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METHODS OF EXTRACTING REPRESENTATIVE SAMPLES OF MUNICIPAL SOLID WASTE FOR WASTE CHARACTERIZATION STUDIES

By

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METHODS OF EXTRACTING REPRESENTATIVE SAMPLES

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FOR WASTE CHARACTERIZATION STUDIES[1/]

The Problem

A typical garbage packer truck, making pickups along residential routes in Dane County, holds between five and ten tons of waste. More than 300 such truckloads are hauled to the landfill every working day. The present paper concerns the method by which a representative sample of manageable size may be extracted from some of those trucks. An entirely different topic concerns how the representative trucks may be chosen; that will be dealt with in a separate paper.[2/]

1/ This paper was prepared during the design and execution of the first stage, or benchmark study, preceding the beginning of major recycling programs in Dane County. The work was financed under a research contract between Dane County and the Department of Agricultural Economics. Special gratitude is expressed to John Reindl, Solid Waste Recycling Coordinator for the County, to Peter Anderson, President of Recycle Worlds Consulting, to my colleague, Professor Aaron (Cobe) Johnson, and to Professors Robert Ham, Phil O'Leary and Pat Walsh, U. W. School of Engineering, for comments over recent months on my approach to the problem of sample selection. Peter Anderson and Liz Nevers also reviewed a draft of this paper; neither they nor the others named are responsible for any errors which may still remain.

2/ The single most useful source currently available on the whole subject of solid waste characterization studies is the "Municipal Solid Waste Survey Protocol," by SCS Engineers, of Long Beach, California. It was done for and published by the U. S. Environmental Protection Agency's Municipal Environmental Research Laboratory, in Cincinnati, Ohio. That study shows that the design of cost-effective resource recovery systems needs locally-derived data more accurate than the common "National averages" or "typical characteristics" found in many references. Of nine studies that documented sample extraction methods, only one (Boisseau) used the area sampling method.

The two principal methods of sample extraction are known as the "Coning and quartering" method and the "Area sampling" method. The former is generally preferred by engineers, and is taught in the solid waste engineering program directed by Professor Robert Ham, of this University. The latter is generally preferred by resource economists, perhaps in part because agricultural economists have long used a version of this method to estimate the area sown to various crops, as well as probable yields and hence probable harvests.

I. The "Coning and Quartering" Method

The traditional method among engineers, vaguely reminiscent of the "Hanging, drawing and quartering" method of brutal punishment inflicted on evil-doers in the middle ages, is quite straight-forward. The contents of a packer truck are dumped into a pile and shoved into a cone with the aid of an end loader. The end loader operator then eye-balls the pile and separates out a slice, top to bottom, that appears to be about one fourth of the pile. The remainder is discarded.

The waste in this "slice" is then pushed up into a new cone-shaped pile, and the process is repeated, various times, until the last "quarter slice" is thought to be the amount desired.[4/] In the "Coning and quartering"

[4/] The SCS Engineers Study suggests that 200 to 300 lb. is a desirable sample size. Little is gained in representativeness by taking larger samples, and smaller samples were thought likely to be extracted by biased methods. We believe the area or grid method eliminates that bias, but we still sought to approximate 200 lb. samples as an ideal. Our actual samples turned out to average somewhat less, in part because we divided the trucks into 80-cell grids for sample selection, but some of the trucks, on afternoon routes, were not full.

method, all of the work of sample extraction is done by the end loader, and no workers need touch any of the waste other than the final sample. That final sample is carried off by the end loader to the place where it will be sorted by hand into its components for the waste characterization study.

II. The "Area Sampling" Method

In the area sampling method, the contents of a packer truck are dumped by the driver onto a concrete floor or a designated area of the landfill. Typically, the driver moves the truck forward as the waste is pushed out, leaving the waste in a ridge about the length and height of the truck. An end loader is then used to push the waste into a bread-loaf shape, roughly rectangular and not more than a yard (about 0.9 meters) high. A packer truck containing nine short tons (18,000 lb. or 8,200 kg.) of waste typically produces a "bread loaf" about 32 feet (10 meters) long and about 12 feet (4 meters) wide, with all four sides sloping at about a 45 degree angle.

Now, the methodological problem is to select a representative sample of the waste in each truck, in such a way that every bit of the waste in the truck has an equal a priori probability of being selected. This requires mapping and the use of a random number table to select cells and sub-cells, of waste.

In the Area Sampling method, a grid is laid out over the waste with twine strung between fence posts or stakes. For example, 20 cells may be produced by using six posts on each side and five posts on each end. Each of these cells may be further divided into four sub-cells, with twine and a tape measure, giving a total of 80 units to choose from.

At the same time, the cost of sampling and sorting is sufficiently high that one wants to be fairly sure that the cells chosen by a random selection process cannot all happen to fall into a "tail" of a probability distribution. That is, one does not want successive random numbers to be able to come up -- by chance -- with several cells adjacent to each other. Nor, because the waste tends to tumble, sift, or otherwise sort itself out a bit when it is handled by the end loader, does one want to wind up with cells only on the outside edge of the truckload, nor only from the center of it.

Thus instead of selecting just one cell out of the twenty into which the truckload has been mapped, it was decided to select four sub-cells, chosen in staggered rows that ensured that two samples would come from the edge or near the edge of the pile, and two would come from well toward the middle of it.

In the Dane County Waste Characterization Study carried out in late 1990, reasoning based on the cost of sampling and the logistics of choosing the representative sample of trucks led to a decision to extract four samples averaging 120-125 lb. (about 54 kilos) from each truckload.

The cells in the map (twenty actual cells, each divided conceptually into four sub-cells), were numbered from 1 through 80. A table of random numbers was then generated by a portable computer, and a researcher with eyes closed stabbed the table. The first two digits which fell in the range of 01 through 80, to the right of the point stabbed, determined the first sub-cell to be extracted from that truckload, and the other three subcells selected were those that were higher and lower by increments of 20, from the subcell selected first.

The technique may be made clearer with a simple map (Figure 1). If the random number turned out to be 39, then the samples from this truckload were the contents of subcells 19, 39, 59 and 79. Since the cells were numbered 8 across, and the chosen increment was 2.5 rows, the method made it fairly likely that the selected cells would include both some cells near or at the edge and some cells well in the center of the truckload.

Once the sample subcells were thus identified, the sample crew climbed onto the waste pile and extracted the contents of the chosen subcell, all the way down to the floor or ground, placing handfuls of waste on a small plastic tarp next to the cell. This was in turn carried to a larger tarp on the floor next to the load. Some adjacent waste inevitably fell into the hole as extraction proceeded; such intruding materials were simply thrown back out.

Inevitably, large objects would be both in and out of the chosen cell. A simple decision rule was used, adopted before sampling began: if the item (a large plastic bag, piece of canvas, ironing board, or whatever)[5/]

[5/] The crew called large items "dead horses" (Peter Anderson's term). Actually, we saw no animals larger than a very dead raccoon. Solid waste facility workers told us live raccoons turn up in packer truckloads, as do

Figure 1

MAPPING A TRUCKLOAD OF SOLID WASTE

Each cell is approximately 0.5 meters wide and 1.0 meters long. Loads may vary; cell size is adjusted proportionately so 80 cells cover the load.

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	**19**	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	**39**	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	**59**	60	61	62	63	64
65	66	67	68	69	70	71	72
73	74	75	76	77	78	**79**	80

Aerial view of waste pile. Four samples are to be extracted. Thus the interval is 80/4 = 20. If cell 39 is chosen by a random number generator, cells 19, 59 and 79 are also selected, ensuring that samples will be drawn from the center as well as from the sides and ends of the load.

fell across the cell edge toward the North or East, it was defined as being entirely IN the sample. And if it fell across the cell edge toward the South or West, it was ruled entirely OUT of the sample, and was tossed to one side. Again, for something to qualify for application of the decision rule, the staffer had to judge that at least 10% of the large item was over the line.

One special problem occurs with trucks from industrial and some commercial collection routes: a relatively large part of a truck load may be made up of just one kind of waste. For example, a store might dispose of a hundred used bicycles accepted as "trade-ins" but not actually saleable. In the first phase study of Dane County waste, one truckload was largely made up of flattened corrugated cardboard boxes. (If the recycling program is successful, of course, that will not happen again because corrugated cardboard is one of the materials to be recycled right from the start.)

Evaluation

This team has now extracted forty samples by the Area Sampling method, plus four samples extracted by this method as a class exercise six months earlier. The main problem encountered was the difficulty of working straight down, clear to the floor, when the sample fell in the higher parts of the truckload. At times, it was necessary to dig in from one side of the cell. In such cases, it was important that the worker take care to put that

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smaller rodents. If a live animal had appeared in a sample, but fled before we could weigh it, we would have had an interesting methodological problem.

material to one side, so that the sample would still only include the waste that was in the original cell that was chosen statistically.

One obvious disadvantage of the Area Sampling method is that the sample must be extracted by workers, who must climb onto and into the waste pile. This requires boots, gloves and safety equipment such as goggles and hard hats; it still exposes them to some risk of cuts or needle injuries.[6/]

One apparent advantage of the Area Sampling method over the Coning and Quartering Method is that most of the plastic bags and glass bottles were unbroken, greatly facilitating their sorting into the designated barrels. It also appears that the material in the "breadloaf" was fairly consistent from top to bottom and edge to center. That is, because the material was only pushed around once by an end loader, and that only at the center, which was spread out somewhat, there appeared to be little tendency of fine material to sift downward to the ground. The "Coning and Quartering" method tends to break bags and bottles, according to those who have used it, and some fine material tends to remain behind each time a "quarter" slice is extracted.

Both methods have the necessary property that the selection of the sample leaves little room for an arbitrary decision by the humans working as sorters. Waste facility workers told us they had watched other, earlier

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[6/] In the December 1990 benchmark study just done for Dane County, forty cells were extracted over three days with only one injury. That was a minor scratch on a finger, which the worker believed came from a tin can, slicing right through a cotton glove. Ten needles, apparently discarded by diabetics, appeared in the entire forty samples. All told, we sorted some three tons, or 6,000 lb. of waste (about 2,700 kg.), in this benchmark study.

studies in which it appeared to them that the sorters simply waded into a pile and pulled out a sample quite arbitrarily, calling this a "random" sample. That procedure is unscientific; it greatly increases the probability that specific items will be included because the sorters think they are interesting or fun, or excluded because the sorters know that handling them will be messy and unpleasant.

Conclusions

The Coning and Quartering method is less expensive in crew time, involving only one end loader and operator. On the other hand, the Area Sampling Method can be carried out with no machinery or machine operator, once the selected truckloads are dumped and leveled on the concrete floor. In the Dane County study, sample extraction was done in the late afternoon, taking all the time necessary to do it right, after most of the regular solid waste facility staff had left for the day.

The Area Sampling method is definitely harder work, forcing workers to climb onto and into the waste pile, instead of relying on an end loader to extract the sample. With waste that was thought to have a significant quantity of needles or other dangerous components, the choice would probably have to go to Coning and Quartering.

In its favor, the Area Sampling method greatly reduces the risk of waste stratification during the repeated pile formation and separation by an end loader. There is little chance in the Area Sampling method for items to roll into or out of the sample, or for fine material to sift to the bottom and be left behind as each quarter is extracted and shoved into a new cone-shaped pile.

Both methods are far more scientific than the amateurish method of simply shovelling out a "sample" at whatever point in a pile is most reachable. This "method" also virtually guarantees non-representativeness, as the "sampler" chooses interesting items and excludes messy or unpleasant items that he or she does not want to have to sort.[7/]

The present author believes that the Area Sampling Method is scientifically superior to the Coning and Quartering Method, for extracting representative samples of solid waste. Even taking time and cost into account, on balance, and for relatively non-dangerous waste such as that found in Dane County, I believe that the Area Sampling Method is preferable.

Ideally, if funds permitted, one would want to do further research through carefully controlled tests of both methods applied to portions of the same day's solid waste collection. That would suggest a definitive answer as to whether the area sampling method's presumed greater reliability is worth the extra effort involved.

Comments and the views of other researchers are sincerely invited.

[7/] The SCS study suggests that such "eyeballing" methods, even when done with no bias to make the work easier or more interesting, tend to favor the selection of what looks like household garbage, which samplers believe to be "representative." That produces a bias against corrugated cardboard or other large items, and against all items typical of commercial and industrial waste.

References

Boisseau, H. J. "Logistic and Economic Factors Affecting the Reclamation and Recycling of Waste Material and By-Products; Interim Report." Washington, D. C.: Logistics Management Institute, 1976, 82 pp.

SCS Engineers, "Municipal Solid Waste Survey Protocol." Cincinnati, Ohio: Municipal Environmental Research Laboratory, U. S. Environmental Protection Agency. 196 pp. plus appendices; no date, but approximately 1979.