

ASSESSMENT OF THE SANITARY QUALITY OF FOOD PREPARATION SURFACES

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ABSTRACT

The sanitary state of 27 tables routinely used for food preparation was measured by monitoring 10 locations per table by both the rodac plate and swab methods. The total bioburden at each location was determined by taking 5 successive rodac plates or three successive swabs. The study compared their efficiency for estimating the normal bioburden and determined the minimum number of locations required for testing to reliably characterize sanitation. The swab method appeared to recover a higher percentage of the bioburden, but microbial counts by rodac plates were higher than the swab method, probably due to a failure of the cotton fibers to release entrapped organisms. An acceptably low incidence of false positives or negatives is obtained if the maximum count of two randomly obtained rodac plates or swabs per surface does not exceed 150 CFU/25.8 cm².

INTRODUCTION

The evaluation of the sanitary state of food contact surface used in food preparation is an important consideration in any quality control program. Maintaining cleanliness can influence not only the safety of the product but its shelf-life and quality (Jennings 1965). While some investigators have not found any direct correlation between microbiological evaluation and safety, others have assumed or concluded that a clean surface is more safe and that common sense dictates that a clean surface will not support the growth of microorganisms, insects, etc. (Jennings 1965; Silverman 1979).

Previous studies (Silverman *et al.* 1975) of military facilities demonstrated, in agreement with conclusions by Jennings (1965) and Chaturvedi and Maxcy (1969), the unreliability of visual

evaluation for determining the sanitary condition of food preparation surfaces. Silverman *et al.* (1975) noted that as high as 60% of the surfaces considered to be visually satisfactory were unsatisfactory when evaluated by rodac plate counts. In that study the rodac plate count standards for determining acceptability were quite stringent, but 38% of the surfaces considered to be visually unsatisfactory were microbiologically acceptable.

It is desirable to monitor, not only the removal of visual soil particles and films, but also soil not detectable by visual examination, especially that capable of supporting microbial viability. The techniques most frequently used in monitoring, are visual and microbiological, the latter including the swab and contact plate methods or modifications of them.

Most studies comparing the rodac plate technique with the swab technique used either inoculated or cleaned surfaces (Angelotti *et al.* 1964; Niskanen and Pohja 1977; Patterson 1971) rather than those naturally contaminated by a mixed flora and sanitized by food service personnel. Exceptions were studies by Hansen (1962), Gilbert (1970) and Silverman *et al.* (1975).

An optimal monitoring program would be capable of maximizing safety and of minimizing error and cost. This study investigated the feasibility of developing such a method. After visual evaluation, 10 locations on each food preparation surface were sampled by rodac plate and swab techniques. The ability of these two methods to detect or to recover organisms was determined and a simple sampling scheme was devised which would yield results similar to those obtained with the 10 locations. The tests were conducted on uninoculated surfaces actually employed in food service preparation.

METHODS AND MATERIALS

Surfaces Tested

Food preparation surfaces from commercial stainless steel tables at military installations, including the authors' facility (NLABS), were examined. Tables were evaluated after sanitization, when personnel at each facility considered the table suitable for food preparation.

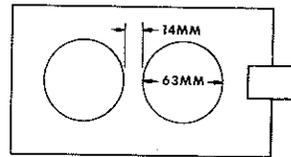
Cleaning and sanitizing procedures were conventional and varied among the facilities evaluated, no attempt being made to influence the degree of sanitation.

Prior to testing, by either the rodac or swab technique, each surface was visually evaluated. A surface was judged to be unsatisfactory if visible food particles or grease film was evident.

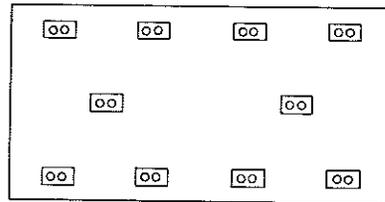
Sampling Locations

A special stainless steel template was used for obtaining microbiological counts from adjacent sites at each location with either swabs or rodac plates. Each template consisted of a flat stainless steel plate with two 63mm diameter discs removed (Fig. 1A). The 63mm cutout in the template allowed a rodac plate to be inserted snugly into the opening with enough clearance to allow the proper rolling technique to be employed.

Ten preselected locations on each table were tested (Fig. 1B). Five successive rodac plates and three swabs were taken from adjacent openings in the template at each location.



A



B

FIG. 1. A. TEMPLATE USED FOR OBTAINING ADJACENT SAMPLES AT EACH LOCATION
B. THE TEN LOCATIONS SAMPLED ON EACH TABLE

The validity for using adjacent openings in the template for determining the bioburdens at each location, was evaluated by testing the 10 locations on each of three randomly selected tables by the rodac technique. Both the paired t test ($P > 0.05$) and the paired sign test indicated that the bioburdens removed by the first sequence ($S = 1$) were not significantly different (data not presented).

Swabs and Rodac Plate Counts

Two types of presterilized swabs, cotton (Torrent Corporation, Lake Geneva, WI) and calcium alginate swabs (Inolex Corp., Glen-

wood, IL) were evaluated. Prior to use each swab was wetted in a buffered-rinse diluent (APHA 1972) and the excess fluid removed by gently rolling the swab against the inside surface of the test tube. A 4 in² (25.8 cm²) test area, as delineated by a stainless steel template (see Fig. 1), was then sampled with 25 strokes in one direction followed by an additional 25 strokes at right angles to the initial direction. The swabs were rotated periodically during sampling.

After sampling, the tip of the cotton swab was broken into a tube containing 10 ml of 0.1% peptone broth and the cotton dispersed by shaking the tube 50 times by hand through a 12 in. arc. The broken-off tips of the alginate swabs were dissolved by shaking them in tubes containing 10 ml of a 1% solution of sterile sodium citrate. One and 9 ml aliquots were then passed through 0.45 μ membrane filters (Millipore Corp., Bedford, MA) by vacuum and the filters incubated on trypticase soy agar supplemented with 0.1% yeast extract (Difco, TSY) for 48 h at ambient temperature (20-25°C).

Rodac plates (trypticase soy agar with lecithin and polysorbate 80) were obtained commercially (BBL) and stored at 2°C in their original package until use. Just prior to use they were equilibrated at ambient temperature (20-25°C). The technique used to sample surfaces by rodac plates was that recommended by the manufacturer. The plates were counted after incubation at ambient temperature (20-25°C) for 48 h.

Inoculated Swab Studies

Pseudomonas fluorescens, *Escherichia coli* and *Staphylococcus aureus*, strain S-6, were obtained from the authors' stock culture collection. All three cultures were propagated twice in trypticase soy broth (BBL) supplemented with 0.5% yeast extract (Difco, TSY). A 1% inoculum was then added to 100 ml of TSY broth in a 500 ml Erlenmeyer flask and the flask shaken at 200 RPM (Model G2, New Brunswick Inc., New Brunswick, N.J.) for 20-24 h. *Escherichia coli* and *S. aureus* strain S-6 were propagated at 37°C and *P. fluorescens* at ambient temperature (20-25°C). Each culture was then standardized to the desired cell concentration of 10³ CFU/swab by diluting the culture to a predetermined colorimetric reading (Klett Mfg. Co., Inc. N.Y., N.Y.) with 1% peptone broth and then subsequently diluting the standardized culture further by a factor of 1:100. A 0.1 ml aliquot of the standardized culture was then pipetted directly onto either cotton or alginate swabs for recovery experiments.

Statistical Analysis

The general form of the original data had

C = Plate Count

as the dependent variable and the following four quantities as independent variables

T = table

L = location on the table

M = method of test (rodac, cotton swab, alginate swab)

S = sequence (succession) number.

The statistical analyses were concerned with the effects of T, L, M and S on C.

There were 27 different tables and 10 locations on each table. Five successive rodac readings were taken at each location. In the swab tests, three successive counts were obtained, each count being found by combining two basic counts, the second of which was gotten from a 1:10 dilution of the sample from which the first count came. If these two counts are called C1 (the first) and C2 (the diluted), the final swab count, C, which was used in all subsequent calculations, was found as follows:

If $C2 > 200$, then $C = 5,000$ (i.e. TNTC, see below)

If $C1 > 200$, and $C2 < 200$, then $C = 10 \times C2$

If $C1 < 200$, then $C = C1$.

A large number of readings were TNTC. The values arbitrarily assigned to these were:

for rodacs $C = 500$

for swabs $C = 5,000$

These definitions are obviously artificial but are based on the notion that swabs can give higher recoveries than rodacs. There were 208 TNTC cases for rodacs and 62 for swabs. In addition there were 6 instances of missing data for rodacs and 15 for swabs. Two slightly different data sets were used in the calculations. Data set (I) discarded all counts = 0, counts > 400 (i.e. TNTC) and missing data and had 945 rodac counts and 504 swab counts. Data set II included all the data except missing counts and contained 1344 rodac cases and 795 swab cases. Most of the calculations were done on both data sets.

The standard statistical computations were done by SPSS programs of the 6.03 level, January 1977. It was found that the original counts were not at all distributed in Gaussian fashion, therefore, most of the tests (especially the analysis of variance, or ANOVA, and Student t test) were done on the common logarithms of the

counts, which more nearly followed a Gaussian distribution. The value -0.3 was arbitrarily assigned as the logarithm if the original count was zero.

An ANOVA was used to see which variables influenced the plate counts. Both data sets led to the same main conclusion, namely all four variables (T, L, M, S) had effects significant at the ($P < .01$) level.

RESULTS AND DISCUSSION

Monitoring procedures are usually designed to limit the number of rodac plates or swabs but one of the objectives of this study was to determine the efficiency of these techniques. Therefore, to obtain the percentage recovery by the initial rodac plate or swab count, the total microbial population was estimated on each of ten selected locations by adding the colony forming units (CFU) of either the five successive rodac plates or the three successive swabs counts. Consequently, a large number of locations were found in which 90% or more of all the recoverable bioburden was removed from the surface after the fourth rodac plate or second swab.

The first rodac swab $S = 1$ recovered, on the average, well over 50% of the viable microflora at levels of bioburden varying from less than 25 CFU/25 cm² to over 200 CFU/25 cm² (Table 1). The swab technique generally gave higher average percentage recovery than the rodac plate although the range for both were extremely broad (17-100%). It also appears that $S = 1$ for either technique does serve as an indication of the total bioburden (Fig. 2). The semi-log plot indicates that a fairly constant proportion is removed even with the

Table 1. Percentage recovery by the first rodac plate or swab

	Total Organisms ¹ Recovered per Location ²							Range (%)
	0-25	26-50	51-75	76-100	101-150	151-200	> 200	
	Percentage Recovery							
Rodac	66	66	62	57	60	59	59	17-100
Swab	68	63	75	67	69	73	80	18-100

¹Total colony forming units recovered from five rodac plates or three swabs for each location

²Those locations for which the last rodac or swab contained 10% or less of the total colony forming units and where the first rodac or swab was not too numerous to count

probable nonhomogeneity of the soil and of the microflora. Linear regression was used in analyzing the effects of the sequence number, S, and led to the estimate.

$$C_o = C_{s=1}^{1.25}$$

where C_o = original bioburden and $C_{s=1}$ is the first plate count. The overall average of removal of the microflora by $S = 1$ for either the rodac or swab techniques was approximately 60%, with the swab being consistently higher than the rodac plate. The data for Fig. 2 were selected from those locations which yielded countable rodac plates or swabs. Locations which were too numerous to count (TNTC) were not included and $S = 1$ for these locations would readily detect inadequate cleanliness.

An evaluation of all 27 tables indicated a wide distribution of microbial contamination (Fig. 3), although the largest number of locations had counts of 50 or less CFU/25.8 cm². The lower capability of the rodac plate to enumerate over 200 to 300 organisms accounts for the higher percentage of locations which were TNTC.

The effect of M, i.e. rodac versus cotton swab counts, was analyzed by paired Student-t tests and paired-sign tests. Both tests led to the same conclusion, namely that rodac counts were higher than swab counts at the $P < .01$ level, regardless of whether data set I or II was used.

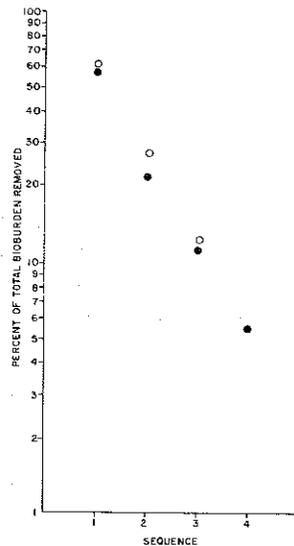


FIG. 2. PERCENTAGE OF TOTAL BIOBURDEN REMOVED SEQUENTIALLY BY EACH OF EITHER FIVE RODAC PLATES (●) OR SWABS (○)

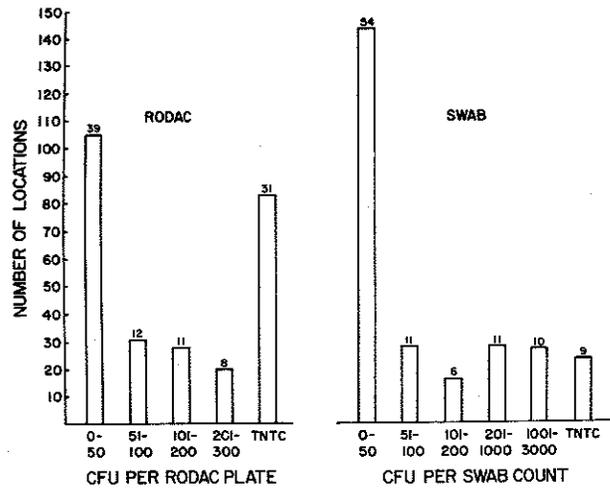


FIG. 3. DISTRIBUTION OF RODAC PLATE AND SWAB COUNTS
The figures above each column indicates percentage.

Of 187 paired locations capable of being enumerated, i.e. without one of a pair being TNTC, 145 had higher rodac plate than swab counts (Table 2).

The apparent contradiction between $S = 1$ of the swab method recovering less organisms than the rodac plate method (Table 2) but having a higher percentage recovery (Table 1) may be explained by the fact that the cotton swab used in these experiments apparently failed to release a portion of the adhering microflora. Removal of the microflora by the swab was demonstrated by an experiment in which after conducting three sequential swab counts on each of 20 locations, subsequent rodac plate counts on these locations failed to

Table 2. Paired locations¹ evaluated by rodac plate and swab methods

	Number of Locations
Rodac plate counts greater than swab counts	145
Swab counts greater than rodac plate counts	42

¹The data from the first rodac plate or swab was used

detect any significant numbers of residual microorganisms (data not presented).

A failure to release many of the adhering microorganisms was demonstrated by a recovery experiment comparing the cotton swab to the calcium alginate swab (Table 3). A significantly ($P < 0.05$) higher recovery of the alginate over the cotton swab occurred. If the cotton swab had released the adhering organisms, it would have been comparable to the rodac plate method.

Table 3. Recovery of organisms inoculated on cotton and calcium alginate swabs

Organism	Recovery % ^a	
	Cotton	Calcium Alginate
<i>Escherichia coli</i>	64	99 ^b
<i>Pseudomonas fluorescens</i>	51	90 ^b
<i>Staphylococcus aureus</i>	53	91 ^b

^aAverage recovery of four separate trials

^bCalcium alginate gave significantly higher recoveries than cotton swabs ($P < 0.05$) by the paired t test

Angelotti *et al.* (1958) compared the ability of cotton and alginate swabs to recover *Staphylococcus aureus* and spores of *Bacillus subtilis* inoculated and dried on glazed china surfaces and found both types of swabs were essentially equal in efficiency, although recovery was low. However, the reviews by Patterson (1971), Favero *et al.* (1968) and Baldock (1974) noted that some studies reported higher recoveries by alginate swabs and others showed lower recoveries.

Release of microorganisms from a swab is just one factor in recovery. Adsorptive tenacity, composition of the soil and longevity of microorganisms on the swab will all influence survival. The recovery experiments in this study involved the removal of a mixed and "natural" microflora from a surface subjected to environmental stresses rather than a more stabilized pure culture inoculum. Additional experiments were conducted to determine reasons for the lower recoveries by cotton swabs when compared to rodac plates. Although the data are not presented, the buffered rinse solution and the 0.1% peptone diluent used in the swab method did not contribute to lower recovery ($P < 0.05$). The lower recovery was also not due to the differences in agars or to any delay that occurred prior to plating.

Angelotti *et al.* (1964) also compared the recovery of rodac plates to cotton swabs and found that swabs gave higher recoveries (47%) than the rodac plate method (41%) but that the rodac plate method was more reproducible. In their study recovery was based upon the removal of washed spores dried on cleaned stainless steel surfaces. Others (Mossel *et al.* 1966; Gilbert 1970) using not rodac plates but the agar sausage method found that the swab technique resulted in higher recovery on artificially contaminated surfaces. Niskanen and Polja (1977) examining wood, plastic and stainless steel food preparation surfaces compared the contact plate (comparable to the rodac plate method) to the swab method and found, in agreement with this study, that the contact method was superior.

In this study the soil entrapped microflora on the tables remained, in most cases, even after being sampled by five successive rodac plates or three successive swabs (Table 4). When swabs were used, many more locations reached zero counts than when the rodac tests were employed. Even if a less severe criterion were used, i.e. 90% instead of 100% of the total recoverable organisms being removed, a large number of locations still demonstrate appreciable resistance toward releasing microorganisms when dealing with naturally contaminated hard surfaces (Jennings 1965).

The effect of T, i.e. the variation among tables was the greatest of the four variables and the effect of location on the table, L, was the weakest (though still statistically significant in the $P \leq .01$ sense).

Table 4. Locations at which the microbial count reached zero during sequential sampling

	Sequence ¹ per Location					Locations Which Did Not Reach Zero	Locations At Which 10% or Less of the Flora Remained ²
	1	2	3	4	5		
<i>Rodac</i>							
Locations	7	8	6	10	36	203	145
No. of tables	2	6	3	6	14		
<i>Swab</i>							
Locations	13	8	29	—	—	226	116
No. of tables	4	7	13	—	—		

¹Five sequential rodac plate counts and three successive swab counts were taken at each location
²By the fifth sequential rodac plate or third swab

In a previous study (Silverman *et al.* 1975) the author suggested a sanitary standard when using the rodac plate count. This proposed standard defined a surface as being adequately sanitized if, "of the number f plates used to test a given surface, one-half or more of the plates contain 50 CFU/plate or less and no plate exceeds 100 CFU/plate." The difficulty with this standard was that in addition to requiring a relatively large number of rodac plates for each area, it was arbitrary and was not modeled upon any data base.

The data base used in this study, consisted of 27 sanitized surfaces each with 10 designated locations per unit surface all sampled in a similar, uniform manner. In practice, sampling 10 locations would be considered too expensive to be routinely employed. Therefore, this data base was used to devise a simpler sampling scheme for ascertaining whether a surface has been satisfactorily sanitized.

In these sampling trials we compared several methods for deciding whether a table was clean or dirty. The comparison was done entirely by using $S = 1$ of the rodac data.

The primary method of assessing cleanliness of a particular table was to average all the rodac data for $S = 1$. This result, A , was then compared with a limit count level, L , and the table declared dirty if $A > L$ and clean if $A \leq L$.

The secondary, simpler methods of evaluating cleanliness were based on randomly choosing one, two or three samples from the plate counts for each table and deriving a simple estimate, C , from those values. Five estimators were evaluated:

- S1: $C =$ any one randomly chosen count from each table.
- S2M: $C =$ the larger of two such counts from each table.
- S2A: $C =$ the average of two such counts from each table.
- S3M: $C =$ the largest of three such counts from each table.
- S3A: $C =$ the average of three such counts from each table.

The effectiveness of these secondary (small-sample) methods was studied by comparing their conclusions as to cleanliness with those of the primary method, using the following procedure. First, a random number was generated in the range 1 to 27 and taken to define a table. The average of all ten counts on that table was found and compared with L to get the primary decision about cleanliness. Next, up to three different random integers in the range 1 to 10 were generated and viewed as the locations at which counts were taken. Each of the five simple estimates was then found by averaging or choosing the maximum of these few counts. The secondary decisions about cleanliness were made by comparing these simple estimates

with λ , a secondary limit level. Finally, we determined whether the simple estimates led to the same decision as the primary method, which we assumed is the "correct" one.

Two types of errors are possible, designated F and D. The event F occurs if $A \leq L$ and $C > \lambda$, i.e. the surface is satisfactorily sanitized, but the simple test indicates that it isn't. The event D occurs when $A > L$ and $C < \lambda$, i.e. the test indicates an acceptable sanitary condition for a surface that is actually unsatisfactory. The probabilities of these two kinds of errors, and the probability of overall error, i.e. either F or D, are shown in Table 5. The probabilities depend on λ , L, and the choice of estimator and were determined for L and λ equal to 100, 150 and 200 for each estimator. For each estimator the cases corresponding to smallest overall error probability are marked by an asterisk.

It will be noted that, generally, one can obtain error probabilities of about 14% for S1, 5% for S2M or S2A, and 1% to 1.5% for S3A and S3M. These results are, in many cases, based on rather small sample sizes, but they indicate that the two- or three sample estimators give acceptably low likelihoods of error. In particular, the S2M scheme with $\lambda = L = 150$, has about a 5% error and gives a roughly equal balance between the two kinds of errors, F and D. This desirable situation is not realized with the other two- or three-sample estimators although the last one is presumably more accurate.

The data for both the rodac plate and swab methods were then evaluated by this apparently most desirable sampling scheme, S2M, i.e., the use of two random locations, with acceptability being based on whether or not the larger count exceeds a limit level (Table 6).

From the existing data, using only $S = 1$ two locations on sanitized tables were randomly selected. The counts at these locations were tested to see whether either exceeded the limiting value L. This prediction (acceptable vs unacceptable) was compared with the presumably more reliable conclusion furnished by averaging the counts of all 10 locations on the same table (A) and comparing that average with L. Three different L values 100, 150 and 200 CFU/25.8 cm² were used. The cases where pairs $A < L$, $M < L$ and $A > L$, $M > L$ are those where the prediction of the S2M sampling scheme gave the same conclusion as the much more stringent test of averaging the counts of all ten locations.

There are several reasons for preferring L to be equal to 150. First, the total number of incorrectly decided cases is smaller at $L = 150$ than at the other L-values. Second the two types of errors (i.e. "false alarms", where $M > L$ and $A < L$ and "undetected danger", where $M < L$ and $A > L$) occur with roughly equal frequency.

Table 5. Evaluation of sampling schemes by the rodac plate count

Sampling Scheme ^b	Allowable Contamination Levels ^c (L)	Type ^e of Error											
		F			D			Any Error					
		100	150	200	100	150	200	100	150	200	100	150	200
S1	100	.0263 ^c	.0074	.0037	.1685	.2222	.2519	.1949	.2296	.2556			
	150	.0575	.0259	.0185	.0889	.1296	.1556	.1467	.1556	.1741			
	200	.1541	.0926 ^d	.0704	.0370	.0481 [*]	.0593	.1912	.1407 [*]	.1296			
S2M	100	.0235	.0070	.0037	.0424	.0679	.0802	.0659	.0749	.0840			
	150	.0514	.0239 [*]	.0177	.0148	.0292 [*]	.0387	.0662	.0531 [*]	.0564			
	200	.1156	.0765	.0613	.0049	.0078	.0082	.1205	.0844	.0695			
S2A	100	.0078	.0021	.0004	.0572	.0831	.1021	.0651	.0852	.1025			
	150	.0329	.0160	.0119	.0267	.0416	.0580	.0596	.0576	.0700			
	200	.0872	.0564	.0374 [*]	.0070	.0078	.0095 [*]	.0942	.0642	.0469 [*]			
S3M	100	.0105	.0033	.0019	.0078	.0152	.0189	.0183	.0185	.0208			
	150	.0229	.0110 [*]	.0084	.0017	.0043 [*]	.0070	.0246	.0153 [*]	.0154			
	200	.0463	.0321	.0269	.0004	.0008	.0008	.0467	.0329	.0277			
S3A	100	.0020	.0003	.0000	.0129	.0236	.0356	.0148	.0239	.0356			
	150	.0129	.0058	.0011	.0052	.0105	.0182	.0181	.0163	.0193			
	200	.0331	.0207	.0094 [*]	.0008	.0008	.0017 [*]	.0338	.0215	.0111 [*]			

^aF is a false alarm, i.e. when the surface is actually acceptable; D means undetected unsatisfactory surfaces. See text for further explanations
^bEither the highest colony forming units/25.8 cm² from the sample (M) or the average (A) CFU of the sample taken for 1, 2 or 3 rodac plates
^cColony forming units/25.8 cm²

^dCases having the smallest overall error probability

^eTable entries are probabilities of error, obtained from sampling trials

Table 6. Comparison of simple and stringent procedures for evaluating cleanliness of tables based on rodac and swab-counts

	L' = 100			L = 150			L = 200		
	A < L	A > L	Total	A < L	A > L	Total	A < L	A > L	Total
RODAC									
M' < L	461 ⁴	150	610	637	71	708	737	22	759
M > L	68	803	871	70	710	780	173	556	729
Total	529	959	1488	707	781	1488	910	578	1488
SWAB									
M < L	747	51	798	823	51	874	850	86	936
M > L	123	567	690	47	567	624	20	532	552
Total	870	618	1488	870	618	1488	870	618	1488

¹That value in colony forming units/25.8 cm² which, if exceeded, indicates that the surface has not been sanitized satisfactorily.

²The average rodac or swab count of all ten locations for S = 1 (stringent method)

³Maximum value of two locations selected randomly for S = 1 (simple method)

⁴Table entries are numbers of cases satisfying conditions stated at top of column and left of row

Although the overall accuracy of the swab method appeared better, in the sense that it gave fewer disagreements between the predicted and the more reliable results, it does not follow that it is superior to the rodac plate count. One reason is, that as noted above, the rodac counts were generally higher and much more sensitive to changes in L than the swab counts. The data in Table 6 shows that changing L from 100 to 200 had no effect on the total number of cases for which A < L according to the swab method, and the numbers of cases for which A < L is greater for the swab method than for the rodac plate count. If further studies indicate that comparable results can be obtained by improving swab methodology, for example, by using alginate swabs, then it could be more highly recommended. Perhaps a more direct way would be to use different L values for different microbiological testing procedures.

The need for this becomes more evident when the counts at each location on the 27 tables from which the samples are drawn were examined (data not presented). With L = 150, there were 13 tables for which A < L according to rodac plate counts but 16 tables according to the swab count. The swab test adjudged clean all the tables that are so classified by the rodac plate count plus three others judged to be unsatisfactory by the rodac plate count. Moreover, when tested by the swab method, there were no tables

with average counts lying between 86 and 626 (this is why there was no effect of L upon the total number of cases with $A < L$). The rodac test found 6 tables with $100 < A \leq 200$. The sampling data indicates that the same conclusion would have been obtained 90% of the time by either determining the rodac plate count on two random locations and having the table adjudged unacceptable if either count exceeds 150, or taking the average of 10 locations. The errors are about evenly divided between false alarms and undetected dangerous conditions. These conditions are supported by elementary probability calculations based on the experimental data.

The arbitrary values of L or λ are not asserted as the true measure of cleanliness. In this study we have merely compared the results obtained by various sampling methods with each other. No attempt was made to relate the terms acceptable or unacceptable to the absence of pathogens. To resolve the latter question would require the use of selective media and a series of taxonomic tests. The main consideration that is answered by the use of the rodac plate or swab count is that the table was acceptably sanitized. There is sufficient evidence to indicate that proper sanitation is attainable by the use of proper cleaning procedures, even without the use of germicides (APHA 1970). The need for the rodac plate and swab methods, or some other comparable technique, to measure the effectiveness of the cleaning operation and of the ability of a surface to support microbial growth is due to the fact that visual evaluation is not effective (Jennings 1965; Silverman *et al.* 1975). This is also shown in Table 7 whereby of the 22 tables judged to be visually satisfactory

Table 7. Comparison of methods of evaluation by rodac plate counts and visually

	Method of Evaluation			
	Visual	NLABS ¹		Maximum Two Plate Test ²
		A	B	
	Number of Tables			
Satisfactory	22	7	11	13
Unsatisfactory	5	20	16	14

¹U.S. Army Natick Research and Development Laboratories' standard. A. That standard used in surveys, whereby a table is judged satisfactory if no rodac plate count exceeds 100 CFU/25.8 cm² or more than 50% of the plates had counts of 50 CFU/25.8 cm². B. By changing the previous constraint to 150 CFU/25.8 cm²

²Rodac plates for two locations were randomly chosen (see text) and judged satisfactory if the maximum of the two plates did not exceed 150 CFU/25.8 cm²

only 13 of these were considered satisfactory by the rodac maximum two plate test and seven by the more stringent NLABS standard. Three of these tables found unacceptable by the NLABS studies were due to a small number of locations having rodac plate counts of over 100 CFU/25.8 cm², the rest of the locations on these table were well below this figure. The evaluation of non-uniformity of the cleaning procedure is a problem that will require additional studies. Of the 16 tables which were unsatisfactory by method B (NLABS) 5 had all 10 locations in excess of 150 CFU/25.8 cm² and a total of 8 tables had 60% or more of their locations in excess of this level of contamination. It is interesting to note that few of these problem tables were correctly evaluated by visual examination.

The suggested use of a limit count, L, of 150 CFU/25.8 cm² is based on the limited data collected in this study. Additional studies involving other food preparation surfaces and processing procedures may result in some other limit count. The use of 150 CFU/25.8 cm² is more than the 50 suggested for hospitals (APHA 1970), and the approximately 50 CFU/25.8 cm² by th U.S. Department H.E.W. (1967) but considerably less than the 258-516 CFU/25.8 cm² proposed by Niskanen and Pohja (1977) and 25,800 CFU/25.8 cm² by Patterson (1971). Baldock (1974), without presenting any evidence to justify the requirement, specified that at least three samples should be taken in order to obtain sound statistical methods. While some additional reliability was obtained by using three rodac plates rather than two, the two-sample scheme did result in a reasonable estimate of the microbiological burden and is an acceptable compromise between effectiveness and the cost of monitoring.

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