

PROBLEMS OF WASTE CHEMICAL HANDLING AT A LARGE BIOMEDICAL RESEARCH FACILITY

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Summary

Present handling and disposal methods for the chemical wastes arising at a large U.S. biomedical laboratory complex are described, with emphasis on the operational and management problems posed by these wastes. A study of incinerators which may be suitable for dealing with a large proportion of the wastes is described, which has led to a more detailed investigation of one of the most promising units. The effects of recent legislation are indicated. It is concluded that improvements are desirable, and these are now being implemented.

Introduction

The National Institutes of Health is a large Federal bio-medical research facility managed under the Department of Health, Education, and Welfare. The underlying mission of the NIH is basic research. To this end, at the Bethesda, Maryland reservation, there are approximately 2,300 laboratories employing nearly 4,700 professional and scientific staff and another 1,800 people in subprofessional and technical laboratory support positions. Other people arrive and leave the laboratories each year who are involved in various fellowships, visiting scientist, foreign scientist, and guest worker programs. Research in nearly all scientific and medical disciplines is represented at the NIH; consequently, the chemical waste is both voluminous and varied. Approximately 100,000 pounds of chemical waste representing 2,800 different compounds are disposed of yearly. Although some industries discard far more chemical waste in terms of volume than does the NIH, it is the great variety of substances which constitutes the disposal problem.

NIH policy requires that all waste chemicals, except flammable liquids, shall be disposed of in the following manner. The investigator should label the compounds correctly and segregate them from any incompatible substances. Next, the chemicals should be securely boxed and the box marked with the appropriate chemical category (corrosive, toxic, shock-sensitive, carcinogenic, etc.). Any special instructions should also be listed. The investigator notifies the NIH Fire Department who then come to his lab, remove the chem-

icals, and transport them to the waste chemical storage facility. The firemen then sort the chemicals inside the building into hazard categories. Finally, every six to eight weeks, at the discretion of the Fire Chief, a contractor comes to the building, packs the chemicals into 55-gallon drums in vermiculite, and transports them by truck away from the reservation for ultimate disposal. Flammable liquids are handled in basically the same way, the only difference being that the Fire Department provides the investigator with an approved five-gallon, wide mouthed safety can which is kept in his laboratory for these solvents. When filled, the Fire Department picks up the can and removes it to the storage area.

As noted earlier, the volume of waste chemicals is rather large and varied; fortunately, the bulk of the wastes are relatively low hazard. Because no chemical wastes are routinely disposed of at the NIH, all waste substances must be handled by the aforementioned procedure. This means that a large number of waste acids, solvents, and relatively low or nontoxic salts and buffer solutions become a part of the disposal system. This is not to say that very hazardous substances are not discarded at the facility. It would be a safe assumption to make that at one time or another almost every hazardous chemical has been used on the reservation. Fortunately, however, most of the highly toxic compounds are used in very small quantities, often in milligram and milliliter amounts. The National Cancer Institute has an ongoing program involving identifying and testing for carcinogenic, mutagenic, and teratogenic effects, which results in fairly large amounts of this type of waste being generated. Other laboratories commonly use ethers, perchloric acid, and picric acid which, among others, may create a potential explosion hazard if these compounds have not been correctly handled. This is often the case when these substances find their way to the storage area.

A recent survey showed that out of the approximately 2,800 compounds discarded at the facility, only 130 fell into the Designated Hazardous Substance category as defined by the State of Maryland. Fortunately, with these and most of the waste chemicals, the containers and volumes are relatively small; consequently, many of the 130 chemicals mentioned above were generated in amounts below the minimum reporting level as specified by the State. The great majority of the containers are one pint or smaller for liquids and one pound or less for solids. Very rarely are any bottles larger than one gallon.

Another source of waste chemicals comes from the National Institute of Environmental Health Sciences field station, located in Research Triangle Park, North Carolina. These wastes come to the NIH already packed in 55-gallon drums and inventoried so that they present no particular problem other than the space it takes to store them until the contractor hauls them away.

Present chemical waste handling system

Pickup

The National Institutes of Health Fire Department performs vital service functions in addition to fire-related activities and emergency ambulance ser-

vice. Pickup and disposal of waste chemicals is one of these many service functions. The waste chemicals are picked up from approximately 2,300 research laboratories, and are then transported to a specially constructed staging area for sorting and packing. An average of six laboratory pickups are made each working day, by request only.

There are 800 laboratories in the hospital research complex. For chemical pickups in this building, a hand truck was specially constructed. This hand truck has a 14-gauge stainless steel body and is water tight. If by chance some breakage should occur inside the steel body involving either powders or liquids, this truck can be loaded on a pickup truck and taken to the chemical disposal staging area where neutralization or transfer of this liquid or powder to another container is performed. This water tight body contains a spill, preventing any leakage of chemicals into the building that might endanger occupants or damage the building. This hand truck is easily transported via freight elevator to all parts of the 14-story building where a pickup of waste chemicals has been requested.

The fireman picking up waste chemicals has protective equipment available to him on the chemical pickup truck. This equipment consists of fire department turn-out gear (protective clothing, boots, helmet), as well as self-contained breathing apparatus, rubber gloves, face shields, and safety glasses. Other equipment on the pickup truck includes absorbent and neutralization compounds, rubber buckets, and hand tools.

Processing

In the waste chemical staging area, there is a remote-controlled hydraulic bottle crusher for waste acids. The operator begins by loading acid bottles into a hopper. As the protective door raises to a closed position, material in the hopper is automatically dumped into the bottle crusher. The operator then lowers the bottle crusher ram to crush the containers. During the entire operation, water continually sprays the crusher ram, grate, and collector pan. The collector pan retains broken glass, cans, etc., while the residue is washed into a concrete holding tank, which is monitored by a pH meter. Sodium hydroxide is used as the neutralizer in this operation. When a pH of 6–8 is reached, the contents of the holding tank are discharged into the sanitary sewer. The bottle crusher is completely enclosed and a ventilating fan is installed at the top to remove any fumes. The crusher operator is protected by a twelve inch reinforced concrete wall on three sides and an eight inch concrete roof. If an explosion should occur, the operator would be protected from all flying objects. Because of the increased demands against the Fire Department's time and manpower, this method of waste acid disposal is now seldom utilized and most of the waste acids are removed by the contractor.

This bottle crusher was also constructed for flammable liquids. Instead of flammables going into the concrete holding tank, they were carried to two 55-gallon drums by a pipe installed for this purpose. At one time these drums were interconnected to an oil burner, which was started on its own fuel supply

and then switched to use the flammable liquids as fuel. This disposal method was discontinued in 1975 because of air quality standards. A plan was developed during the 1973 energy crisis to add the waste flammable liquids to the NIH fuel oil storage tanks and burn the wastes in this manner. Several 55-gallon drums added to the 500,000 gallon oil supply would do little to alter the characteristics of the fuel oil and would not cause any pollution problems. This idea, however, was never implemented because of the concern for the potential clogging of the oil burner nozzles.

Packing

To make the task of packing the drums easier and to maintain compatibility of chemicals the following disposal categories were developed:

A — Flammable liquids, and solvents

B — Salts

C — Cyanides, Poisons

E — Explosives

M — Pyrophoric metals

R — Alcohols and oils that can be recycled into use at the NIH Power Plant

U — Chemicals which can neither be disposed of at the NIH nor by regular contract

Z — Chemicals which may be disposed of at the NIH Disposal Plant

As the drums were filled, an inventory list of contents was made. The purpose of the inventory list is to provide the waste disposal contractor with information in the event of a vehicular accident, fire, or when removing contents from the drum. Before sealing the drum for transporting, the drum was numbered to correspond with the inventory list. Two lists accompanied the drum, one of which was placed immediately under the drum top and the other attached to the outside. If the inventory list attached to the outside of the drum was destroyed, the waste disposal contractor would find the other upon opening the drum.

Operation problems

As the volume of waste chemicals increased, using Fire Department personnel to pack drums and prepare inventory lists became too time consuming. Since fire fighters are not chemists, chemical names had to be laboriously copied from container labels. If an emergency call was received during the inventory and packing procedure, the fire fighters had to leave, handle the emergency, and then return to inventorying and packing chemicals.

To prevent organic solvents from being flushed down sanitary sewer drains, five-gallon wide-mouth safety cans equipped with a flame arrestor were supplied to the investigators by the Fire Department. When the can is full it is picked up from the laboratory by a fire fighter and is replaced with an empty can. The contents of the can are poured into 55-gallon drums which are then removed by the contractor. The safety can is then washed out with water and allowed to dry so that it will be ready for future use.

When this program was begun, only terne plate safety cans were available for purchase. If someone inadvertently poured acid into the can, it was ruined. At \$50—\$55 per can, one mistake was very costly. Two self-adhering labels were then developed. One label is attached to all laboratory sinks:

CAUTION
BECAUSE OF FIRE HAZARD,
DO NOT POUR
FLAMMABLE SOLVENTS
INTO THIS SINK
Discard all waste Flammable
Solvents into Safety
(Disposal) Can
Nearest Disposal Can Located
in Room

The other label is attached to the safety can. This label reads:

DISPOSAL CAN
.....
WASTE FLAMMABLE
SOLVENTS ONLY
FOR PICK-UP AND DISPOSAL CALL 496-2372

Later a polyethylene lined safety can was developed and we have since purchased only this can in order to reduce the physical damage done by acid being poured into the can.

As the workload increased, it was impossible for Fire Department personnel to keep up with the inventory and packing procedures for waste chemical disposal. When the next contract was negotiated, an additional stipulation was inserted to require the contractor to pack waste chemicals, using the same method that the Fire Department used. However, because the contractor packed the waste chemicals, it was not feasible to make an item by item inventory list. Waste chemicals were packed by categories. To comply with the State of Maryland Water Resources Administration regulations, a Hazardous Waste Manifest is to be completed and all drums are to be labeled with Hazardous Waste Labels supplied by the Water Resources Administration.

Management problems

Unknowns and constantly changing waste mix

The problem of "unknown" waste chemicals is a matter of great concern. Although the numbers of these unknowns are small, occasionally this situation is encountered. Investigators will frequently use an empty acid bottle for waste disposal and then not re-label it appropriately, or the labels from some compounds will fall off or become unreadable, either from age or improper pouring procedures. The firemen transport the unknown from the laboratory to the storage area where it is then treated as a high risk waste.

Other materials encountered in the disposal operation are the industrial wastes such as pump and transformer oils. Except for a small amount of waste containing PCB's, these oils are simply transferred to 55-gallon drums and removed by the contractor; thus, they pose no unusual problems.

Any research facility as large as the NIH is, by necessity, going to generate large volumes of chemical wastes. As new areas of investigation open up, the types and volumes of waste change. In the same light, the recognized degree of hazard associated with certain chemicals may also change. Only a few years ago, chemicals such as benzene were not treated any differently from other flammable solvents. Also, as the state of the art of containment is improved, greater numbers of researchers feel more comfortable using more hazardous compounds in their work. At the NIH, "High Hazard" laboratories with specially designed glove boxes, ventilation, and filtering systems protect the investigator while he is using these compounds, yet they all end up entering into the same disposal operations as low risk materials.

The turnover of researchers is high at the NIH. Aside from the permanent staff positions, there are a large number of scientists entering and leaving yearly. Each person is brought into an existing laboratory and is then encouraged to set up his own specific research problem. Very seldom do these scientists utilize the same procedures and assays as those already ongoing in the parent lab; therefore, each new program means a new inventory of chemicals. After working for one to two years and then leaving, a researcher often cleans out an entire laboratory and disposes of the chemicals before a new scientist is brought in. This cycle accounts for a large volume of waste chemicals. In addition, many times the researcher departs without cleaning out his space, leaving it for the next worker to do. It is here that many of the "unknown" wastes evolve.

Unused chemical disposal

The purchasing system at the NIH is also a matter which causes problems in the waste management area. Many scientists complain that the time lag between the ordering of chemicals and their delivery is such that chemicals must be ordered in quantity, and then stockpiled for future use. Large quantities are also sometimes ordered because of a price reduction for bulk orders, with the anticipation of future use. This hoarding causes safety and space management problems because of the lack of storage space available in laboratory buildings. Often, after a quantity of chemicals has accumulated, either the scope of the research changes or the investigator leaves, resulting in quantities of unused compounds to be disposed of in the usual manner.

The NIH is now in the process of developing a program in which all relatively nonhazardous, unopened containers of "waste" chemicals will be separated from other discarded compounds. Representatives of science departments from local colleges and universities will, on a regular basis, be able to review these substances and take whatever chemicals they can utilize in their work. Government regulations regarding surplus items and all Federal and State

transportation requirements must, of course, be met by the NIH and these schools. The scientific community has discussed recycling waste chemicals in-house at the NIH, but the idea still faces obstacles for implementation. If this program is to be undertaken, it would again only pertain to unopened containers, and in-house recycling would have priority over the outside program.

There are several specific areas which are causing most of the problems in the present method of chemical waste disposal. To begin with, the investigator should accurately assess his needs as to what quantity of a substance will actually be used in a particular time span and then order accordingly. Purchasing methods should be implemented to expedite the ordering and receiving of chemicals by the scientist and smaller quantities should be ordered, even if it requires more frequent purchasing. This might mean higher costs initially, but it would certainly reduce the amount of unused chemicals being discarded. The investigator should also be required to fill out and sign a waste chemical discard sheet stating specifically what is being discarded, the associated hazards, and the methods for correct handling. Presumably, the investigator should be aware of any precautions to be taken and the toxicity information of all hazardous materials he uses. All investigators should be personally responsible for cleaning out their own work places when they are leaving or changing laboratories. This would avoid most unknown wastes and permit re-labeling of old or unreadable labels by the user.

The NIH is fortunate to have its own well-equipped Fire Department on the reservation. These men are well trained as fire fighters and rescue personnel, but they are not, nor are they expected to be, knowledgeable in the field of chemistry. The responsibility of handling hazardous chemicals, making the decisions as to hazard categories, and inventorying and sorting the wastes is not their field of expertise. The NIH also has little specialized equipment with which to transport hazardous wastes away from the laboratories to the storage facility. In many cases this necessitates hand carrying the wastes to a pick-up truck and then hand carrying them into the storage area. Highly toxic substances, potential explosives, and shock-sensitive compounds are also handled in this manner. The hand truck, which was discussed earlier, is adequate for containing spills and leaks but it is not designed for transporting potentially explosive compounds through occupied buildings.

Storage facility problems

The waste chemical storage facility is a problem at the NIH. The facility was originally designed and constructed in 1954, and at that time was isolated from other major buildings. The total number of employees at the NIH in 1954 was approximately 4,600 (as compared to 14,900) and the volume and nature of chemical wastes generated was miniscule by present day standards. The facility consists of a fenced area of approximately 50 feet square containing one small building (see Fig. 1). It is presently located approximately 20 feet from one of the main vehicle and pedestrian arteries through the reservation and only 50 feet from an employee parking lot. The building is basically

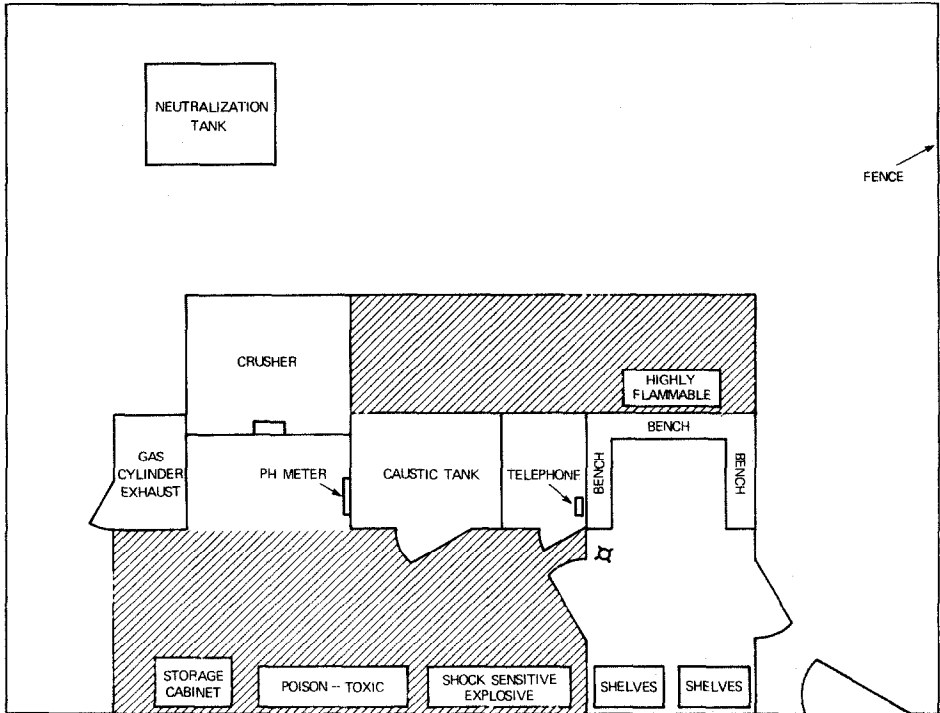


Fig. 1. NIH chemical disposal area.

open and contains several small rooms. In one of these is a telephone, another contains the "crusher" which was previously described, and a larger room which has limited bench and shelf space. In this room also is an exhaust fan and a safety shower and eyewash station, both of which must be manually charged with water and drained each time the facility is used in the winter, to prevent freezing. Two pull type fire alarm boxes are also inside the building. The outer area is open on two sides, one of which is bordered by the outside fence. Metal shelving is against the fence on which "shock-sensitive" and "toxic" compounds are stored. These are the only designated categories within the building for storing all the varieties of wastes encountered. A large metal storage cabinet is also housed in this area. On another outside building wall facing the area is a set of metal shelves on which "Highly Flammable" compounds are kept. These shelves are exposed to the weather. "Danger High Explosives" and "Danger No Smoking Within 50 Feet" signs are prominently posted around the area. The building (that portion which is under a roof) has no heating or cooling capabilities and only a concrete slab serves as the floor.

Most of the chemicals brought to the facility are stored in cardboard boxes or fiberboard "tote boxes" on the floor. Only those designated as shock-sensitive, toxic, or highly flammable are placed on the shelves. All materials housed

at the facility are exposed to the temperature range of Washington weather, usually from 5° to 95° F in the course of a normal year. There is no refrigeration available or even an insulated area for chemicals which should be kept cool or are not to be exposed to extremes of heat or cold. It is not uncommon in the winter to find liquids frozen in bottles or broken bottles due to freezing.

Fifty-five gallon drums into which the firemen empty safety cans containing mixed flammable solvents and drums of mixed "oils and alcohols" are stored outside of the building. No records are made by the investigators as to the nature of the solvents discarded in the safety cans, therefore, the exact contents of the drums are unknown. Two charged frost-free faucets are located outside, within the enclosed area. The Fire Department has the only set of keys to the one gate of this facility, and it is kept locked; nonetheless, security at the area is poor. Chemical bottles on the "hazard" shelving could be handled through the fence or damaged from the outside. The fence could be scaled or materials could easily be thrown over the fence into the facility. Because of limited space, drums from the North Carolina facility, as well as NIH oil filled containers are, on occasion, placed outside the fence on the driveway leading to the building.

Although the disposal facility does represent an area of concern to the NIH now, it should be acknowledged that when it was designed, this facility represented the highest state of technology known at that time. The "crusher", the neutralization pit, and the method of burning flammable liquids were innovative ideas back in 1954. The size and location of the facility were more than adequate for the population of the NIH and for the volume and variety of the waste chemicals generated at that time. Plans are now being made for the removal of this facility from its present location and these will be discussed later.

Other concerns

The contractor who removes the chemical wastes from the reservation presents additional concerns, both for his safety and for the safety of other people in the area. Contractor personnel have been observed smoking at the gate of the facility next to several drums of flammable liquids, even though the area was posted with "No Smoking" and "Danger High Explosives" signs. Men were observed packing 55-gallon drums with containers of wet and dry chemicals ranging in size from several ounces to one gallon. They placed a layer of vermiculite on the bottom of each drum and then a layer of chemicals, alternating layers until the drum was filled. No apparent attempt was made by the contractor to segregate incompatible chemicals. The contract requires that a list of contents be made and attached to each drum, but this was not done. Proper labels (corrosive, poison, etc.) were not always affixed to the drums as is also required by the contract. Two of the workmen were seen not using any eye protection and the gloves they were wearing were common leather and cotton work gloves. No rubber gloves, aprons, or face-

shields were being worn. These problems represent some of the drawbacks of storing chemical wastes for longer periods of time thus necessitating large quantity removal.

The above touches briefly on the physical setup of the NIH and a brief description of the chemical disposal operation and some of its problems. We shall now turn to future developments involved in chemical waste management.

Waste chemical handling in the future at NIH

New legal requirements

In the past the system for collecting and disposing of waste chemicals has served the NIH reasonably well; however, there are a number of recent developments such as the problem areas above, which demonstrate a need to modify and update this system. Another very important development is the emergence of new regulations controlling the handling, processing, and disposal of these wastes.

The Resource Conservation and Recovery Act of 1976 (RCRA) [1] is very likely the single most influential piece of legislation involving the control of waste chemicals. This Act calls for the U.S. Environmental Protection Agency to promulgate regulations that will set standards for all phases of hazardous waste management. Criteria are set forth for determining what wastes are hazardous, as well as the minimum amount of waste generated on a monthly basis which will require adherence to RCRA standards. Design and operating standards are set forth for any facility that stores, processes, or disposes of more than the minimum generation of hazardous wastes. These standards cover facility design, location, and security considerations, as well as environmental and long term maintenance provisions. Minimum performance standards are also proposed for incineration processes.

Another important feature of this Act is the requirement for the complete tracking of a hazardous waste from its point of generation through any handling or processing steps, to its ultimate disposal. To accomplish this tracking function, the U.S.E.P.A. is devising a multi-part manifest system which will carefully document each step in a waste's journey to disposal. The Act also covers shipping regulations of hazardous wastes to assure safe transport of these materials.

It is presently intended that the states will establish programs to carry out the goals of the RCRA. Each state has the option of setting their hazardous waste standards to be even more stringent than those set forth under the RCRA. Once individuals state programs are approved by the U.S.E.P.A., each state can carry out and enforce its own program.

The State of Maryland is the controlling jurisdiction for the NIH, and has been very aggressive in developing a hazardous waste program. It already has in effect a very elaborate manifesting and inventory report system for "Designated Hazardous Substances". The State requirements have given primary impetus to the modification of the existing handling system at the NIH.

To comply with the requirements of the State of Maryland, each shipment of waste chemicals that the NIH designates for disposal must be accompanied by a completed manifest form. This form requires a listing of the names and amounts of all the chemicals shipped, as well as each of the associated hazards. For a large research complex such as the NIH, the manifest requirements prove to be a most formidable task.

Improved contract work scope

Approximately every six weeks, the NIH generates enough waste chemicals to make a shipment. Anywhere from fifteen hundred to two thousand different chemicals may be included in a shipment, and though most of these chemicals are in small quantities, each must be examined for manifest reporting. This identification and sorting operation requires a degree of chemical expertise that the NIH Fire Department personnel do not possess.

One potential solution to the manifesting problem would be to hire a chemical waste disposal contractor capable of carrying out all the required documentation. The NIH has explored this option and is moving forward to implement it. The NIH intends to initiate contract pickup of waste chemicals in the laboratory, thereby removing the Fire Department from a task calling for a high level of chemical expertise.

Reduction of waste chemicals for disposal

Most of the preceding discussion has focused on legal requirements for disposing of waste chemicals. The ultimate goal for any hazardous waste management system is the provision of a safe work place, including the protection of both the environment and the public health. With this goal in mind, the management of the NIH has sought supplementary techniques to minimize the hazardous chemical problem at its source. It is thought that by reducing the total amounts of waste generated for ultimate disposal, the risks associated with transportation or land burial can also be minimized.

One method for reducing the total amounts of waste chemicals is to improve the chemical procurement system. Researchers should respond favorably to a purchasing system that provides quick turnaround on reorders and currently frees up valuable laboratory space previously used for the storage of excess chemicals.

Another waste reduction technique that is receiving increased attention is the inactivation of chemicals in the laboratories. Many hazardous waste chemicals can be reacted or neutralized in small batch quantities to form harmless end products that may be safely disposed of with general waste or in the sanitary sewer system. Because of the extreme variety of waste chemical encountered at the NIH, the impact of this waste reduction technique would probably be minor.

NIH is exploring one final method for the reduction of chemicals for disposal which has been discussed previously; that is recycling.

Even if all the above reduction techniques are maximized, there will be considerable amounts of chemicals designated for ultimate disposal. To further

reduce the load of chemicals leaving the facility for disposal, the NIH has explored on-site disposal in some depth.

Waste chemical incineration

In 1975, a study was undertaken to find a technology suitable for the destruction of a large fraction of waste chemicals at the site where they are generated. It soon became apparent that incineration was probably one of the most appropriate techniques for the destruction of a wide variety of chemicals. Unfortunately, it was also found that there was little operating experience demonstrated for this method of mixed chemicals waste disposal. In view of this lack of data, it was decided that the NIH would run some preliminary tests on several incinerators.

Selection of incinerators for testing

The selection of the test units was based on several factors, the most important of which was the capability of physically accepting waste chemicals in their original containers. At the time that the test units were being selected, there appeared to be several promising destruction units available that required waste materials to be in either a liquid or a finely divided granular form. These units were dropped from further consideration because of the potential aerosolization risk involved in emptying containers for feeding purposes. The units that were selected were capable of handling the chemicals in their original containers.

The selection of units was also based on a review of pertinent literature and discussions with experts in the field of incineration. From these considerations it was found that waste chemical destruction required fairly rigorous combustion conditions. Most units reviewed appeared capable of delivering sufficient combustion air and auxiliary fuel for good combustion; there were, however, considerable variations in two other very important parameters — namely, maximum temperature levels and residence time. For very refractory (difficult to oxidize) compounds such as polychlorinated biphenyls, it appeared that an incinerator must be capable of maintaining at least 2000°F with a residence time of several seconds. [2]. The residence time, sometimes called dwell time, is the time that volatilized gases from the waste remains in the combustion chambers. In general, the incinerators chosen for this study appear to have good time/temperature characteristics.

After site visits were made to a number of incinerators, five units were selected for the study. These units represented a reasonably broad range of variations of combustion chamber design, as well as variations in air pollution control devices.

Test results

In the summer of 1978, the five units were field tested for the destruction of waste chemicals. Each unit was sampled for two 4-hour burn cycles while

being fed with a controlled mix of chemicals and containers. For comparison purposes, it was important that each incinerator be fed both constant portions of chemicals in glass and plastic containers. Stack gases were sampled for particulates, unburned hydrocarbons, nitrogen oxides, sulfur oxides, hydrogen chloride, carbon monoxide, carbon dioxide, and two specific tracer chemicals. The tracer chemicals were chosen to see if any of the raw feed material escaped unaltered with the exhaust gases.

The results of the field testing were encouraging [3] (Table 1). Three of the five test units easily met the federal standard for particulate emissions from incinerators (0.08 gr/dscf at 12% CO₂) [4]. Although standards for incineration typically do not exist for the other test parameters, the units met standards set for these parameters for other combustion processes [5]. Also, the units sufficiently destroyed the two trace chemicals.

Even though the preliminary test results were quite encouraging, the NIH management feels that further, more refined testing will be necessary to develop a high level of confidence in the destruction capabilities of a particular unit. To that end, the NIH is pursuing the procurement of one of the original test units so that detailed analysis can be carried out for specific classes of chemicals.

Through such techniques as gas chromatography and mass spectroscopy, the waste gases will be analyzed for specific hazardous chemicals. Similarly, scrubber waters and residues will be given in-depth analysis for hazardous components. This testing will lead to a definition of a range of chemicals suitable for on-site incineration.

TABLE 1

Results of field investigations

Test Parameter	Unit A	Unit B	Unit C	Unit D	Unit E
1. Particulate (gr/dscf)*	0.0157	0.0045	0.1015	0.0156	0.0282
2. Particulate @ 12% CO ₂ (gr/dscf)	0.0425	0.0120	0.2452	0.0467	0.1552
3. NO _x (ppm)	12.7	24.3	29.4	24.4	14.2
4. SO ₂ (ppm)	31.2	19.9	78.6	21.9	21.0
5. H ₂ SO ₄ , SO ₃ (ppm)	14.6	0.3	24.6	8.1	3.8
6. H _x C _x (ppm)	9.1	11.2	7.1	-†	72.6
7. HCl (ppm)	<4.7	7.8	<2.4	32.6	<2.4‡
8. CO (ppm)	40.0	58.0	190.0	229.0	110.0
9. CO ₂ (%)	4.5	4.5	4.9	4.0	2.5
10. Uranine (μ gr/dscf)	0.36	<0.12	<0.20	<0.10	<0.28
11. Firemaster 680 (μ gr/dscf)	<1.5	<1.5	<2.4	<1.5	<7.0

* gr/dscf = grains per dry standard cubic foot, 1 grain = 64.86 milligrams, ppm = parts per million.

† Analyzer was not working for this test.

‡ Wherever "<" is shown - results were below the detectable limit for that test as corrected for actual flow conditions.

Conclusion

The first step in improving any system is to identify its weaknesses. Expanded research activities, changing legal requirements and newly emerging disposal technology have highlighted the need to reassess the condition of disposal operations at NIH.

The disposal system problems identified included institutional, operating, and facility problems. A growing and more complex mix of waste chemicals has demanded an unprecedented level of sophistication in their management. The present storage facility is often crowded and lacks adequate sorting and holding provisions. Chemical procurement is cumbersome and encourages the ordering of excessive amounts of chemicals. New manifesting requirements demand an increased level of effort and expertise. This compilation and definition of major system problems leads into the development of remedial actions.

The NIH is currently taking positive steps to correct many of the problems described by this paper. A new contract will provide the necessary expertise for waste chemical pickup, sorting, packing, and manifesting. Better purchasing procedures and increased chemical recycling will help reduce the total amounts of chemicals for ultimate disposal. Finally, the development of an on-site incinerator will help to mitigate the potential hazard of waste chemicals where they are generated; and additionally will provide a new, secured, temperature-controlled facility for sorting and packing waste chemicals. This new facility will be located away from the general traffic flow.

With the continued development of new regulations governing hazardous waste disposal, it is expected that the waste chemical management system at the NIH will take several years to evolve into a final, optimal system. It is recognized that some fraction of waste must ultimately be disposed of by land burial; however, by careful planning this fraction can be minimized [6]. Management will have to periodically review and update all phases of chemical handling, processing, and disposal in order to incorporate new and improved technological developments aimed at increased efficiency with protection of health, safety, and the environment.

Addendum

In the period of time since this paper was completed, the contract operation has been modified to include contractor removal of chemicals from the laboratory, daily sorting and packing of chemicals into the drums, and weekly removal of the drums from the reservation. As anticipated, this procedural change has reduced the burden to the Fire Department, allowed for better control over the management of chemical wastes in general, and alleviated crowding problems previously experienced at the storage facility. Additional steps to improve the waste management system, as were outlined in the paper, will be forthcoming.

References

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