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Representative Sampling of "Street" Drug Exhibits

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ABSTRACT: The value of a scientific analysis and the significance of the results are influenced by the degree to which the sample analyzed reflects the composition of the material or population under study. An appropriate methodology will result in representative sampling.

Formulae for representative sampling protocols were evaluated, and an optimal formula to be used in a sampling plan for "street" drug exhibits with a large number of units was selected. The selected formula was applied to choose a number of sample units for routine chemical analysis of controlled substances, with the analytical result considered to be representative of the entire lot of powdered drug units in the exhibit.

The results obtained during the research demonstrate that adoption of the formula $n = 20 + 10\%(N - 20)$ [where n = sample size, N = total population ($N \geq 20$)] can be used for selection of an appropriate representative sample from powdered street-drug exhibits. This sampling procedure results in forensic analyses of controlled substances which are supportable to a reasonable scientific certainty, and which are obtained in an efficient manner.

KEYWORDS: criminalistics sampling, controlled substances, powdered material

Over the past few years the abuse, availability and quality of controlled substances have been increasing within all social spheres. Recently, the newspaper "El Nuevo Dia" published an article about the expanding street-drug market in Puerto Rico; reference was made to cocaine salt, "crack" (cocaine base) and heroin [*1*]. This increase was well reflected in the amount of drug evidence submitted to the laboratory by law enforcement agencies. For example, the Institute of Forensic Sciences of Puerto Rico received 12 401 more units of powdered drugs in 1990 than in 1989 (Fig. 1), with cocaine being the controlled substance that registered the largest increment.[2]

Exhibits of controlled substances are received by the laboratory in large number and in a variety of small containers. At present, our forensic drug chemist performs a qualitative analysis where the only option is to test each unit, individually. This expensive procedure could be obviated if a representative sampling plan is established to assist in the accurate and efficient chemical analysis of street drugs. The laboratory report will

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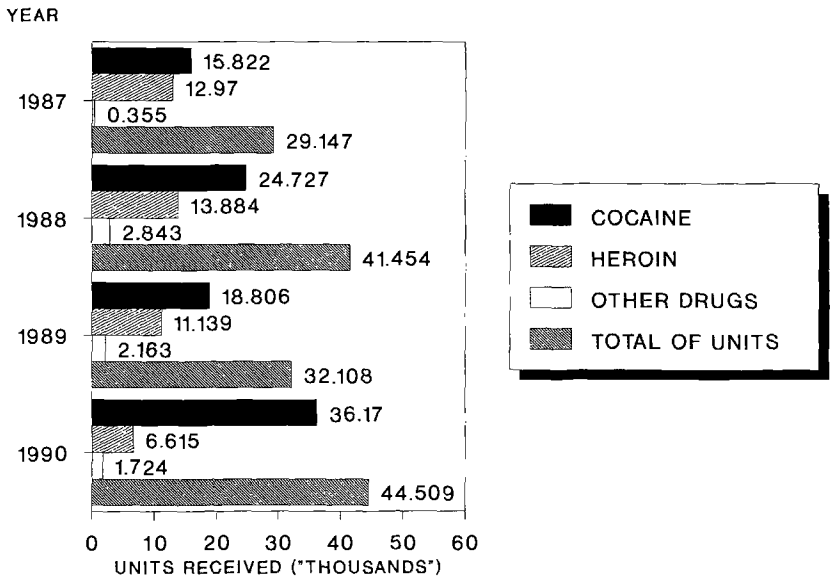

FIG. 1—*Units of powdered drugs received by the Institute of Forensic Sciences from law enforcement agencies.*

then provide the results regarding the composition of the population based on this representative sample. Some of the benefits of a sampling plan are to:

1. Reduce the number of analytical determinations needed.
2. Reduce overall workload.
3. Decrease exposure (oral, nasal and cutaneous) to controlled substances.
4. Reduce handling of biologically contaminated evidence.

A variety of sampling plans or procedures are being used or recommended by several forensic laboratories around the world. For example, colleagues in Australia, Austria, Canada, England, Hong Kong (China), New Zealand, Northern Ireland, Switzerland and the U.S.A. revealed different methods in place.[3] These plans were derived from work experience, military standards, statistical models and recommendations from the United Nations Division of Narcotic Drugs or the United States Pharmacopeia [*2–5*]. The plans used by these countries had never been selected or adopted by any forensic science laboratory in Puerto Rico.

In the process of selecting an existing sampling plan its evaluation before use would be considered. The plan can be effectively supported when it is evaluated, to define the scientific certainty to be expected using the method. This is very important, because when a forensic laboratory adopts a plan there inevitably will appear questions about the influence of this plan on the final results. The investigation of a sampling protocol will require an evaluation of characteristics and variants from populations (multi-unit exhibits) that come from an unstable environment; drug evidence from the streets. If the exhibit is homogeneous, any sample taken would be representative. However, with street drugs, often little is known about their origin and preparation.

This scientific investigation of representative sampling methods for powdered drugs was conducted between 1989 and 1991. It was based on street-drug populations at the

[3]Personal communication (interviews, mail or telephone) with 32 forensic laboratories around the world.

local level, specifically the criminal community in Puerto Rico. The main purpose of this investigation was to support a sampling procedure to be used by the Institute of Forensic Sciences (IFS). In addition, it was important to maintain the results of the forensic drug analysis within the necessary certainty to be presented in laboratory reports as well as during expert testimony in courts of justice.

Population

The Controlled Substances Section of the IFS receives for analysis all the drug evidence purchased or seized in Puerto Rico by local law enforcement agencies. The evidence is related to the possession, consumption, manufacture, traffic, distribution, and/or sale of controlled substances. A large percent of this physical evidence is composed of drug units in powdered form received in a variety of containers. Figure 2 shows graphically the relation between powdered drugs and other drug units (liquids, capsules, tablets, plant material, etc.) received for analysis during the past four years.[2]

Each population considered by this investigation is finite; the number of sampling units is limited. It is defined as a street-drug exhibit, purchased or seized at one time and location, and whose elemental units are small containers (bags, wrappings, vials, etc.) Each unit contains controlled substances (cocaine, heroin, etc.), diluents, and adulterants in powdered form.

Selection of the Sampling Formula

One of the most difficult tasks in an investigation about sampling is to determine the number of units that must be selected to represent the population. Analysis of a large number of units will limit the efficiency of a sampling plan, whereas analysis of a very small number of units would reduce the certainty of the results.

In the quest for an appropriate sample size, different sampling plans used by government and private laboratories around the world were evaluated. It was also necessary to

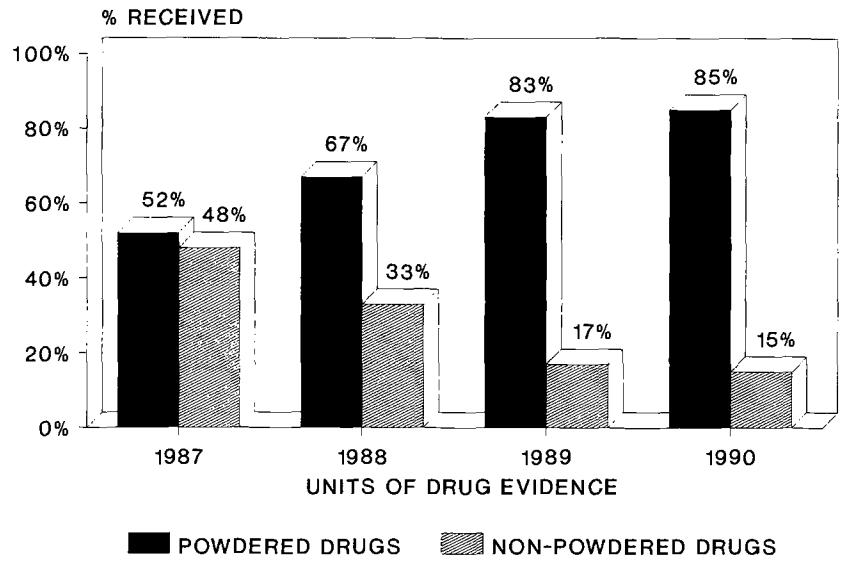

FIG. 2—*Comparison between drug units received for analysis: powdered versus non-powdered.*

gather information concerning work experience in our laboratory (as well as others) related to controlled substances analysis. Table 1 presents a variety of sampling formulae recommended or used in several countries to select a representative sample for forensic drug analysis.[3]

Once the information and plans were obtained and evaluated, it was found that the majority of forensic science laboratories determine a representative sample (n) of a population (N) based on one of the two following formulas:

1. $n = \sqrt{N}$
2. $n = 10\%(N)$

It was noticed that these laboratories select representative samples based on no more than 10% of the whole population, especially in cases in which a random sample is made from populations containing more than 100 individual units ($N > 100$).

Considering the findings mentioned, it was possible to start preliminarily with the selection and evaluation of a sample size that was equal to or larger than the one used by the countries mentioned before. It was decided to evaluate a sampling formula based on 10% of each population, for the selection of sample units to be analyzed. Thus, the formula $n = 10\%(N)$ was applied to determine the size of the representative sample during this investigation.

Sampling Procedure

During the investigation, 173 exhibits were obtained from 85 criminal cases suspected by narcotic agents of containing illicit drugs. A total of 19 994 units containing alleged powdered drugs were available for forensic chemical analysis. For the purpose of data evaluation and comparison, each population was classified by unit interval (Table 2).

Initially, a visual examination was conducted to evaluate the physical characteristics of all units in the population. The investigators took into consideration the type of container, material, color, approximate size, label or stamp, and the physical appearance of the contents, whenever possible. If all units (containers with powdered material) were equal in appearance, the population was considered preliminarily homogeneous. On the contrary, if the units were different, all of those presenting the same visual characteristics were grouped together, obtaining various sub-populations independent from one another.

Once a homogeneous population was obtained, the units were counted. The formula

TABLE 1—*Sampling formulae used or recommended by several forensic science laboratories in some countries. These formulae are involved in the chemical analysis of controlled substances.*

Sampling Formula	Country (Number of Laboratories)[a]
1) $n = \sqrt{N}$	Australia (1), Austria (1), Canada (4), England (2), New Zealand (1), Hong Kong (1), Northern Ireland (1), U.S.A. (3) and U.S.A. Army-Europe (1).
2) $n = 10\%(N)$	Australia (1), Canada (1) and U.S.A. (3)
3) $n = 4\%(N)$	England (1)
4) $n = \sqrt{N}/2$	Switzerland (1)
5) Statistical model based on hypergeometric distribution.	U.S.A. (2)
6) $n = 1$ unit for any N.	U.S.A. (1)
7) $n = 4$ units for any N.	U.S.A. (1)
8) $n = 15$ units for any N	U.S.A. (1)

[a]Total number of laboratories: 27

TABLE 2—*Unit interval used to classify the populations under study.*

1–10
11–50
51–200
201–500
501–1000
>1000

$n = 10\%(N)$ was then applied to determine the representative sample upon which qualitative analyses of controlled substances were performed (Fig. 3, upper portion). The units were randomly selected from the population under consideration. In this way, each unit had the same opportunity or probability to be chosen. The first 10% selection was given the denomination S_1. The population was then exposed to three additional random selections (S_2, S_3, and S_4) of 10% of the original units in the population without unitary replacement. Finally, the nonselected units were grouped together to be analyzed in the same way as S_1, S_2, S_3, and S_4. This nonselected group was given the denomination "remainder."

The S_1 units were individually analyzed using traditional wet chemistry methods such as color, precipitation and microcrystal tests. If the test results were the same for all units, a composite was prepared for analysis by ultraviolet/visible spectrophotometry and gas chromatography. Liquid extraction, column chromatography and/or thin layer chromatography were used to eliminate substances which interfered with the test results. The drug analyses were performed in accordance with our routine analytical methodologies, which are generally accepted by the forensic scientific community.

The results of each test were recorded on the Qualitative Analysis Form (Fig. 3, lower portion). Then, the units of each subsequent selection (S_2, S_3, and S_4), as well as the "remainder" of the population, were analyzed under the same procedure as that used for S_1. Thus, the entire population was tested (as aggregates). The analytical results obtained in S_2, S_3, S_4, and the remainder, were utilized to validate those in S_1. If all the results were the same (all positive or negatives) for all selections and the remainder, it would be possible to infer that a sample size based on 10% would represent a population during a forensic drug analysis.

Results and Discussion

During the investigation, 85 criminal cases, containing 173 drug exhibits with a total of 19 994 powdered units, generated 238 different populations. A total of 95 698 analytical tests were performed. Table 3, section A, presents the results obtained.

Four populations, composed of 10, 11, 12 and 16 units, presented different analytical results (negatives and positives) between selections of the same population. These differences were observed between the second or third selection (S_2 or S_3) and the first selection (S_1) from the population. The differences were detected in the initial qualitative tests (color and microcrystal). Also, populations containing fewer than 20 units were frequently submitted to liquid-liquid extraction, column chromatography and/or thin-layer chromatography to separate the substances which interfere with microcrystal and/or ultraviolet/visible (UV spectra) tests from controlled substances.

The most important finding of this investigation was obtained for 95 populations containing more than 20 units. After conducting the examination, none of these populations presented any difference during the analytical tests performed on each one of their units. This situation was observed, between all units of the first random selection of 10% (S_1),

INSTITUTE OF FORENSIC SCIENCES
REPRESENTATIVE SAMPLING OF CONTROLLED SUBSTANCES
PART II: QUALITATIVE ANALYSIS

CASE No. Q91-187 DATE: March 25, 91

EXHIBIT No. 3 POPULATION: 230 units

NOTE: EACH SELECTION (S), AT RANDOM AND WITHOUT UNITARY REPLACEMENT, WILL BE BASED ON 10% OF THE ORIGINAL POPULATION.

	S_1	S_2	S_3	S_4	REMAINDER	OBSERVATIONS
	23	23	23	23	138	
I. COLOR TESTS:						
A. MARQUIS	−	−	−	−	−	Color: Orange
B. MAYER'S	+	+	+	+	+	
C. SCOTT	+	+	+	+	+	
D. MECKE'S						
E. FROEHDE'S						
II. MICROCRYSTAL TESTS:						
A. H_2PtCl_6	+	+	+	+	+	
B. HgI_2						
III. INSTRUMENTAL TESTS:						
A. UV/VIS	+	+	+	+	+	After Acetone Wash
B. GC/FID	+	+	+	+	+	
C. OTHERS						

IV. CONTROLLED SUBSTANCES: Cocaine

FORENSIC ANALYST

FIG. 3—*Qualitative analysis form. The upper portion contains information about the selection of sample units, and the lower portion contains laboratory observations and test results.*

and the subsequent selections (S_2, S_3, and S_4) including the "remainder" (Table 3, section B).

The results of this investigation indicates that a sample size based on 10% will be representative of a population when it is composed of more than 20 drug units. Due to the variety of results and interferences presented during analyses of populations within an interval of 1 to 20 units, all the units of these populations should individually analyzed. In such cases, the sample will be equal to the population ($n = N$). In addition, when the population totals close to 20 units, a sample larger than 10% must be considered for analysis. If not, an uncertainty can be introduced; the sample size may not accurately represent the population under examination.

Reviewing the results led us to elaborate a sampling formula to be applied to drug

TABLE 3—*Results obtained during this investigation.*

Populations	Unit Interval	Units	Analytical Tests	Result S2 Different from S1	Result S3 Different from S1	Result S4 Different from S1	Remainder Different from S1
Section A							
120	1–10	438	2 095	1 (10)	0	0	0
60	11–50	1 574	7 406	1 (12) 1 (16)	1 (11)	0	0
39	51–200	3 711	16 944	0	0	0	0
12	201–500	4 140	18 826	0	0	0	0
2	501–1000	1 291	6 475	0	0	0	0
5	>1000	8 790	43 952	0	0	0	0
238	Total	19 944	95 698	3	1	0	0
Section B							
143	1–20	803	3 725	3 (10,12,16)	1 (11)	0	0
95	>20	19 141	91 973	0	0	0	0
238	Total	19 944	95 698	3	1	0	0

S = Random selection based on 10%.
(#) = Number of units in the population.

exhibits containing multiple units, and obtain a representative sample for analysis. The formula is described as follows:

$$n = 20 + 10\%(N - 20) \quad [\text{for } N > 20]$$

N = total number of units (powdered drugs) in the population (street-drug exhibit).
n = number of units representing "N" during qualitative and quantitative analysis of controlled substances.

The sampling formula demands the selection of a larger number of units as the population becomes smaller (Table 4). Also, it offers the opportunity to discover heterogeneous populations before the analysis is completed.

The information obtained through this investigation supports the establishment of an effective and valid sampling plan for the Institute of Forensic Sciences of Puerto Rico. It also maintains the accuracy of results and improves the consistency of procedural steps between forensic drug chemists. The application of this procedure and its sampling for-

TABLE 4—*Several examples that illustrate the application of the sampling formula.*

Population	$n = 20 + 10\%(N - 20)$ Representative Sample	$\% = n/N\ (100)$
3000	318	10.6
2000	218	10.9
1500	168	11.2
1000	118	11.8
800	98	12.2
500	68	13.6
200	38	19.0
100	28	28.0

mula, $n = 20 + 10\%(N - 20)$, selects a representative sample for analysis that is greater in number than those used by other forensic science laboratories worldwide (Tables 1 and 4). This conservative approach increases productivity, while at the same time sustains the forensic drug analysis within an acceptable level of scientific certainty. In other words, the sampling plan maintains the analytical methodology and defensibility necessary to comply with the legal definition of proof in our criminal justice system.

Acknowledgment

The authors wish to thank all our colleagues in the Controlled Substances Section (I.F.S.) who supported this investigation. Thanks are also due to those forensic science laboratories providing information about their sampling plans.

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