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Representative Sampling of Drug Seizures in Multiple Containers

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ABSTRACT: Exhibits of illicit drugs in a large number of containers are frequently submitted to crime laboratories. The forensic chemist often needs to select randomly and then examine a number of these containers to provide information regarding the composition of the overall exhibit which is sufficient to support the requirements of the criminal justice system. Although various methods of sampling can be shown to provide samples that will allow statistical inferences to be made with a high degree of confidence, no procedure has been identified that specifically meets the sampling objectives associated with an exhibit of this sort.

The authors have addressed this sampling problem by applying the probability theory of the hypergeometric distribution to the sampling of drug exhibits contained in multiple containers. The resulting model will permit strong probability statements to be made regarding the presence of the controlled substance in a predetermined quantity of the exhibit, thereby supporting the prosecution and sentencing of violators of controlled substance laws.

KEYWORDS: toxicology, controlled substances, sampling, probability, hypergeometric distribution

The concept of representatively sampling an exhibit of evidence to demonstrate its composition when it consists of a number of individual packages or units, rather than testing each and every unit, has been utilized for many years. Limited resources and backlogs of unanalyzed evidence predicate using a representative sample, one that will permit the forensic scientist to present information about the composition of an exhibit of evidence which will be sufficient to demonstrate fact beyond a reasonable doubt. In addition, personal safety and health considerations require that the forensic scientist minimize contact with evidentiary material as much as possible. As exposure to controlled substances or biohazard evidence increases, the chance of accidental ingestion of controlled substances or contact with biologically contaminated evidence increases.

Random sampling procedures are universally accepted by the courts and have been upheld under challenge. Three notable decisions upholding the use of representative samples with respect to drug exhibits in Federal courts are *U.S. v. Webster,* 750 F.2d 307 (5th Cir. 1984); *U.S. v. Maceo,* 873 F.2d 1 (1st Cir. 1989); *and U.S. v. Powell,* 886 F.2d

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81 (4th Cir. 1989). There are also a significant number of state citations involving challenges to the reliability of drug sampling procedures [*1–31*] (Table 1).

When deciding to sample representatively drug exhibits which are comprised of multiple packages or units, one must provide strong evidence regarding the presence of a controlled substance in the exhibit. In addition, guidelines and policy statements promulgated by the United States Sentencing Commission [*32*] establish sentencing policies and practices for the Federal criminal justice system that tie specific quantities of controlled substances to base offense levels, and these permit the court to impose particular lengths of sentence. Such policy makes it all the more critical that the evidence be strong. The main issue becomes how to determine what size of sample is sufficient to demonstrate the composition of the entire exhibit with reasonable scientific certainty.

Various methods for selecting a random sample from an exhibit of drug evidence have been accepted by the courts [*1,2,6–29,31*]; however, these methods did not allow the use of a preestablished standard of statistical probability. The method that follows provides such standards in the form of confidence levels. Accordingly, it permits strong probability statements to be made regarding the portion of the exhibit that contains a controlled substance. It is based on the hypergeometric probability distribution, whose theoretical basis is described in Refs *33* and *34*.

TABLE 1—*Cases challenging the reliability of drug sampling procedures.*

Reference	Case
[*1*]	*State v. Myers*—approving random testing of 20 methaqualone tablets out of 30 241 seized
[*2*]	*State v. Wilhelm*—approving random testing of 3 methaqualone tablets out of 5000 seized
[*3*]	*People v. Ayala*—disapproving testing of only 1 bag of heroin out of 2 seized
[*4*]	*Sims v. State*—disapproving testing of four 1-g samples of marijuana not shown to be representative of 4 seized bales weighing 170 lb (77 kg)
[*5*]	*People v. Games*—disapproving testing of only 1 bag of marijuana out of 2 bags seized, where the chemist forgot to give an expert opinion as to the second bag
[*6*]	*State v. Miller*—approving random testing of 1 amphetamine pill out of 100 seized
[*7*]	*People v. Newell*—approving random testing of 3 small samples of marijuana from 609 g seized
[*8*]	*Kenny v. State*—approving random testing of 24 samples, each weighing 20 to 120 g, from 24 bales of marijuana, totaling 1589 lb (721 kg)
[*9*]	*People v. McCord*—approving random testing of 100 amphetamine tablets out of 10 000 seized
[*10*]	*State v. Absher*—approving random testing of 5 phencyclidene tablets out of 400 seized
[*11*]	*People v. Yosell*—approving random testing of 16 capsules of barbiturates out of 1000 seized
[*12*]	*Dixon v. State*—approving random testing of 1 sample, weighing 0.1 g, out of 29.7 g of marijuana seized
[*13*]	*State v. Hayes*—approving random testing of 5 small samples of marijuana out of 19 envelopes containing a total of 56 g
[*14*]	*People v. Kline*—approving random testing of several grams of marijuana out of 500 g seized, and random testing of several capsules of lysergic acid diethylamide (LSD) out of 3 bags of capsules seized

TABLE 1—*Continued.*

Reference	Case
[15]	*State v. Hill*—approving random testing of 15 small samples of marijuana cut from 15 packages seized, totaling 15 lb (6.8 kg)
[16]	*People v. Schmidt*—approving random testing of 4 small samples of marijuana out of 4 bags seized, totaling 71 g
[17]	*State v. Edwards*—approving random testing of 1 small sample of marijuana out of 120 g seized
[18]	*People v. Hering*—approving random testing of 30 LSD capsules out of several bags seized, totaling 18 g
[19]	*Ansley v. State*—approving random testing of 1 small sample of marijuana out of 11 g seized
[20]	*State v. Wooten*—approving random testing of 4 small samples of heroin out of 4 of 19 bags seized
[21]	*Waldrup v. State*—approving random testing of several capsules of barbiturates out of 24 seized
[22]	*State v. Bowers*—approving random testing of 11.2 lb (5 kg) of marijuana out of 10 bricks, totaling 246 lb (112 kg)
[23]	*State v. Jester*—approving the testing of 2 bags of heroin randomly acquired from a cache of more bags that could not be seized
[24]	*State v. Vigil*—approving random testing of 1 small sample of marijuana out of a mixture of 4 bags seized, totaling 394 g
[25]	*State v. Clark*—approving random testing of 1 small sample of marijuana out of a mixture of 4 bags seized, totaling 20 g
[26]	*People v. Ohley*—approving random testing of 6 LSD tablets out of 89 seized
[27]	*State v. Hults*—approving random testing of several small samples of marijuana out of several of 40 bricks, 1 kg each, seized
[28]	*Vaugh v. State*—approving random testing of 1 bottle of Robitussin A/C out of 180 seized
[29]	*State v. Mosier*—approving random testing of 6 LSD pills out of 65 seized
[30]	*Fierst v. Commonwealth*—disapproving random weighing of only 20 codeine tablets out of 100 seized, where the chemist's estimate of the total weight of codeine was merely 0.25 g above the statutory minimum weight, resulting in a substantially longer prison term
[31]	*State v. Riera*—approving random testing of 3 barbiturate tablets out of 205 seized

Sampling Objective

The initial consideration is to determine what confidence level or levels should be employed in the sampling. For the composition of the entire exhibit, it should be sufficient to demonstrate with good probability that most of the exhibit contains the controlled substance. This should be the sampling objective. An inference, made at the 95% confidence level, that 90% or more of the packages in an exhibit contain the controlled substance should be accepted as sufficient proof in such cases. The combination of these principles and the experience of the forensic scientist should enable a conclusion to be made with reasonable scientific certainty about the contents of the entire exhibit.

The Appropriate Statistical Model

Essentially, the sampling problem can be characterized in the following manner. A population of N packets contains N_1 "positives" and $(N - N_1)$ "negatives." It is desired that a sample of size R be drawn and the number of positives in it, t_p, be observed. It is necessary to know in advance what value of t_p will be sufficient for rejecting a null hypothesis that N_1 is less than K and accepting instead an alternative hypothesis that N_1 is greater than or equal to K, where K is some predetermined value. In practice, K may be derived in a variety of ways, depending on the sampling objective. For example, it could be derived in a manner that ensures that the weight of any K packages in the population will meet or exceed some target weight of interest. Throughout the present discussion, K will be assumed to have a value equal to 90% of N.

If T represents the random variable generating the number of positives, t_p, that would be observed if a large number of samples were taken from the population; Then, the required probability statement is

$$P[T \geqq t_p | N_1 < K] \leqq \alpha \tag{1}$$

in which α represents some probability that may be made arbitrarily and suitably small. By way of explanation, this probability statement ensures that there will be only a small probability of observing a value of T that is greater than t_p when N_1 is actually less than K. In other words, with t_p suitably chosen, we would expect to be wrong about the target amount (K) being exceeded only a small percentage of the time, namely, $100\alpha\%$.

Clearly, Eq 1 can be rewritten as

$$P[T \geqq t_p | N_1 \leqq K - 1] \leqq \alpha \tag{2}$$

Since the left side of Eq 2 decreases as N_1 decreases, any set of conditions that will satisfy the equation for a value of $N_1 = K - 1$ will also satisfy the equation for smaller values of N_1. Accordingly, it will be sufficient to examine only the special case of Eq 2, given below.

$$P[T \geqq t_p | N_1 = K - 1] \leqq \alpha \tag{3}$$

that is, the case for which $N_1 = K - 1$ or the case in which the exhibit actually contains one fewer positive than the target number of containers.

To reduce this equation to its simplest terms, making use of the hypergeometric probability distribution results in Eq 4.

$$\sum_{i=t_p}^{R} \frac{\binom{K-1}{i}\binom{N-K+1}{R-i}}{\binom{N}{R}} \leqq \alpha \tag{4}$$

If the sample is expected to contain all positives and one wishes to determine the smallest—and therefore the most economical—sample size in such situations, Eq 4 can be further simplified by letting $t_p = R$ and reducing it as demonstrated in Eq 5.

$$\frac{(K-1)(K-2)\ldots(K-R)}{N(N-1)\ldots(N-R+1)} \leqq \alpha \tag{5}$$

Equation 5 can easily be solved for the minimum value of R by forming the required product in stages and observing the point at which the product drops below α for the first time. The point at which this occurs would identify the required value of R.

Of course, the solution obtained from Eq 5 is applicable only to those situations in which the entire population of packets probably consists of positives. If one negative is found in the sample, it could not be concluded that the target amount (K) had been exceeded. In such cases in which it is advisable to allow for the fact that some negatives might be observed in the sample, the hypergeometric probabilities in Eq 4 could be used to solve for the required value of R. In so doing, it will be necessary to make some implicit assumptions regarding the number of negatives that should be expected in the sample.

The exactness of such assumptions is not that critical. If no (or fewer than the expected number of) negatives are observed, the desired proof has been obtained. On the other hand, if more than the expected number of negatives is observed, further sampling can be performed. In such instances, it would even be appropriate to draw a second sample, reducing the value of K by the number of the positives actually found in the first sample, as illustrated in one of the examples below.

Application of the Model

This consists of two basic steps or determinations:

- use the statistical model to determine the sample size, R, and
- perform the presumptive tests.

Determination of Sample Size, R

In actual application, automated routines may be required to assist with the determination of the required sample size (R). However, for present purposes, a table such as Table 2 can be used to illustrate the manner in which sample sizes can be determined with or without provision for the possibility that some of the presumptive tests in the

TABLE 2—*Sample sizes* R_0, R_1, *and* R_2 *required to demonstrate that a controlled substance is present in* K *of* N *containers given that 0, 1, and 2 negative test results, respectively, are observed in the sample.*

N	K	R_0	R_1	R_2
70	35	5	7	10
70	50	8	13	18
75	25	3	5	7
75	60	12	19	35
100	20	2	4	5
100	80	12	20	26
110	100	26	39	51
120	60	5	8	10
120	90	10	16	21
125	111	24	38	50
130	10	2	3	4
130	60	4	7	9
140	50	3	6	8
140	70	5	8	10
150	135	25	39	50

sample fail to detect the controlled substance. This table provides information regarding sample sizes that would be required to demonstrate that an exhibit contains at least the target number of drug-containing packages (K) with 95% probability. Values of R_0, R_1, and R_2 are determined from Eqs 4 and 5. The table is formatted as follows:

1. The first three columns are labeled N, K, and R_0, respectively. R_0 represents the sample size required to demonstrate the fact that a collection of N packets contains at least K positives in those situations in which the forensic scientist's experience indicates the sample can be expected to contain all positives.
2. The fourth column displays values of R_1 which represent the sample size required to demonstrate the fact that a collection of N packets contains at least K positives in those instances in which the sample can be expected to contain no more than one negative.
3. The fifth column displays values of R_2 which represent the required sample size when no more than two negatives can be expected in the sample.

The values of R_0, R_1, and R_2 are calculated using the minimum value of R for which Eq 4 is true. The following example demonstrates how to determine the required size R:

> *Example:* Suppose that an exhibit of suspected cocaine base is contained in 150 vials and that it must be demonstrated that at least 135 of the vials contain cocaine base.
>
> Then from Table 1 it can be seen that for a population size of 150 and a K-value of 135, a sample size of $R = 25$ is required by the model.

Presumptive Testing

Once a determination has been made to use representative sampling techniques for the exhibit, the required number of packages should be subjected to presumptive testing. If the sampling option had not been chosen, this would entail presumptively testing and observing positive results for packages until the target amount is achieved. If the sampling option had been adopted, it would involve presumptively testing the R packages chosen as a random sample and observing an appropriate number of positive results in the sample. Representative sampling allows the presence of the substance in most of the exhibit to be claimed with a high level of probability (exceeding 95%) as opposed to the virtual certainty of its presence in the entire exhibit if enough packages are tested to exceed the target amount.

Note that if sampling fails to produce the required number of positive test results, a second sampling can be performed based on a target weight that is reduced by the weight of the positively tested packages observed in the first sample.

> *Example:* Continuing with the same example used previously, recall that a sample size of 25 was proposed for demonstrating with a high level of probability that 135 of 150 packages contain cocaine base. If all 25 packages test positively for the presence of cocaine during the presumptive testing, the required proof is obtained. If, however, one of the packages tests negatively, the evidence based on this sample alone is not conclusive and a second sample will be required. The most economical way to conduct this additional sampling would be to randomly select an additional, smaller sample from the remaining 125 of the original 150 containers. The purpose of this second sample should be to demonstrate that $135 - 24 = 111$ of the remaining collection of 125 packages contains cocaine base. Using logic similar to that used in generating

Table 1, it can be shown that a sample of about 24 would be required. However, since another negative test result in the sample might result in an inconclusive finding, the sample size should be increased to about 38. If the resulting analysis of the sample includes one or fewer negative test results, the required target weight has been successfully demonstrated and, hence, the case is proven.

Of course, had the presence of negative test results in the sample been anticipated, the original sample size could have been increased from 25 to about 39 to make allowance for that possibility, in which case the second sampling might have been avoided altogether.

Summary

A procedure for selecting a representative sample from multiple package controlled-substance exhibits has been described which should meet the needs of the criminal justice system. The procedure, which applies the probability theory of the hypergeometric distribution, provides a model that permits strong probability statements to be made regarding the presence of controlled substance in a predetermined quantity of the exhibit, thereby supporting the prosecution and sentencing of violators of controlled substances laws.

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