on-site RCRA-permitted treatment, disposal, or recycling facility, therefore Duke is exempt from RCRA permitting requirements for treating, disposing, and recycling hazardous waste according to their 1991 Hazardous Waste Report. Duke's goals in waste minimization are to reduce costs and avoid long term liability.

On-site recycling of chemicals is available for researchers on the Duke campus who are not fastidious about utilizing old or partially used chemicals from other laboratory facilities. Approximately 1,500 gallons of xylene and acetone are distilled and recycled and nearly 700 pounds of acids and bases are neutralized annually. Duke uses a closed automated system to neutralize acids and bases. An ice bath is used to decrease exothermic reactions. Another option for managing hazardous waste is to use spent non-halogenated solvents as a substitute for fossil fuel in incinerators.

Laboratory personnel at Duke are encouraged to implement waste minimization and recycling when feasible. Departments are encouraged to operate a recycling program for PI's unused chemicals. A campus newsletter is published frequently for the University community which lists unused chemicals for recycling by other laboratory facilities. PI's are encouraged to buy only the quantities they need for their work. PIs are also encouraged to treat their chemical wastes as an integral part of their laboratory experiment procedures. Frequent communication between the Occupational and Environmental Safety Office and the laboratory community is necessary for the effective minimization of chemical waste streams. PIs at Duke are held

responsible for removing chemicals from their laboratory if they leave the University. If the PI leaves without cleaning out his laboratory facility, then the department is charged a fee by the Occupational and Environmental Safety Office for the removal of the chemicals.

NCSU's waste minimization program is a joint effort between the generators and contractors. They are not considered RCRA-exempt for the treatment, disposal, or recycling of hazardous waste. Waste reduction is the responsibility of the PI with the aid of the Environmental Health and Safety Center. There does not appear to be any recycling by PIs on this campus. These universities recycle mercury and use solvents as a fuel substitute. Neutralization of acids and bases is not done on this campus at the present time. All laboratory personnel are urged to practice source reduction or neutralization as the final step of their laboratory research.

VII. MEETING WASTE MANAGEMENT GOALS

The initial step in establishing a hazardous waste management program at a university is determining how much hazardous waste is generated and how the waste will be managed. Once the quantity of waste is known, EPA must be notified either of their status as either a Large Quantity Generator, Small Quantity Generator, or Conditionally Exempt Small Quantity Generator. The Environmental Protection Agency assigns the university an EPA ID number(s) if their generator status is either a LQG, SQG, or a combination. Once the university has been assigned an EPA ID number, they must abide by federal or state regulations, as long as the state's provisions are at least as stringent as the federal regulations in managing hazardous waste from cradle-to-grave.

Administrative Infrastructure

Planning a hazardous waste program depends upon the needs and constraints of the university. Therefore, the organizational structure of the responsible unit may differ in one or more ways. Hazardous waste management employees may perform different tasks depending on their job descriptions. The hazardous waste manager must have thorough knowledge of RCRA, and DOT regulations; be familiar with waste minimization techniques; and understand treatment, storage, and disposal options. Personnel responsible for picking up and handling hazardous waste must have some knowledge of chemistry and be properly trained in emergency response and the use of personal protective equipment. There are different levels of training required for emergency response depending on each employee's job function. Every employee in the hazardous waste unit must have thorough knowledge of the hazardous waste management program and RCRA.

Universities may have different requirements for selecting contractors to operate their hazardous waste program. For instance, UNC-CH uses a contractor only to transport its waste from the TSDF to an incinerator or landfill. Duke uses a contractor to pack specific wastes and transport the waste to a TSDF. NCSU uses a full service contractor to manage all its waste, including pickup, treatment and disposal.

In selecting a contractor, universities , as well as all other generators of hazardous waste, are concerned about liability, performance and cost in that order. If program funding is inadequate, this may expose the university to increased liability and decreased performance. The two state institutions, UNC-CH and NCSU, use similar procedures for selecting a contractor to handle their hazardous waste, however, Duke University's three-phase evaluation process appears to be a more dependable system for selecting a contractor (*see chapter IV, p. 20, Contractors*). Each university can be held accountable if the hazardous waste is mismanaged by the contractor, transporter, or the TSDF during treatment, storage, or disposal.

Hazardous waste management operating procedures are similar in each of the three universities. Hazardous waste is typically generated in a PI's laboratory, either by the PI or his/her laboratory employees. This waste is usually placed in a four liter bottle. A running log is maintained of each waste stream being place in the collection bottle. Once the waste bottle is full, a hazardous material transfer form is completed and signed by the PI or supervisor. NCSU requires each generator to keep a log of each waste being disposed of in the collection bottle. No special form is provided. UNC-CH uses a hazardous material transfer form, HSO Form 510, which is legible and easily understood because it lists the most common RCRA waste codes and the chemical name for each waste code. If the RCRA waste code is not listed, the information required on the form includes the name of the PI, telephone number, building and room number where the waste was picked up, the container size and weight of the contents in kilograms. Duke University's

tracking system may be used by all three universities in the future. They use a computer network system which allows the PI or supervisor to fill out a manifest on a computer screen which is then transferred electronically to the appropriate university unit; however, they still require that the waste container be labeled before pickup.

Manifests, reports and records are critical for the safe management of hazardous wastes at any level of operation. These forms and documents enable the generator to track his waste from the point of generation to the TSDF. Records of waste analysis, biennial reports, exception reports and annual reports must be retained in case of a problem with any waste stream. Prior to 1991 there was no uniform format in NC for hazardous waste annual reports. It was not until 1991 that a uniform hazardous waste annual report form was approved for use by generators. RCRA regulations require that all hazardous waste documents be retained for three years.

Generation of RCRA Listed Hazardous Waste

The typical generators of RCRA listed hazardous waste at universities are research laboratories. Occasionally there are supervisors in a non-laboratory facility that also generate hazardous waste. PIs and supervisors are responsible for the generation of RCRA listed hazardous waste in their work environment.

RCRA listed hazardous waste streams at these universities were relatively consistent year after year, but waste volumes varied from absolutely no waste generated to approximately 40,000 kilograms. The consistency at UNC-CH was partially due to detailed information acquired from HSO Form 501 and not UNC-CH's annual reports. However, there were problems in collecting complete information from Duke and NCSU since they changed their annual report forms in 1991. Another problem in gathering information on specific RCRA waste codes from Duke's and NCSU's annual reports was that sometimes more than one waste was listed on Form GM, Waste Generation and Management. Form GM may have only one or as many as 32 waste codes in

Duke's and NCSU's annual reports; therefore, only the two waste codes with the highest waste volumes were identified from their annual reports.

Information on waste treatment, disposal, and recycling was obtained from Form PS during 1991 and 1992. This information was not available in the 1990 annual reports. UNC-CH used the following waste management techniques during 1991 and 1992: Neutralization of mineral acid solutions, cyanide destruction, neutralization of reactive waste, and vial crushing and/or bulking for volume reduction. Duke University practiced the following waste management techniques during 1991 and 1992: solvent recovery, distillation of xylene and acetone, and simple neutralization of acids and bases. NCSU practiced the following waste management techniques during 1991 and 1992: fuel blending (D001, F003), consolidation of non-fuel solvents and aqueous wastes, degradation of iodoxybenzene, and consolidation of liquid wastes (photographic chemicals).

Universities which generate RCRA listed hazardous wastes require a substantial budget to operate their hazardous waste management program. The size of this budget will depend on the university's approach to hazardous waste management and the volume of waste generated. Labor costs, including the use of a contractor, are a significant component in all of these programs. Contractor labor can vary from $30,000 to a several hundred thousand dollars depending on how many contractor employees are needed. It is usually more economical not to use a contractor to manage university generated waste; however, this may significantly increase the university's cost for liability coverage. Safe management of hazardous wastes relies on good communication and adequate supervision in the handling, packaging and storage of chemicals wastes, as well as record keeping and waste reduction strategies. Institutions must provide sufficient funding to staff and support their hazardous waste management programs.

Treating, storing and disposing of waste is also a significant expense. Non-halogenated chemicals are relatively cheap to dispose because they can

often be used as a fuel. Halogenated chemicals are more expensive to discard because of their toxicity and low BTU value. This requires that non-halogenated and halogenated wastes be bulked according to their BTU content. Lab packing small containers of hazardous waste in 55 gallon drums is usually the most expensive method for disposing of hazardous wastes. A decision guide should be prepared and followed for lab packing and segregating chemicals into appropriate compatibility categories.

Training of employees is also expensive. Training typically costs from 500 to 1,000 dollars per year; however, this may vary from a few hundred dollars or as much as $1,000. External contractors will charge even more for this service. Budgeting for university hazardous waste management programs is not easy. This is principally due to: (1) the large number of small volume wastestreams generated, (2) changes in the character of wastestreams from year to year and often monthly, and (3) increases in the unit price for small volumes of many wastestreams shipped off-site.

Operating a University Waste System

A single operating unit should be delegated the authority and responsibility for the university's hazardous waste management program. The manager or director of this program should have a thorough knowledge of the RCRA regulations, the Hazardous Material Transportation Uniform Safety Act and the requirements of 29 CFR 1910.1450, *Occupational Exposures to hazardous Chemicals in Laboratories*. Hazardous waste policies and procedures should be developed in cooperation with principal investigators, laboratory managers and the supervisors of other units generating hazardous waste on the university campus.

Continuous training is essential to an effective hazardous waste management program. All university personnel who handle or could be exposed to hazardous chemicals, including hazardous waste, should be provided with post employment and frequently scheduled training sessions

throughout their employment. New or revised hazardous waste and occupational safety and health regulations and university policies should be codified in a health and safety manual which is distributed to all appropriate university departments.

Accurate information covering all hazardous waste activities should be collected and maintained in a current data base. This data base should include information from generators, manifests and TSDFs required by EPA and OSHA regulations, state regulatory authorities and any other deemed necessary by the university.

An active hazardous waste minimization program should be promoted by the university hazardous waste management unit. This unit should continuously investigate innovative minimization technologies and communicate them to laboratory and other personnel who generate hazardous waste. The objectives of this program should be to protect human health and the environment, reduce both the volume and toxicity of hazardous waste generated and to reduce waste management costs. In addition to waste minimization, reducing the amount of hazardous waste produced, operating units must be encouraged to recycle chemicals whenever possible.

Each University must provide sufficient program funding to ensure that not only are federal and state regulations complied with but that the health and safety of all faculty, students and employees is protected.

VIII. CONCLUSION

The purpose in evaluating these three universities was to examine and pinpoint the most effective component(s) of each hazardous waste management program. Creating a unique hazardous waste management system for an individual university is dependent upon numerous factors. The volume of RCRA listed hazardous waste a university generates is a function of the types of research practiced and the presence or absence of a medical center. Costs and liability considerations will also shape program policies, operations and training functions. The university must decide whether it will take total responsibility for managing its hazardous waste including the operation of a TSDF or use a full time contractor to provide these services. These factors need to be considered in planning a hazardous waste management program.

All three universities generate similar types of hazardous wastes. The volumes of the wastes vary, but the types of wastes are relatively consistent. Even though there are a variety of listed discarded commercial chemical wastes (P waste) and other commercial chemical products (U waste) generated at each university, only a small amount of these two wastes codes are generated. UNC-CH, Duke, and NCSU generate large volumes of similar RCRA regulated hazardous wastes.

Recommendations

A model hazardous waste management program would consist of several components. All chemicals ordered for the university by PIs and supervisors need to be tracked by keeping detailed records. The best system for keeping track of chemicals is through a computer network system. This type of data base can be used to track waste from cradle-to-grave and enable the university's waste management unit to ascertain how waste is actually being managed

by the PIs and supervisors. Based on this study, maintaining thorough and complete records needs to be improved on university campuses. Using uniform hazardous waste manifests and annual reports would reduce inaccuracies in record-keeping and in documenting hazardous waste activities at most colleges and universities. Hazardous waste management units on university campuses should compile and distribute pertinent information, on a monthly basis, to each department generating hazardous waste. This monthly summary might include information on the amounts and types of hazardous wastes generated by the department during the current month, previous month, same month last year, and a running total of hazardous waste generated year-to-date. This would provide a clear picture of their hazardous waste activities on a continual basis.

Training individuals in the handling of hazardous waste is an important element in waste management. In-service or in-house training of the hazardous waste management group should be provided on a continual basis. Opportunities should also be provided for all research personnel, laboratory managers, and student research assistants to participate in training sessions.

Hazardous waste managers on university campuses do not communicate with each other even though they share many of the same problems. These professionals should consider forming a national organization which could serve as a vehicle for sharing information, solutions to problems and communicating concerns to state and regulatory agencies.

Universities can decrease expenditures through an aggressive waste minimization program and on-site treatment if practical. The following practices should be used by universities in reducing hazardous waste costs: (1) source reduction, (2) recycling (metal recovery) unused chemicals, (3) waste treatment, (4) utilize microscale research experiments, (5) chemical substitution, (6) inventory of chemicals, (7) segregating halogenated and non-halogenated solvents, and (8) consolidating or bulking wastes in 55 gallon drums. Consolidating or bulking hazardous wastes can reduce off-site transport and treatment or disposal costs as much as 90%. Universities that practice on-site

treatment can reduce long term liability and often decrease disposal costs. Balancing long term liabilities and investments with short term costs should be a planning objective. The volume of waste, its toxicity and the types of wastes generated determine the liability and many of the costs of waste management.

Incineration rather than landfilling of hazardous waste reduces liability. Disposal in hazardous waste landfills extend the generator's liability, whereas incineration, if available, essentially eliminates liability. Wastes should only be shipped to fully permitted incineration facilities which have a history of few regulatory violations, good inspection and monitoring reports. Universities should consider incineration as a high treatment option.

Areas For Further Study

The information generated in this analysis suggests other areas for further study:

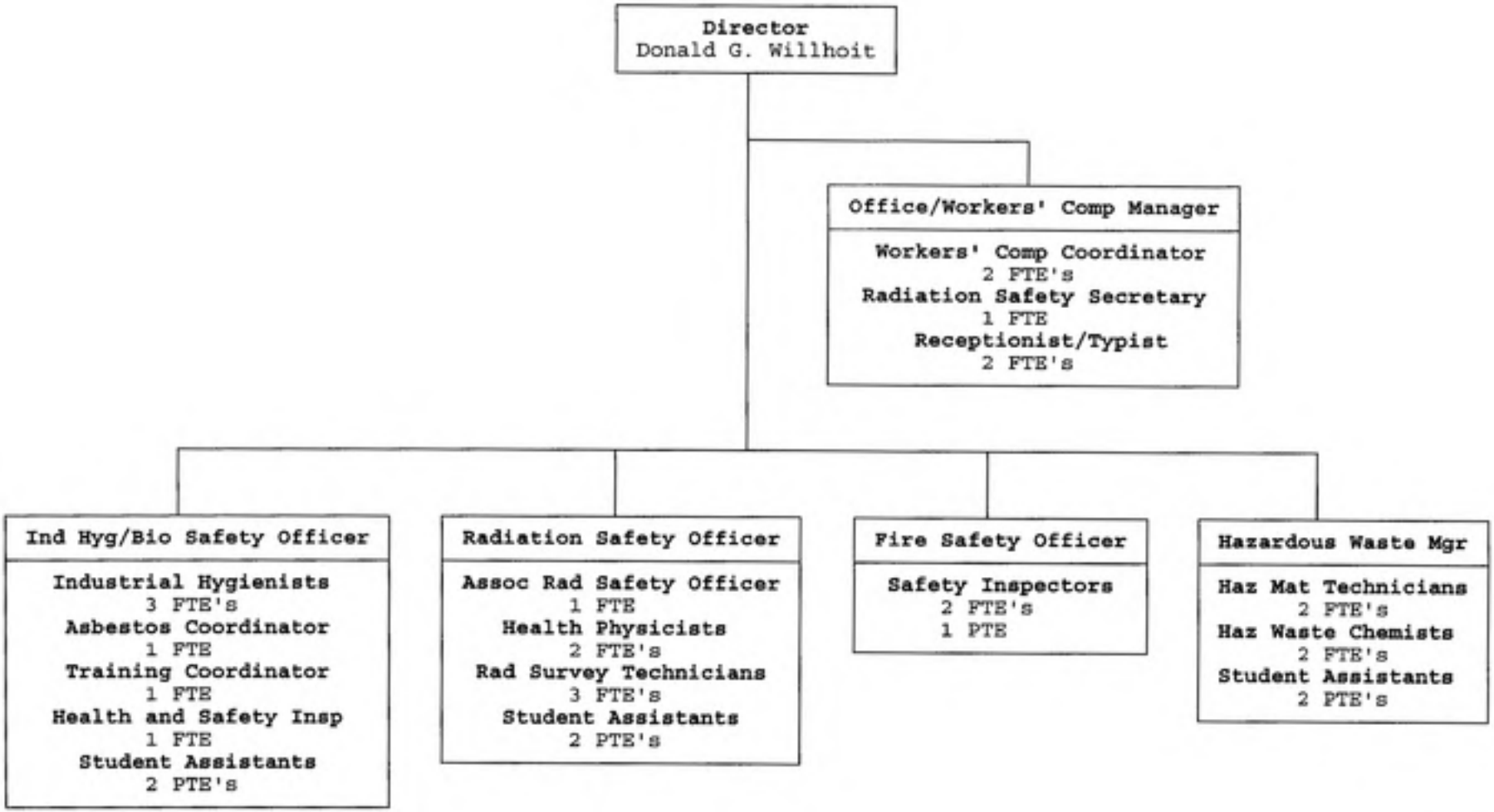
a. Waste minimization practices at the laboratory level should be examined to help reduce the generation of hazardous waste on university campuses. The reduction or destruction of characteristic hazardous wastes is not considered as treatment according to RCRA regulations as long as it is an integral part of the PI's laboratory experiment. Many PIs are practicing some form of waste minimization by changing both the volumes and the types of hazardous chemical waste generated.

b. Educational approaches which will encourage good waste management practices at the laboratory level should be identified. Principal investigators and lab personnel must share the responsibility / accountability for university generated hazardous waste. The PI must be held accountable for all generated hazardous waste.

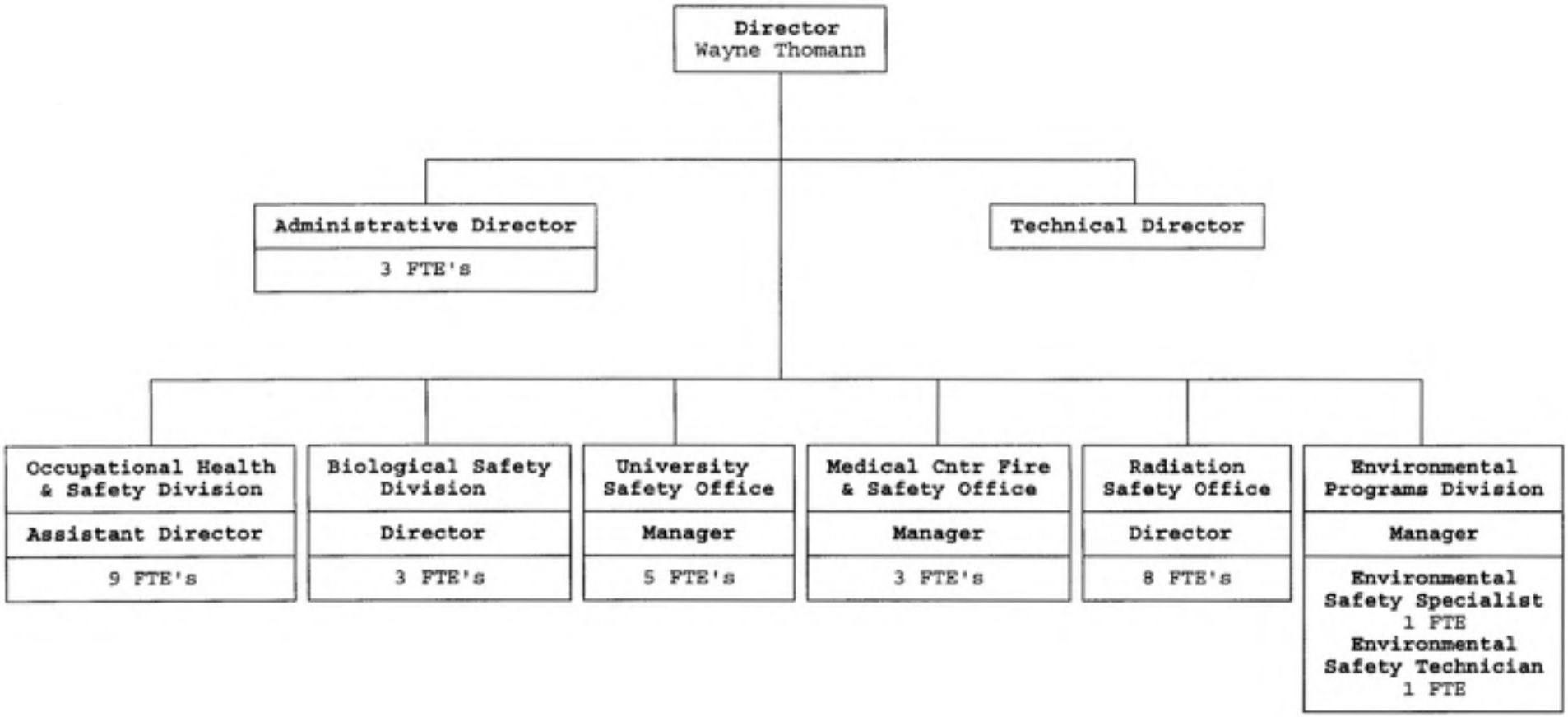
APPENDIX A

OFFICE FLOWCHARTS

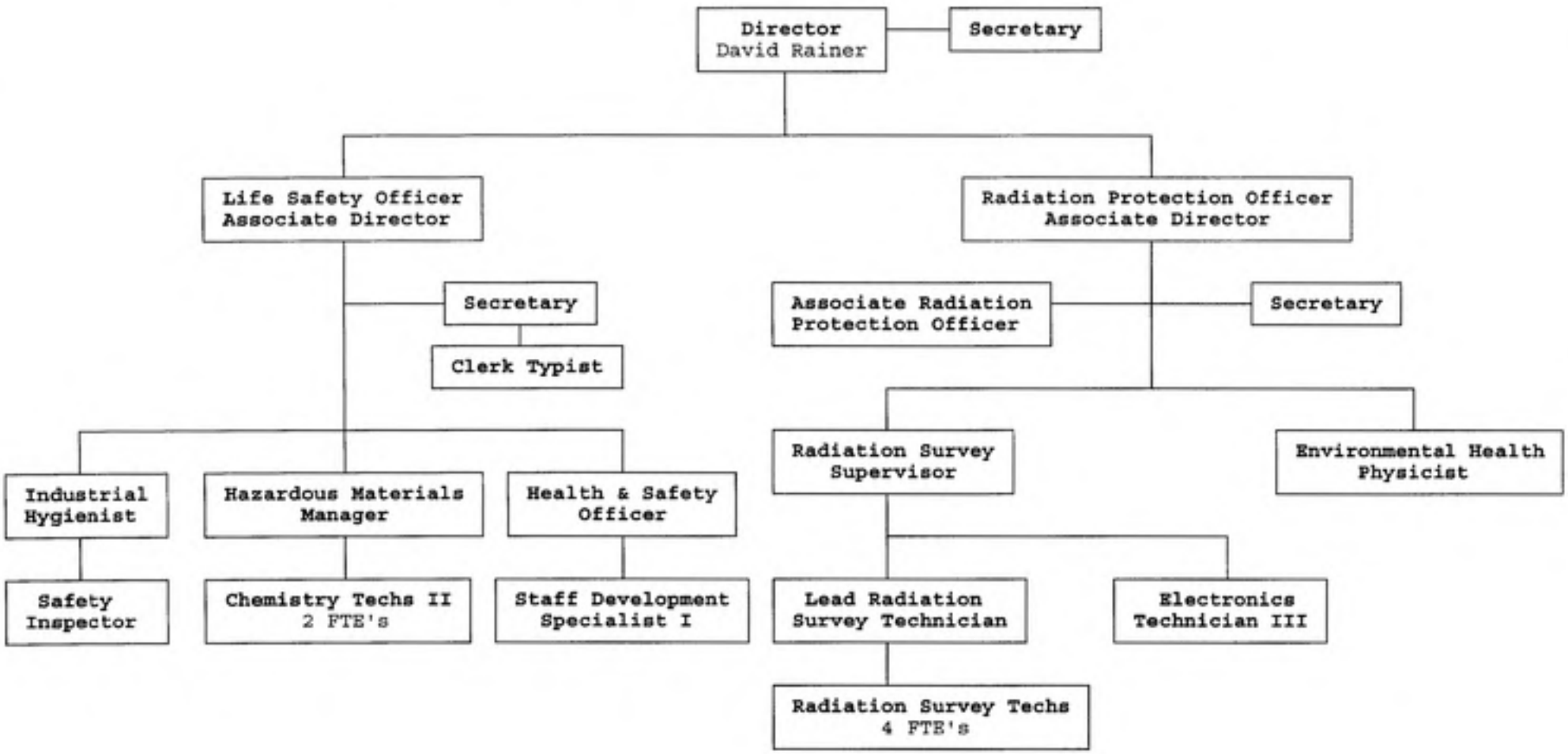
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
HEALTH AND SAFETY OFFICE



DUKE UNIVERSITY
OCCUPATIONAL AND ENVIRONMENTAL SAFETY OFFICE



NORTH CAROLINA STATE UNIVERSITY
ENVIRONMENTAL HEALTH AND SAFETY CENTER



APPENDIX B

RCRA LISTED HAZARDOUS
WASTE NUMBER'S

Table B.1 D Listed Wastes

Waste #	Characteristic Wastes
D001	Ignitable
D002	Corrosive
D003	Reactive
D004	Arsenic
D005	Barium
D006	Cadmium
D007	Chromium
D008	Lead
D009	Mercury
D010	Selenium
D011	Silver
D013	Lindane
D016	2,4-D
D018	Benzene
D019	Carbon Tetrachloride
D022	Chloroform
D036	Nitrobenzene
D038	Pyridine
D040	Trichloroethylene
D041	2,4,5-Trichlorophenol

Table B.2 F Listed Wastes

Waste #	Wastes From Non-Specific Sources
F001	Spent Halogenated Degreasing Solvents
F002	Spent Halogenated Solvents
F003	Spent Non-Halogenated Solvents
F004	Spent Non-Halogenated Solvents
F005	Spent Non-Halogenated and Toxic Solvents
F027	Discarded unused formulations of chlorophenols
F038	Petroleum refinery secondary (emulsified)

Table B.3 P Listed Wastes

Waste #	Discarded Commercial Products
P003	Acrolein
P010	Arsenic acid
P012	Arsenic (III) oxide
P018	Brucine
P020	Dinoseb
P021	Calcium cyanide
P022	Carbon disulfide
P028	Benzyl chloride
P029	Copper cyanides
P030	Soluble cyanide salts not elsewhere specified
P043	Diisopropyl flourophosphate
P044	Dimethoate
P048	2,4-Dinitrophenol
P054	Aziridine
P064	Methyl isocyanate
P077	Aldicarb
P075	Nicotine and salts
P077	p-Nitroaniline
P087	Osmium Tetroxide
P093	N-Phenylthiourea
P094	Phorate
P098	Potassium cyanide
P104	Silver cyanide
P105	Sodium azide
P106	Sodium cyanide
P108	Strychnine and salts
P109	Tetraethyldithiopyrophosphate

Table B.4 U Listed Wastes

Waste #	Discarded Commercial Products		
U001	Acetaldehyde	U091	3,3-Dimethoxybenzidine
U002	Acetone	U092	Dimethylamine
U003	Acetonitrile	U095	3,3-Dimethylbenzidine
U006	Acetyl chloride	U098	1,1-Dimethylhydrazine
U007	Acrylamide	U102	Dimethyl phthalate
U009	Acrylonitrile	U103	Dimethyl sulfate
U010	Mitomycin C	U107	Di-n-octyl phthalate
U012	Aniline	U108	1,4-Dioxane
U015	Azaserine	U112	Ethyl acetate
U019	Benzene	U113	Ethyl acrylate
U021	Benzidine	U115	Ethylene oxide
U022	Benzo(a)pyrene	U117	Ethyl ether
U031	n-Butanol	U119	Ethyl methanesulfonate
U037	Chlorobenzene	U120	Fluoranthene
U044	Chloroform	U122	Formaldehyde
U048	o-Chlorophenol	U123	Formic acid
U051	Creosote	U124	Furan
U052	Creosols	U129	Lindane
U056	Cyclohexane	U133	Hydrazine
U058	Cyclophosphamide	U135	Hydrogen Sulfide
U059	Daunomycin	U136	Cacodylic acid
U066	Dibromo-3-chloropropane	U138	Methyl iodide
U067	Ethylene dibromide	U142	Kepone
U069	Dibutyl phthalate	U144	Lead acetate
U072	p-Dichlorobenzene	U147	Maleic anhydride
U077	1,2-Dichloroethane	U150	Melphalan
U080	Methylene chloride	U151	Mercury
U081	2,4-Dichlorophenol	U154	Methanol

Table B.4 U Listed Wastes (continued)

Waste #	Discarded Commercial Products		
U162	Methyl methacrylate	U213	Tetrahydrofuran
U165	Naphthalene	U218	Thioacetamide
U167	1-Naphthylamine	U219	Thiourea
U169	Nitrobenzene	U220	Toluene
U170	p-Nitrophenol	U221	Toluenediamine
U185	Pentachloronitrobenzene	U222	o-Toluidine hydrochloride
U188	Phenol	U223	Toluene diisocyanate
U190	Phthalic anhydride	U225	Bromoform
U191	2-Picoline	U238	Ethyl carbamate
U196	Pyridine	U239	Xylene
U201	Resorcinol	U240	2,4-d, salts and esters
U211	Carbon Tetrachloride	U246	Cyanogen bromide
U212	2346-Tetrachlorophenol	U328	2-Methyl benzenamine

APPENDIX C

TOTAL QUANTITY GENERATED,
RCRA LISTED HAZARDOUS WASTE,
BY WASTE NUMBER
1990, 1991, 1992

Table C.1 D Listed Wastes 1990

Waste #	UNC-CH	Duke	NCSU
D001	7,997.9	38,882.8	9,446.7
D002	1,246.0	884.6	2,854.3
D003	10.8	25.7	34.5
D004	1.7	71.7	278.6
D005	2.0	13.2	25.4
D006	11.8	10.4	28.5
D007	24.5	2.3	374.6
D008	14.6	60.3	19.5
D009	102.7	28.0	145.1
D010	40.0	3.9	0.9
D011	1.0	277.2	772.9
D013	53.8		
D016		1.1	
D019		3.9	
D022	201.9		37.2
D036		0.5	
D041			0.9
Total	**9,708.7**	**40,265.6**	**14,019.1**
Percent	**35.96 %**	**71.55 %**	**43.42 %**

Table C.2 F Listed Wastes 1990

Waste #	UNC-CH	Duke	NCSU
F001			0.9
F002	1,613.0	1,499.1	2,582.3
F003	12,753.1	12,526.2	14,384.3
F004	4.7		12.7
F005	1,850.6	136.7	138.7
F027	0.1		
Total	**16,221.5**	**14,162.0**	**17,082.9**
Percent	**60.08 %**	**25.17 %**	**52.91 %**

Table C.3 P Listed Wastes 1990

Waste #	UNC-CH	Duke	NCSU
P012			0.5
P018		0.1	
P020			0.5
P021			12.2
P022			5.4
P028			2.3
P029			0.9
P030		1.1	50.3
P048		0.1	1.4
P054			1.8
P064			0.9
P075			0.9
P087	11.6	7.7	11.3
P093			0.5
P094			1.8
P098		1.1	15.9
P104			2.7
P105		63.6	1.4
P106	2.5		3.2
P108		3.7	
P109			0.5
Total	**14.1**	**77.4**	**114.4**
Percent	**0.05 %**	**0.05 %**	**0.35 %**

Table C.4 U Listed Wastes 1990

Waste #	UNC-CH	Duke	NCSU
U001		0.5	2.7
U002		1.5	
U003	1.1	2.4	
U006			1.3
U007	1.7	46.4	7.3
U009			0.5
U010		2.3	
U012		4.7	0.9
U015		0.1	
U019		0.1	
U021		2.5	1.8
U022	4.0		
U037			0.9
U044	334.3	4.6	362.9
U051		0.5	0.9
U052			0.5
U056		0.1	
U058	0.2	702.9	
U059		1.7	
U066			7.3
U067			103.0
U069			5.0
U072			1.4

Table C.4 U Listed Wastes 1990 (continued)

Waste #	UNC-CH	Duke	NCSU
U077	0.5	0.5	
U080		4.4	
U081			0.5
U091			0.9
U092		54.4	5.4
U095			0.5
U098	0.3		
U102		46.3	
U103	0.5		0.5
U108	1.1		0.9
U115			0.5
U117		0.1	0.9
U119			0.5
U120	1.0		
U122	75.0	226.3	454.1
U123		3.8	
U124		1.0	
U129		0.5	0.5
U133	0.6	0.1	
U135		18.1	
U136			0.9
U138			0.5
U142			0.9

Table C.4 U Listed Wastes 1990 (continued)

Waste #	UNC-CH	Duke	NCSU
U144			1.4
U147	19.5	2.8	1.8
U150		0.3	
U151		557.0	
U154		4.0	
U162		0.5	
U165		2.2	6.4
U167	5.0		
U169			4.5
U170		1.0	1.4
U185		0.2	
U188	4.9	55.2	26.3
U190			2.3
U191			0.5
U196		1.5	21.8
U201		0.1	1.4
U211		0.1	
U212			0.5
U213		3.8	2.7
U218		0.1	0.9
U219		1.0	2.3
U220	4.0	1.0	
U221		0.2	

Table C.4 U Listed Wastes 1990 (continued)

Waste #	UNC-CH	Duke	NCSU
U222			0.5
U223			1.4
U225			5.9
U238		6.2	0.5
U239	8.0	0.3	
U240			18.1
U246	0.3	5.0	
U328			8.6
Total	**462.0**	**77.4**	**1,073.1**
Percent	**1.71 %**	**0.05 %**	**3.32 %**

Table C.5 Unknown Listed Wastes 1990

Waste #	UNC-CH	Duke	NCSU
Unknown	591.6		
Total	**591.6**	**NONE**	**NONE**
Percent	**2.19 %**		

Table C.6 D Listed Wastes 1991

Waste #	UNC-CH	Duke	NCSU
D001	17,518.3	26,470.6	17,266.4
D002	1,008.5	3,206.8	734.0
D003	75.6		
D004	14.0		907.2
D005	8.0		
D006	2.0		
D007	24.1		1,179.4
D008	393.7		1,179.4
D009	278.0	9.1	544.3
D010	34.6		
D011	91.0	1,907.4	130.6
D013	4.0		
D014	27.0		
D019	16.2		
D022	739.6		
D038	5.0		
Total	**20,239.6**	**31,593.9**	**21,941.3**
Percent	**66.61 %**	**63.01 %**	**40.41 %**

Table C.7 F Listed Wastes 1991

Waste #	UNC-CH	Duke	NCSU
F001	20.0		646.4
F002	3,957.8		362.8
F003	3,376.6	18,541.8	7,025.4
F005	2,723.1		3,254.1
F027			45.4
Total	**10,077.5**	**18,541.8**	**11,334.1**
Percent	**33.17 %**	**36.98 %**	**20.87 %**

Table C.8 P Listed Wastes 1991

Waste #	UNC-CH	Duke	NCSU
P003			47.1
P008			47.1
P011			47.1
P012			47.1
P014			47.1
P098	6.0		
P106	1.0		
Total	**7.0**	**NONE**	**235.5**
Percent	**0.02 %**		**0.43 %**

Table C.9 U Listed Wastes 1991

Waste #	UNC-CH	Duke	NCSU
U007	4.0		
U019	2.0		
U044	30.0		
U051		9.1	970.8
U052	2.0		
U167			272.2
U185			45.4
U188	19.0		
U190	1.0		
U206	2.0		
U223	1.0		
Total	**61.0**	**9.1**	**1,288.4**
Percent	**0.20 %**	**0.02 %**	**2.37 %**

Table C.10 Labpack Listed Wastes 1991

Waste #	UNC-CH	Duke	NCSU
LABP			19,501.2
Total	**NONE**	**NONE**	**19,501.2**
Percent			**35.91 %**

Table C.11 D Listed Wastes 1992

Waste #	UNC-CH	Duke	NCSU
D001	20,846.1	17,830.0	11,059.7
D002	605.7	73.4	3,991.3
D003	57.3		9.0
D004	11.6		575.9
D005	7.0		
D006	47.5		
D007	12.0		
D008	325.9		4.5
D009	115.9		323.4
D010	16.0		
D011	122.4	385.6	113.3
D018	27.2		
D019	37.0		
D022	650.9		157.4
D036	1.0		
D038	45.8		
Total	**22,929.3**	**18,289.0**	**16,234.5**
Percent	**71.39 %**	**42.83 %**	**33.44 %**

Table C.12 F Listed Wastes 1992

Waste #	UNC-CH	Duke	NCSU
F002	4,972.7	17,756.6	1,186.2
F003	842.0		4,319.7
F004	6.6		
F005	3,033.9		
Total	**8,855.2**	**17,756.6**	**5,505.9**
Precent	**27.78 %**	**41.58 %**	**11.34 %**

Table C.13 P Listed Wastes 1992

Waste #	UNC-CH	Duke	NCSU
P043			0.2
P044			0.2
P070			227.2
P105	0.2		
Total	**0.2**	**NONE**	**227.4**
Percent	**< 0.01 %**		**0.47 %**

Table C.14 U Listed Wastes 1992

Waste #	UNC-CH	Duke	NCSU
U006	0.1		
U007	3.0		
U012	0.5		
U022	76.0		
U048	0.1		
U067			54.4
U081	0.1		
U103	2.0		
U115			4.5
U122			285.8
U170	1.0		
U188	8.5		26.1
U246	1.0		
Total	**92.3**	**NONE**	**370.8**
Precent	**0.29 %**		**0.76 %**

Table C.15 Labpack Listed Wastes 1992

Waste #	UNC-CH	Duke	NCSU
LABP		6,665.2	26,205.8
Total		**6,665.2**	**26,205.8**
Percent		**15.61 %**	**53.98 %**

APPENDIX D

UNC-CH RCRA LISTED

HAZARDOUS WASTE NUMBER'S

BY DEPARTMENT

1990, 1991, 1992

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
ART	D001	324.0	255.0	601.0
	D002			4.0
	F002			
	F003	136.0		
	F005			
BRAIN & DEVELOPMENTAL RESEARCH CENTER	D001	3.3	36.5	59.1
	D002	0.9	31.0	7.0
	F002		4.0	
	F003		16.0	16.0
	F005		21.0	17.5
BIOCHEMISTRY & BIOPHYSICS	D001	231.3	505.6	401.4
	D002	18.4	35.4	4.5
	F002	12.0	28.2	
	F003	345.8	61.0	
	F005	94.4	38.0	12.0
BIOLOGY	D001	97.6	309.1	425.9
	D002	39.3	50.5	37.5
	F002			95.0
	F003	148.0	29.0	4.0
	F005	5.8	14.9	25.5
CELL BIOLOGY & ANATOMY	D001	104.9	126.3	73.0
	D002	39.6	2.0	10.0
	F002	4.0		
	F003	83.6	56.0	11.3
	F005	46.0	30.5	8.7

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
CENTER FOR ENVIRONMENTAL MEDICINE & LUNG BIOLOGY	D001	10.0	9.5	68.3
	D002			17.4
	F002			4.0
	F003	4.0	1.0	16.0
	F005			
CHEMISTRY	D001	1285.5	4823.7	4895.2
	D002	462.2	433.1	173.0
	F002	1338.6	2233.3	1803.7
	F003	6172.2	1107.1	306.8
	F005	281.3	685.0	1090.7
DERMATOLOGY	D001	0.1	14.5	14.5
	D002		4.0	
	F002			
	F003		4.0	
	F005			
DIVISION OF LABORATORY ANIMAL MEDICINE	D001	4.0	82.0	100.0
	D002		5.0	2.0
	F002			2.0
	F003		1.0	1.0
	F005			
SCHOOL OF DENTISTRY	D001	149.8	327.0	388.0
	D002	27.1		10.5
	F002	24.0	8.0	72.5
	F003	199.7		14.4
	F005	40.5	21.0	10.0

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
ENVIRONMENTAL PROTECTION AGENCY	D001	1.5		
	D002	48.0	48.0	2.0
	F002			
	F003			
	F005			
ENVIRONMENTAL SCIENCES & ENGINEERING	D001	75.6	531.2	561.5
	D002	137.2	100.2	192.2
	F002	31.8	172.1	355.3
	F003	72.7	101.0	150.2
	F005	1.0	215.0	111.7
EPIDEMIOLOGY	D001	4.0	9.8	96.0
	D002			6.2
	F002			
	F003		5.0	19.0
	F005	36.0		16.0
GEOLOGY	D001	4.0	1.0	
	D002	53.5		
	F002			
	F003			
	F005			
HISTOLOGY	D001	2890.0	3697.4	3877.0
	D002	1.0	6.4	0.5
	F002			
	F003	1602.6	401.3	23.0
	F005	698.2	1118.7	1407.0

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
HOSPITAL	D001	8.0	9.5	739.0
	D002			22.5
	F002			
	F003	4.0	8.0	
	F005			
MEDICINE	D001	410.8	1024.6	652.5
	D002	54.7	32.5	9.9
	F002	1.0	39.2	2.0
	F003	292.0	94.0	22.0
	F005	78.7	35.2	7.0
MICROBIOLOGY & IMMUNOLOGY	D001	483.8	1054.8	1483.1
	D002	39.1	50.1	31.1
	F002	129.0	396.0	266.0
	F003	329.3	142.5	21.5
	F005	123.3	120.5	63.7
NUTRITION	D001		33.5	4.0
	D002		1.0	0.5
	F002			
	F003			
	F005	29.6		12.0
OBSTETRICS & GYNECOLOGY	D001	22.2	90.5	119.0
	D002	2.0		2.0
	F002			
	F003	9.5		
	F005			12.0

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
PATHOLOGY	D001	795.3	708.7	687.2
	D002	41.1	48.6	16.6
	F002	16.1	5.0	8.0
	F003	299.6	189.1	11.5
	F005	80.1	31.0	22.5
PEDIATRICS	D001	98.0	280.0	133.9
	D002	4.2	23.0	5.0
	F002	16.0	5.0	9.0
	F003	172.2	110.0	27.0
	F005	28.0	12.5	1.0
PHARMACOLOGY	D001	94.5	594.0	440.8
	D002	8.6	12.3	11.9
	F002			125.0
	F003	352.4	17.0	9.0
	F005	27.8	52.0	10.5
SCHOOL OF PHARMACY	D001	431.3	1473.5	1651.8
	D002	72.4	16.9	21.9
	F002	35.6	1061.0	2167.2
	F003	1778.1	902.0	102.6
	F005	151.0	202.6	180.7
PHYSICS & ASTRONOMY	D001		19.0	
	D002		29.0	
	F002		6.0	2.0
	F003	18.6	8.0	
	F005		2.0	

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
PHYSIOLOGY	D001	34.6	194.0	175.4
	D002	49.1	9.4	5.5
	F002			
	F003	76.0	52.0	29.0
	F005	10.0	4.1	19.0
PHYSICAL PLANT	D001	209.0	429.0	1551.0
	D002	28.0		
	F002			19.0
	F003			
	F005			
PSYCHIATRY	D001	47.5	87.5	21.5
	D002	5.0	3.9	
	F002			
	F003	103.5		
	F005	8.0	8.0	
PSYCHOLOGY	D001		17.5	9.5
	D002			
	F002			
	F003	74.0	38.0	
	F005		4.0	
RADIATION	D001	9.5	17.0	43.8
	D002			
	F002			
	F003	99.8		0.7
	F005		12.0	

Table D.1 UNC-CH Top Generated Waste Codes Measurements in Kilograms

UNC-CH Department	Waste Code Number	1990	1991	1992
SURGERY	D001	23.8	108.0	212.6
	D002	12.0	14.0	4.1
	F002			
	F003	76.7	8.0	
	F005	80.0	84.5	2.4
MISCELLANEOUS DEPARTMENTS	D001	144.0	648.6	1360.1
	D002	102.6	56.2	7.9
	F002	4.9		42.0
	F003	302.8	29.6	58.0
	F005	30.9	10.6	4.0

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