Radioactive Waste Cost Analysis For the University of California, Berkeley

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Introduction

Over two hundred researchers at the University of California, Berkeley, use radioactive materials in their experiments. In the process, radioactive waste is generated which is picked up and disposed of by the Environmental Health and Safety (EH&S) office on campus. EH&S maintains records of all radioactive waste they pick up. The information, however, has never been analyzed in great detail, making it difficult for EH&S to determine what the disposal of radioactive waste costs the University. Even though EH&S knows the total spent on the direct costs of disposal, the office does not know how these costs are broken down by categories such as billing classes. EH&S also does not know the indirect costs involved.

The purpose of this project is to analyze the EH&S records on radioactive waste disposal in order to make a reliable assessment of the disposal costs. This report is a condensed version of a project conducted for the Hazardous Waste Management Committee (HWMC) under the supervision of Susan Belkin, formerly Senior Administrative Analyst, Chancellor's Office (Wong, 1988). The goal of the project is to find ways in which the University's costs for disposal can be reduced without compromising safety and academic excellence.

Background

In order to understand the methodology used in this study, an overview of the general flow of radiological materials and waste on campus is warranted.

1) Researchers place orders for radioactive materials, which arrive at Central Receiving.
2) An EH&S technician picks up the packages and brings them to the "Hot Lab," a small lab located in the basement of Cowell Hospital.

3) At the Hot Lab, the technician checks for leaks and damages to each package and takes radiation level readings. Each package is then opened and the inspection process repeated for the contents inside.

4) After inspection, the technician repackages the material and fills out a transmittal slip for each order.

5) The technician delivers the materials to the researchers.

6) The researchers use the materials, and radioactive waste is generated which is either stored in the lab or a central processing unit (CPU). The CPU may be a department
facility or a building facility used by more than one department.

7) When the capacity of the lab or CPU is reached, EH&S is notified, and the principal technician for radiological waste is sent to pick up the waste. The principal technician maintains a solid waste pick up log for the wastes he collects.

8) The principal technician also picks up radioactive aqueous liquid waste which is not recorded on the solid waste log. A limited volume of radioactive aqueous liquid is poured down the drain either at an authorized lab or by the principal technician. A radioactive waste pour log is maintained to record all drain disposals.

9) Radioactive waste is stored for transport to a disposal facility at the "Acid House" located across the road from the Botanical Gardens. A manifest is filled out for each shipment. The principal technician also maintains monthly reports which summarize the flow of radioactive wastes for each month.

10) The transporting company sends an invoice to the University, a copy of which reaches accounting at EH&S.

Each of these steps involves some record keeping, which provided the data for this paper. A brief description of these records will show what data are kept by EH&S.

The transmittal slips record incoming radioactive material, listing the isotope, activity, chemical form, the company from which the material was ordered, and the user who placed the order. The solid waste pick up log records what was picked up by isotope(s), activity, classes of waste, volume, and location where the waste was collected. The radioactive waste pour log records what was poured down the drain by isotope(s) and activity, and sometimes by volume. The monthly reports are maintained by Principal Technician Mark Van Valkenburgh for his records and are not an official EH&S procedure. These reports show the total radioactive waste picked up and shipped out each month by activity, volume, and class. The monthly reports are the only place where the volumes of aqueous liquid waste picked up are recorded. The manifests show the class, volume and activity of waste disposed for each shipment. The invoices show how much the University spent on the direct costs of disposal of radioactive waste and how they are broken down in terms of billing classes.

Methodology

Collecting and analyzing data along the radiological flow from transmittal slips to invoices was the main component of the methodology used in this study. Data were analyzed for fiscal year 1986-87 (FY 86-87), which is July 1, 1986 to June 30, 1987. The volumes are converted to cubic feet (ft^3), the unit by which waste disposal is charged. The radioactivity, expressed in millicuries (mCi), often determines how materials and waste need to be handled.

Although each source of data provided some valuable information, each also presented some obstacles. Table 1 lists the nine objectives of this study and the corresponding sources of information that were needed to fulfill them. Point 5 is not readily achievable with the available data. Point 7 is discussed in greater detail in Wong (1988) and due to limited time and space, points 8 and 9 are covered only in Wong (1988).

Objectives	Sources of Data
1. Compare incoming volume to outgoing volume	Transmittal slips, manifests, pour log, samplings
2. Determine common units of cost	Default
3. Determine the direct costs of disposal	Invoices
4. Break down the direct costs by billing costs	Invoices
5. Break down the direct costs by isotope	Not readily obtainable
6. Determine the indirect costs	Personal communications, accounting
7. Develop a model to do cost projections	Solid waste pick up log, pour log, monthly reports, manifests, invoices
8. Comparisons of waste generation between departments	Solid waste pick up log, pour log
9. Comparisons of costs between universities	Personal communications, tours

Table 1. The Objectives of the Report

Beginning with the incoming flow of radioactive materials, the transmittal slips show who the largest users are, the most-often used isotopes, and the incoming stock in terms of activity. The transmittal slips, unfortunately, do not show what the incoming volume is, a most crucial factor for doing a cost analysis. In order to estimate the incoming volume, two one-day samplings of incoming materials were conducted to determine an average volume for each vial of incoming radioactive substance. The first was taken on November 6, 1987, with the assistance of former EH&S Radiation Technician Trish Banks, and the second taken on March 4, 1988, with the assistance of EH&S Senior Technician Mike Capps.

The outgoing flow of radioactive waste takes two routes, drain disposal and solid waste. The radioactive waste pour log shows how much was disposed of down the drain by activity. The principal technician also records what volume he poured, but this information was not kept at the labs, rendering it impossible to determine the total volume poured. In some instances, isotopes are grouped together in each entry. Furthermore, data provided by the labs are entered as a single entry per lab over a period of time. These obstacles make it difficult to do a waste balance by activity, and impossible to do one by volume. Waste balance is needed for creating a projection model.

The second outgoing route is solid radioactive waste, which includes scintillation vials of radioactive organic liquids and biological waste. The solid waste pick up log shows how the volumes of waste are broken down by billing class and source. In most cases, the source listed in the log indicates who the generator was, but in the cases where a building CPU is used, it is impossible to determine what fractions of the waste came from which department. As on the pour log, each parcel of waste may sometimes consist of more than one isotope, in which case all isotopes and their aggregate activity and volumes are recorded as one single entry. This makes it impossible to break down the data by isotope. For this version of the study, the solid waste pick up log is not very important.

The solid wastes are eventually transported to disposal facilities about once a month, and manifests are prepared for each shipment. The manifests show the class, volume, and activity of waste disposed for each shipment. However, because one single volume is listed for all the waste packed in a drum, the volume cannot be broken down by isotope (point 5). The volume and activity listed on the pick up log do not match the values listed on the manifests. There are four reasons why this is so: the activities in both sources are best estimates because the isotopes are constantly decaying; the log does not record aqueous liquid waste picked up which may be disposed of as solid waste; packaging changes the volume; and wastes picked up in one fiscal year are not always disposed of in the same fiscal year. It is assumed that the amount of waste left over from FY 85-86 offsets the amount left over for FY 87-88. These hindrances add to the difficulty of trying to reach a waste balance.

The monthly reports summarize the pour log, pick up log, and manifests for each month. They show the total waste picked up and shipped out for each month by volume and activity broken down by billing class. The reports are the only place where aqueous waste picked up by the principal technician is recorded. The reports, however, do not break down the information by source or isotope. Over the years, the reports have had format changes and were not always maintained. Nevertheless, the information from the reports provide rough yearly comparisons of waste generated since FY 83-84.

For each manifest, there is an invoice. The invoices verify the information on the manifests and how the University's direct disposal costs are broken down by billing class. There are five basic classes--dry solid, exempted scintillation vials, regulated scintillation vials, biological, and absorbed aqueous liquid. The invoices also show what was spent on disposal supplies. A change from one transporting contractor to another during FY 86-87 complicated the data analysis. During this transition stage, seldom-used billing classes of waste, such as absorbed organic liquid, bulk liquid, and lab pack, were also shipped. In addition, EH&S disposes of some of its scintillation vials through another contractor who handles only this type of waste.

The trail of records analyzed show what the direct costs of disposal are. The final leg of the methodology involved determining the indirect costs. The indirect costs include items such as salaries and benefits, outside labor, consultants, training, maintenance, and office supplies. Information on salaries and benefits and breakdown of work loads was based on personal communications with David Belk, Supervisor, Hazardous Waste Management Unit, EH&S. The other indirect costs were obtained from summary balances dated June 29, 1987, provided by EH&S accountant, Allan Lazaroff. These summary balances break down EH&S' operational costs by items such as office supplies. The direct costs of disposal and the indirect costs of disposal make up the total cost of disposal of radioactive waste at U.C. Berkeley.

Flow Comparison

Radioactive material has a remarkable propensity to mutiply and become radioactive waste. Everything that comes into contact with a radioactive substance becomes contaminated and has to be handled as a radioactive waste. A comparison of incoming material and outgoing waste illustrates this problem.

The two samplings of incoming vials show the average volume of the content in each vial to be 0.22 ml. Assuming a density equal to that of water for all the materials surveyed, the average volume is 7.8×10^{-6} ft^3 per vial. Table 2 compares the incoming stock to outgoing waste by volume and activity. There was a total of 6,221 vials of incoming radioactive material in FY 86-87. The product of this number and the average volume per vial yields 0.05 ft^3 of incoming radioactive material for the entire fiscal year, 0.67% the volume of a 55-gal drum. The principal technician poured 824 gallons, or 110 ft^3, of radioactive aqueous liquid waste. The volume poured by individual labs is not available. The manifests show a total of outgoing solid waste volume of 2,843 ft^3. Based on the available information, the total volume of outgoing waste is approximately 3000 ft^3 or 60,000 times the volume of the incoming material.

	Incoming	Liquid Waste	Solid Waste	Total Outgoing
Activity (mCi)	11,227	200	2,793	2,994
Volume (ft^3)	0.05	110	2,843	2,953

Table 2. Comparison Between Incoming Radioactive Material and Outgoing Radioative Waste for FY 86-87

Total Costs

The total cost of radioactive waste disposal is the sum of the direct costs and indirect cost. Table 3 shows how much EH&S spent on the disposal costs in FY 86-87. The data were collected from the invoices. The University spent $93,172.16 on disposal costs. The two largest components were dry solids and exempted scintillation vials, together making up 82.5% of the total disposal cost. EH&S also spent $8,665.12 on disposal supplies minus a one time discount of $90.78 as shown in Table 4. The total direct cost for FY 86-87 was $101,746.50.

Class	Amount	Percent
Dry Solid	$47,487.39	51.0
Ex. Scint. Vials	29,344.58	31.5
Reg. Scint. Vials	5,892.08	6.3
Biological	3,070.80	3.3
Abs. Aqueous Liq.	2,754.56	3.0
Abs. Organic Liq.	925.00	1.0
Lab Pack	3,461.25	3.7
Bulk Liquid	236.50	0.3
Total	$93,172.16	100.0

Table 3 Radioactive Waste Disposal Costs for FY 86-87

Costs	Amount
Disposal	$93,172.16
Supply	8,665.12
Discount	<90.78>
Total Costs	$101,746.50

Table 4. Total Direct Costs for Radioactive Wastes Disposal for FY 86-87

The indirect costs are made up of salaries and benefits and operational costs, which are training office supplies, vehicle, and public relations and education. Outside labor and taxes are factored into the contracted prices and are therefore included in the disposal costs. Items such as telephones, duplicating, and EH&S general office supplies, are considered as general operating costs of EH&S and are not included in the indirect costs. The estimated total indirect cost for FY 86-87 is $114,450, and the estimated total cost of radioactive waste disposal is $216,200 (Table 5). The estimated indirect cost for FY 87-88 is $120,450 and the projected direct cost (see below), including disposal supplies, is $103,000. The estimated total cost of radioactive waste disposal for FY 87-88 is $223,450.

	FY 1986-87 (in 1000 dollars)	FY 1987-88 (in 1000 dollars)
Indirect Costs:		
Administrative Costs		
Salaries	$ 42.40	$ 44.10
Benefits	12.30	12.80
Technician Costs		
Salaries	29.00	31.00
Benefits	8.40	9.00
Support Staff		
Salaries	4.75	5.25
Benefits	1.40	1.50
Programmer Costs		
Salaries	7.80	8.20
Benefits	2.30	2.40
Total Salaries & Benefits	108.35	114.25
Training	1.30	1.40
Office Supplies	0.80	0.80
Vehicle	2.00	2.00
Public RelationsEducation	2.00	2.00
Total Operations	6.10	6.20
Total Indirect Costs	114.45	120.45
Total Direct Costs (Table 4)	101.75	103.00
Total Disposal Costs	$216.20	$223.45

Table 5. Total Costs of Radioactive Waste Disposal for FY 86-87 and Estimated Total Costs of Radioactive Waste Disposal for FY 87-88

Trends

According to EH&S, the volume of radioactive waste handled by the office has been *increasing* each year (Van Valkenburgh, 1988, pers. comm.). Table 6 shows the volume of waste picked up by class from FY 83-84 through the current fiscal year. The data were obtained from monthly reports. The figures for FY 87-88 are best estimates because data were available only up to January 1988. FY 86-87 figures are compiled from the solid waste pick up log, except for aqueous liquids. FY 83-84 figures are best estimates based on monthly averages because reports from three months were missing. The volumes for exempted scintillation vials were not recorded from August 1984 to April 1986 because this class was then disposed of as hazardous chemical waste. Because of these irregularities, a well-defined trend in waste generation cannot be determined from the data. There is a substantial estimated increase in FY 87-88, mainly in dry solids. Overall, the volumes of solid waste are expected to increase by 27%; whereas, the volume of aqueous liquid is expected to decrease by 22%.

Fiscal Year	Dry Solid (ft^3)	Exempt Scint. Vials (ft^3)	Reg. Scint. Vials (ft^3)	Biol-ogical (ft^3)	Total Solid (ft^3)	Aqueous Liquid (ft^3)
1987-88 (est.)	3228	780	156	60	4224	1056
1986-87	2437	762	84	37	3320	1363
1985-86	2209		262	88	2559	1486
1984-85	2243		172	31	2446	1447
1983-84 (est.)	2035	183	450	33	2701	1441

Table 6. Wastes Picked Up for FY 1983-84 to 1987-88

Projections

As noted earlier, the volume of waste picked up is not the same as the volume of waste disposed. The figures listed in Table 6 for FY 87-88 are best estimates of pick-up volumes. In order to project what the disposal costs for FY 87-88 will be, the pick-up volumes have to be converted to disposal volumes. Table 7 gives the calculated disposal volume for FY 87-88. These values were obtained by multiplying the pick-up volume by their corresponding pick-up-to-disposal (p-d) ratios.

The p-d ratios were determined by comparing the pick up volumes compiled from the solid waste pick up log to the disposal volumes compiled for the manifests and invoices for FY 86-87. The calculated disposal volumes for absorbed aqueous liquids and bulk liquids were determined from FY 87-88 monthly reports because there is no reliable way to calculate p-d ratios for these two classes.

The calculated costs are obtained by multiplying the unit price by the calculated disposal volume for each billing class. The prices are fixed under contract until April 30, 1988. The total projected disposal cost for FY 87-88 is $94,582. Again, dry solids and exempted scintillation vials are expected to account for the bulk of the costs, making up 77% of the total disposal costs.

Billing Class	Current Prices (per ft^3)	Pickup Volume (ft^3)	p-d ratio	Calc. Disp. Vol. (ft^3)	Amount	Percent
Dry Solid	$27.43	3228	2.2	1467	$40,240	43
Ex. Scint. Vials	20.67	780	0.5	1560	32,245	34
Reg. Scint. Vials	29.55	156	0.5	312	9,220	9
Biological	44.98	60	0.5	120	5,398	6
Abs. Aqueous Liq.	46.49			148	6,881	7
Bulk Liquid	39.89			15	598	1
Total Cost					$94,582	100

Table 7. Projected Radioactive Waste Disposal Costs for FY 87-88

Recommendations

From the analysis of the data, the following recommendations are made to the Hazardous Waste Management Committee regarding radioactive waste disposal at the University of California, Berkeley.

Drain disposal. It is recommended that all drain disposal be carried out by EH&S. At present, an unknown volume of radioactive aqueous waste is poured down the drain at labs authorized for drain disposal. EH&S allows each user to pour 100 uCi (0.1 mCi) per week. The University, as a generator, is allowed to pour a total of 1 Ci (1000 mCi) per year (Van Valkenburgh, 1987, pers. comm.). In FY 86-87, Berkeley poured 200 mCi of radioactive liquid waste down the drain of which 167 mCi or 84% was poured by the principal technician. For the other 26%, EH&S has to rely on the laboratories' records and reliability. EH&S is not able to test how much was poured either by volume or by activity; it is basically an honor system (Yokoro, 1988, pers. comm.). Redirecting all drain disposal to EH&S would yield a more reliable accountability. It is true that this will not stop anyone from pouring radioactive waste if he is determined to do so. Nevertheless, if radioactive waste is detetected in the sewer system, and it is not traced to EH&S, then at least the office knows there is something wrong.

Identifying generators. The solid waste pick up log should record the source of the waste by department. The ability to determine what volume of waste was generated from what department will allow EH&S to make projections of future costs. In places where more than one department shares a CPU, departmental CPU's need to be created or a CPU divided into sections, one for each department. If space is not available, then a system of record keeping needs to be established to record the source of the waste. This can be accomplished by having qualified lab workers fill out waste inventory sheets for each trip to the CPU. These sheets should be deposited in a box for the principal technician to collect. The box should be near the CPU for convenience but kept outside to prevent contamination of the contents.

Data processing. The bulk of the records on radioactive waste at EH&S are sitting on desks and in file cabinets. These records provide valuable information but are not readily decipherable unless they are entered into data bases and processed in a coherent manner. EH&S should be able to obtain on demand monthly reports of drain disposal and waste pickups. The office should know the breakdown of waste generated by department and by billing classes to be able to project costs.

Source reduction. The initial source of radioactive material multiplies 60,000 times on its way to becoming radioactive waste; it is, therefore, obvious that even the smallest reduction in use of radioactive materials can result in large reductions of waste generated. Researchers should be requested to use only what is absolutely needed and to share unused materials with each other. Although information is not available to determine how significant widespread implementation of this practice would be on waste reduction, it certainly warrants further research.

Waste Reduction. Dry solids make up the bulk of the solid waste generated (73% of solid waste picked up for FY 86-87). Most of this class of waste is made up of gloves, paper towels, and glassware. The volume of solid waste generated could be reduced if each lab worker is assigned one pair of latex gloves instead of using the often-used disposable surgical gloves. The latex gloves should be treated as personal equipment like safety glasses and should never leave the lab except in the form of radioactive waste. Disposable gloves should only be used when contamination of experimental samples is feared.

Since the transport contractor charges by volume and not by weight, costs may be reduced if smaller paper towels are used. The same concept applies to scintillation vials which make up a large portion of the disposal cost. Typically, scintillation vials are 25 ml bottles and a third full when disposed of (Van Valkenburgh, 1988, pers. comm.). The volume and, consequently, costs can be reduced signficantly if smaller bottles are used. Using 15 ml bottles, for instance, could have saved the University $14,000 in disposal costs in FY 86-87; 10 ml bottles could have saved $20,000.

Waste Diversion. The volume of radioactive waste shipped could be significantly reduced if the waste had been decayed out and treated as ordinary garbage. In FY 86-87, phosphorous-32 (P^{32}) accounted for 74% of the incoming material by weight and 57% by activity. P^{32} has a half life of 14.3 days and can be decayed out in six months. EH&S currently decays out P^{32} in scintillation vials that have only tritium (H^3), carbon-14 (C^{14}) and P^{32}. This allows these vials to be treated as exempted scintillation vials. The available data cannot show how much of the waste, particularly dry solids, is contaminated by P^{32} only. If an effort is made to segregate all radioactive waste contaminated only with P^{32} and other isotopes with short half lives (such as iodine-131 with a half life of 8 days), substantial volumes of radioactive waste can be held for decay and diverted.

There are realistic limitations to decaying out radioactive waste decay. The most obvious is the need to segregate the waste by isotope, for which EH&S will have to rely on the labs. A second factor is space, which EH&S does not have. To ensure that no radioactive waste is accidentally disposed of in the garbage, EH&S would have to test each load of waste before disposal. The major obstacle here is that Geiger counters do not detect H^3 or C^{14}; the only way to test for these two isotopes is to take time-consuming swipe samples. The time factor, however, may be offset by the time the principal technician would save from not having to prepare diverted waste for shipment nor to fill out manifests. The potential for reduction in costs is great, if not now, certainly in the near future. The idea warrants further study. It is, therefore, recommended that EH&S select two or three departments that use average volumes of materials and generate average volumes of waste and conduct a one-year pilot project to test the feasibility of implementing a waste diversion program.

Conclusions

The purpose of this project was to analyze the available data on radioactive waste disposal at the University of California, Berkeley and do a cost analysis. As simple as they may appear, the most effective means of reducing disposal cost are source reduction, waste reduction, and waste diversion. However, in order to implement the recommendations made in this paper, one crucial element needs to be addressed--cooperation from the researchers. The researchers have to agree to use fewer materials if possible, use non-disposable gloves whenever possible, fill out waste inventories correctly, agree to separate waste by isotope, etc. Although it may sound inverted, what is the purpose of reducing costs? This is a question that researchers may very well ask if they are required to follow new guidelines, not for safety reasons, but for fiscal reasons.

The main point is not how much money can be saved, but how much waste can be reduced. The cost reductions are, in fact, means of reaching the real goal. The volume of radioactive waste generated appears to be increasing as the popularity of biological science fields of study is growing. It would be in the best interest of both the University and the researchers to try to reduce as much waste as possible. Emphasis should be placed on diverting waste from landfills and applying long-term--and not yearly--planning for disposal. Working with the researchers and gaining their cooperation and knowledge are the key to this long-term process.

References

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