Diarrheal Disease Control by Improved Human Excreta Disposal

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THE EFFECT of fly control on the reduction of diarrheal disease has been demonstrated twice (*1*, *2*). In south Georgia, Lindsay, Stewart, and Watt (*2*) observed that the prevalence of *Shigella* infections was reduced during fly control activities. As long as flies were easy to control with DDT and other insecticides, an effective diarrheal disease control procedure was available, but the development of insecticide-resistant flies necessitated a closer examination of the fly's role in the transmission of diarrheal disease in the hope of finding another control procedure.

The exclusion of flies from their source of human enteric pathogens should prevent fly transmission of shigellosis. An experiment was therefore designed to measure the effect of excluding flies from contact with human excrement in an area where they had previously had ready access to such excrement. Flush toilets, water-carried sewage, and sewage treatment would have been the most effective method, but for the purposes of this study a cheap and easily effected alternative was necessary. An adaptation of the bored-hole latrine was used. This consisted of a hole 8 feet deep and 16 inches in diameter, covered with a concrete slab 4 feet square, with an aluminum riser, seat, and lid. The old privy structure was moved over the slab; if there had been no privy, the householder built a simple structure. (Details of design and construction are given on pp. 926–927.)

This privy rehabilitation program was conducted in Boston, Ga. (1950 population, 1,035). Boston had been included in an early fly control study (*2*). Until fly resistance made their use ineffective, DDT, dieldrin, and chlordane had been used there as residual sprays and DDT, as a space spray.

Plan of Study

All premises in the study town were inspected in January 1952 and notes were made of the excreta disposal methods used and their relative effectiveness. About half of the community was served by a sewerage system with treatment, which made the correction of disposal methods easier. Fifty-two percent of the 344 occupied dwellings had unsatisfactory facilities for excreta disposal, mostly surface privies. During April and May the excreta disposal facilities at 178 dwellings were improved by constructing a new privy or rehabilitating the old privy with an 8-foot-deep bored hole. At three dwellings it was necessary to renovate privies that were used by servants, and an additional 19 privies were remodeled at schools, churches, and commercial buildings.

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This paper is the fifth in a series on control of diarrheal diseases.

Upon completion of the construction phase of the program, at no cost to the residents, all available excreta disposal facilities in Boston were satisfactory. Information leaflets were distributed through the schools and were left at each house where work had been done. These leaflets explained the program and requested cooperation in the correct use of the privies A notice was also stenciled on the seat lid to the effect that flies carry sickness and should be kept out of privies. Almost everyone used the privies because the units were a marked improvement, esthetically and otherwise, over previous facilities.

The method of making epidemiological observations of morbidity and *Shigella* prevalence before and after the privy rehabilitation program were the same as that used in a previous study (*2*). Blocks with a high proportion of children were selected for study. The families in the study blocks were visited monthly by trained lay enumerators, and histories of diarrheal disease were obtained for all family members. The average study population was 333, or about one-third of the community. Rectal swab cultures for the isolation of *Shigella* organisms were collected monthly from children under 10 years of age.

The evaluation of fly populations was a continuation of the entomological observations reported previously (*2*). A visual count method based on the Scudder grill was used. Representative blocks, consisting of about 15 percent of the total blocks, were sampled weekly and the five highest grill counts observed in each block were recorded. Observations were curtailed during the coldest weather when fly activity was minimal.

To obtain a measure of the contact of flies with human excreta, samples of privy contents were collected every 2 weeks from 10 percent of the privies in the community. The privies were selected at random, and each sample consisted of two quarter-pint portions. One portion was treated by brine flotation and the larvae were removed and identified. The other portion was held in an insectary and the insects that emerged were identified. At the time of sampling, observations were made of the condition of the privy, including a count of adult flies in the pit and in the privy structure. During the late months of the study, this schedule was reduced to sampling 5 percent of the privies in the community every third week.

For the purpose of comparison, similar epidemiological and entomological observations were made in three other towns—Pavo, population 806; Coolidge, population 764; and Meigs, population 1,125—where nothing had been done to the privies. The study populations in these towns were similar to the study population in Boston as to race and age distribution and environment.

Results

Remodeling the privies made a considerable change in the proportional distribution of flies breeding in them. The bored hole was very dark, and in half of the privies there was ground water in the hole. The relative frequency of fly breeding in unmodified privies and in the bored-hole privies is shown in table 1. *Hermetia illucens* and members of the Phoridae, Drosophilidae, and Culicidae were observed to be breeding more frequently as a re-

Table 1. Percentage of privies breeding insects in areas with unmodified privies and in an area with bored-hole privies, south Georgia, April 1952–March 1953

Unmodified privies [1]		Bored-hole privies [2]	
Insect	Percent privies	Insect	Percent privies
Hermetia illucens [3]	51. 2	*Hermetia illucens* [3]	59. 6
Ophyra spp	23. 0	Phoridae	11. 2
Sarcophaga spp	14. 8	Drosophilidae	6. 4
Fannia spp	10. 8	*Ophyra* spp	6. 1
Musca domestica	8. 7	*Psychoda* spp	5. 6
Psychoda spp	8. 3	*Sarcophaga* spp	4. 8
Muscina spp	5. 1	Borboridae	2. 9
Hydrotaea houghii	4. 8	Culicidae	2. 9
Dendrophaonia spp	3. 2	*Musca domestica*	1. 6
Borboridae	3. 1	*Muscina* spp	1. 6
Phoridae	1. 7	Scatopsidae	1. 6
Syrphidae	1. 6	*Milichella lactei-pennis.*	1. 6
Drosophilidae	1. 6	Phyllomyzidae	1. 3
Culicidae	1. 6	*Fannia* spp	1. 1
Sepsidae	1. 2	*Hydrotaea houghii*	1. 1
Scatopsidae	1. 0	All others	[4]
All others	[4]		

[1] Check towns, 939 samples.
[2] Boston, Ga., 377 samples.
[3] Stratiomyidae.
[4] Less than 1 percent each.

sult of the privy reconstruction, but the majority of the muscoid group showed a marked decrease. The amount of housefly (*Musca domestica*) breeding in privies had been similar in all the towns, but after privy remodeling there was a reduction in the percentage of privies breeding houseflies in Boston, and this rate of breeding is significantly lower than the rate of housefly breeding in the check towns (tables 2 and 3). On only eight occasions were the privies in Boston found to be breeding sites for houseflies after the program began, and the rate was low, 3.5 (larvae and reared adults) per half-pint sample of privy contents compared with 50.3 in samples taken from privies in the check towns.

The bored-hole privy was less attractive to houseflies than the unmodified privies. Adult flies were observed in the pit or privy structure only 4 percent of the 377 times samples were taken, with a median count of 2.5 flies for these times. In the check towns, the conditions were different—in the 939 samplings, houseflies were observed 31 percent of the time with a median count of 10.

The reduction of housefly breeding observed in rehabilitated privies had no appreciable effect on community fly populations. Since

Table 2. Unmodified privies—entomological and epidemiological observations, by climatic periods, south Georgia, April 1951–April 1952

Observations	Boston	Check towns			
		Total	Pavo	Coolidge	Meigs
	Warm weather (April–October 1951)[1]				
Privies breeding *Musca domestica*	(2)	(2)			
Grill count *M. domestica* [3]	30	28	36	21	
Shigella cultures [4]	382	915	355	281	279
Positive:					
Number	23	26	14	6	6
Percent	6.0	2.8	3.9	2.1	2.2
Diarrhea symptoms: [5]					
Person-months of experience	1,215	3,352	1,012	829	1,511
Number cases	21	68	28	10	30
Rate per 1,000	17.3	20.3	27.7	12.1	19.9
	Cool weather (November 1951–April 1952)[6]				
Privies breeding *M. domestica:* [7]					
Number sampled	164	196	126	45	25
M. domestica:					
Number	23	31	27	4	0
Percent	14	16	21	9	0
Grill count *M. domestica* [3]	11	15	13	21	12
Shigella cultures [4]	303	774	255	226	293
Positive:					
Number	9	30	15	13	2
Percent	3.0	3.9	5.9	5.8	0.7
Diarrhea symptoms: [5]					
Person-months of experience	[8] 1,246	[8] 3,212	994	614	1,604
Number cases	18	49	11	15	23
Rate per 1,000	14.4	15.3	11.1	24.4	14.3

[1] Mean monthly temperature 65° F. or more.
[2] Comparative data not available.
[3] Average third high grill count. Index of *M. domestica*, average of recorded monthly averages. In some months, particularly in cool weather, no counts were made. However, these omissions occurred in all towns and the counts are relative.
[4] Obtained by culturing rectal swabs of children less than 10 years old.
[5] Attack rates per 1,000 person-months of experience for total population in study area.
[6] Mean monthly temperature less than 65° F.
[7] Larvae identified and adults reared from a half-pint sample of privy contents.
[8] January–April 1952.

Table 3. Remodeled privies—entomological and epidemiological observations, by climatic periods, south Georgia, May 1952–October 1953

Observations	Boston [1]	Check towns, unmodified privies			
		Total	Pavo	Coolidge	Meigs
	Warm weather (May–September 1952)[2]				
Privies breeding *Musca domestica:* [3]					
Number sampled	186	459	121	177	161
M. domestica:					
Number	4	51	20	18	13
Percent	2	11	17	10	8
Grill count *M. domestica* [4]	32	52	28	83	44
Shigella cultures [5]	295	843	242	232	369
Postive:					
Number	10	46	21	20	5
Percent	3. 4	5. 5	8. 7	8. 6	1. 4
Diarrhea symptoms: [6]					
Person-months of experience	1, 568	3, 816	1, 222	768	1, 826
Number cases	16	78	26	27	25
Rate per 1,000	10. 2	20. 4	21. 3	35. 2	13. 7
	Cool weather (October 1952–April 1953)[7]				
Privies breeding *M. domestica:* [3]					
Number sampled	221	329	104	107	118
M. domestica:					
Number	3	15	10	5	0
Percent	1	5	10	5	0
Grill count *M. domestica* [4]	8	10	9	15	7
Shigella cultures [5]	316	1, 054	346	216	492
Positive:					
Number	2	32	13	0	19
Percent	0. 6	3. 0	3. 8	0. 0	3. 9
Diarrhea symptoms: [6]					
Person-months of experience	1, 752	5, 592	1, 547	1, 026	3, 019
Number cases	10	59	13	17	29
Rate per 1,000	5. 7	10. 6	8. 4	16. 6	9. 6
	Warm weather (May–October 1953)[2]				
Privies breeding *M. domestica:* [3]					
Number sampled	74	43	43	----	----
M. domestica:					
Number	1	4	4	----	----
Percent	1	9	9	----	----
Grill count *M. domestica* [4]	40	53	64	61	33
Shigella cultures [5]	293	872	285	200	387
Positive:					
Number	13	80	36	10	34
Percent	4. 4	9. 2	12. 6	5. 0	8. 8
Diarrhea symptoms: [6]					
Person-months of experience	1, 809	4, 976	1, 479	921	2, 576
Number cases	19	102	41	12	49
Rate per 1,000	10. 5	20. 5	27. 7	13. 0	19. 0

[1] All privies in Boston remodeled in April and May 1952.

[2] Mean monthly temperature 65° F. or more.

[3] Larvae identified and adults reared from a half-pint sample of privy contents.

[4] Average third high grill count. Index of *M. domestica*, average of recorded monthly averages. In some months, particularly in cool weather, no counts were made. However, these omissions occurred in all towns and the counts are relative.

[5] Obtained by culturing rectal swabs of children less than 10 years old.

[6] Attack rates per 1,000 person-months of experience for total population in study area.

[7] Mean monthly temperature less than 65° F.

Table 4. Shigella prevalence rates in areas with unmodified privies and with remodeled privies, south Georgia, April 1951–October 1953

Type of privy and area	Before privy remodeling (April 1951–April 1952)			After privy remodeling (May 1952–October 1953)			"P" (X^2 test)[1]
	Number rectal swab cultures	*Shigella* isolations		Number rectal swab cultures	*Shigella* isolations		
		Number	Percent		Number	Percent	
Bored-hole privies (Boston)	685	32	4. 7	904	25	2. 8	
Unmodified privies	1, 689	56	3. 3	2, 769	158	5. 7	<. 001
Pavo	610	29	4. 8	873	70	8. 0	<. 001
Coolidge	507	19	3. 7	648	30	4. 6	. 05
Meigs	572	8	1. 4	1, 248	58	4. 6	. 025

[1] Probability that, in the postremodeling period, observed or greater difference in *Shigella* prevalence between the area with remodeled privies and the check towns would have occurred by chance. Probability that difference in *Shigella* prevalence rates between 1 year before to 1 year after privy remodeling periods in Boston, Ga., occurred by chance is 0.008–4.7 percent vs. 2.0 percent.

houseflies have been found to breed in a greater variety of media than have other common muscoid flies, it was to be expected that the reduction of breeding in one medium would have little effect (*3*). The average fly counts, by climatic periods, are shown in tables 2 and 3. Lindsay, Stewart, and Watt (*2*) observed that the increase in *Shigella* transmission came after they lost control of houseflies when the other fly species were still controlled. Consideration has been given to the housefly because small numbers of other fly species were observed in these communities; during the study period, the average monthly count for all other species was 1.3 flies.

During the 18 months of observations after the privy remodeling program was completed, Boston had a significantly lower rate of *Shigella* infections than it had before the program, 2.8 percent vs. 4.7 percent (table 4). In this comparison, two-thirds of the postprogram data taken were obtained during warm weather, whereas only 7 of the 13 months in the preprogram period were the warm months commonly associated with higher rates of *Shigella* infection. The infection rate in Boston was higher than in the check towns for the 13 months before the program (4.7 vs. 3.3 percent), but after the privies were remodeled the Boston rate was lower (2.8 vs. 5.7 percent), as shown in table 4.

The number of persons reporting diarrhea as a symptom of illness is shown in tables 2 and 3. After the excreta disposal methods were improved, the reported diarrhea rate in Boston was only half as high as in the check towns.

Discussion

The bored-hole privy of the design used in this study did not exclude all houseflies from human excreta, but its low attractiveness to houseflies did mitigate this problem somewhat. Deficiencies noted in the design were that the size of the riser permitted fouling of the inside rear of the riser and that, in some of the privies, portions of the contents were floating on the high ground water.

The reduced housefly breeding observed in the bored-hole privies in Boston, where the fly had become highly resistant to the hydrocarbon insecticides, is more remarkable in light of recent ecological studies. In unpublished data, Lindsay states that during studies conducted in Hidalgo County, Tex., in 1946, "not a single housefly was reared from material from anything resembling a pit privy although surface samples frequently were producers." More recently, results from housefly breeding surveys following treatment with hydrocarbon insecticides in the same general areas as well as in other areas, have shown decided increases in housefly production from privy pits (*4–6*).

Results of this study show the approximate maximum level in the reduction of *Shigella* transmission that can be obtained and maintained by the use of good privies alone. With

a water-carried excreta disposal system, the exclusion of flies from human excreta would be more effective than with privies. Also, when water-carried excreta disposal methods are installed, hand-washing facilities usually are also made more available, and the availability of water has been shown to have an influence on rates of *Shigella* infections (*7, 8*). It would be difficult to assess the effect of a water-carried excreta disposal system only, except in an expensive controlled study.

The various recognized mechanisms of transmission of *Shigella* need evaluation in order to develop the best diarrheal disease control program. It is now possible to compare the relative effectiveness of two control procedures: fly exclusion using bored-hole privies, as reported here, as opposed to reduction of fly population with chemicals, as performed in Texas (*1*) and Georgia (*2*). The Georgia studies virtually eliminated flies from the environment, thereby providing an estimate of the effect of complete

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design and construction OF BORED-HOLE PRIVIES

Some of the techniques of privy design and construction presented here may be helpful in rural sanitation programs since the privy will continue to be an important means of excreta disposal in the United States for some time, and in many sections of the world it may be the principal method used. The 1950 census of housing reports that 8,900,641 rural dwellings in this country did not have flush toilets inside the structure, and over 2 million urban dwellings did not have flush toilets.

The bored-hole privy used in this study is an adaptation of the bored-hole latrine 18 to 20 feet deep used by the Rockefeller Foundation in the Philippines. The same type of Iwan 16-inch latrine borer was used. An **A**-frame was constructed on the rear of a pickup truck to hoist the auger out of the hole as the bucket filled (fig. 1). The shaft on the auger was 12 feet long with a crossarm that could be raised as the digging progressed. A crew of 5 men, a carpenter and 4 laborers, bored the hole and set a precast concrete slab over it. Minimal repairs were made to the old privy structure, which was moved to the new location (fig. 2). The privy contents at the old location were buried.

The concrete slabs for the remodeled privies were made 4 feet square and reinforced so that they could be used later on standard pit privies. The slabs were made by pouring ready-mixed concrete into a series of forms at a central site. Later the slabs with the embedded risers were hauled to the location where they were to be used. The truck used to transport the slabs was equipped with an old bomb hoist to facili-

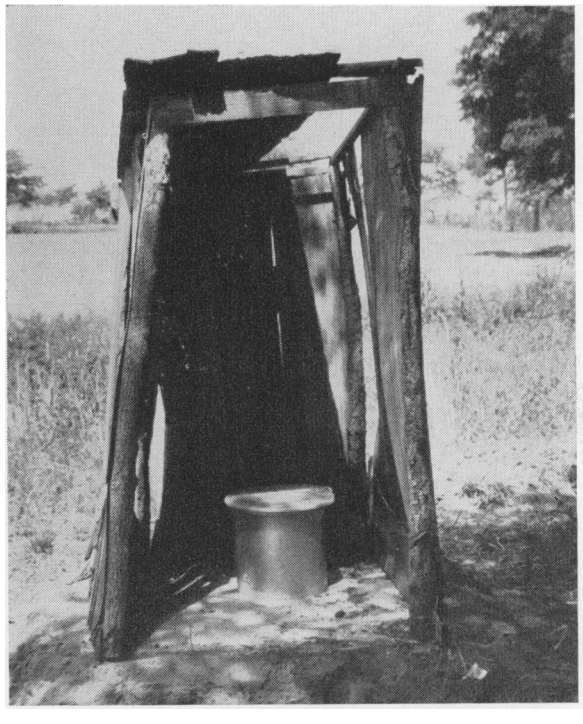
◀ **Figure 1**

exclusion of flies from human excreta. Applying the statistical method used by Francis (*9*) in evaluating the effectiveness of poliomyelitis vaccine, the bored-hole privy technique had an estimated effectiveness of 52 percent in reducing *Shigella* infection rates. This compares with 61 percent in Texas and 67 percent in Georgia when chemical fly control techniques were used. (The lower 95-percent confidence limits of findings in these areas were 33, 55, and 44 percent effectiveness, respectively.) In each of the above studies, some *Shigella* was transmitted during the test period by the other mechanisms. The effectiveness of controlling these other mechanisms should be determined. Increased water availability would decrease the prevalence of dirty hands, for example.

Summary

All privies in Boston, Ga. (population 1,035), were reconstructed in the spring of 1952 by

Figure 2 ▶



tate loading and positioning the slab over the hole.

The aluminum riser, seat, and lid were a unit used by the Georgia Department of Public Health in their improvement programs. The riser was 14 inches in diameter with a stamped metal seat mounted at the top. The lid was hinged at the back and covered the hole and seat completely. It is recommended that the riser be redesigned in the shape of a truncated cone, with the projection to the rear, to minimize fouling.

Curbing of the hole in areas of high ground water is also recommended. In clay, the wall of the hole did not slough off, but if ground water came up to the topsoil, caving of the wall was noted.

The cost of a typical privy (fig. 3) was $26.20. Of this, $11.06 was for material and equipment and $15.14 for approximately 12 hours of labor. This cost is itemized below.

Equipment	$4.04
Truck depreciation	1.02
Truck operation expense	1.46
A-frame and augers	.91
Labor (0.53 hours)	.65
Slab and riser	10.41
Forms	.12
Concrete and steel	2.70
Aluminum riser, seat, and lid	4.85
Labor (1.94 hours)	2.74
Digging hole, setting slab, and moving old privy	10.85
Labor (8.97 hours, range 5–19 hours)	
Travel between privies	.90
Labor (0.74 hour)	
Total	$26.20

Figure 3 ▶

drilling bored holes 8 feet deep. This markedly curtailed housefly breeding in privies but did not significantly reduce the housefly population in the community. Epidemiological observations were continued for 18 months following the privy remodeling. From rectal swab cultures taken monthly, a significant reduction of *Shigella* infections was observed in children less than 10 years old. Also, after improvements were made in the methods of excreta disposal in the community, the reported diarrheal disease rate in Boston was one-half the rate observed in the check towns.

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Medical Research Fellowships

The division of medical sciences of the National Academy of Sciences–National Research Council has announced a program of postdoctoral research fellowships for 1958–59. Applications for the fellowships, which will be awarded in the late winter, will be accepted until December 1, 1957.

The fellowships fall into three categories: the National Research fellowships in the medical sciences offering research experience in the basic medical sciences for persons preparing for careers in academic medicine and investigation; the Donner fellowships for medical research for full-time research at the fundamental level; and fellowships in radiological research, administered for the James Picker Foundation by the division's committee on radiology, for the development of research skills leading to investigative careers in the field of radiology.

Candidates for all three fellowships must hold an M.D., Ph.D., or Sc.D. degree or the equivalent, and should ordinarily not be more than 35 years of age. Applicants for the NRC and Donner fellowships must be citizens of the United States or Canada.

Details and application blanks may be obtained from the Division of Medical Sciences, National Academy of Sciences–National Research Council, 2101 Constitution Ave., NW., Washington 25, D. C.