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METHODS OF SEWER RAT CONTROL

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The control of rats in the urban environment involves more than merely dealing with the above-ground populations. The average urban sewage system provides a vast labyrinth of passages and nesting places for the Norway rat, Rattus norvegicus. Here, in a protected underground habitat the rodent population is free to reproduce and ultimately expand to the maximum number that the environment can support. Eventually, the population outgrows its environment. At this point population pressures force animals to move out of the system. Rat burrows begin appearing in front yards, under sidewalks and driveways, and in flower beds, and rats themselves are occasionally seen emerging from drains and swimming into toilets. The result may be a new colony of rats on the surface and almost certainly numerous complaints to the control agency. In short, the uncontrolled populations of rats in sewers constitute a reservoir which extends into all parts of a city and is capable of establishing new infestations on the surface.

The structural damage caused by sewer rats can be considerable. They are able to burrow into the soil surrounding the sewer through faulty joints or because of deteriorating brick or concrete structures. They excavate chambers, kicking the excess dirt into the sewers. The soil adds to the load the sewer must carry and the excavation itself may eventually lead to a collapse of the street above. In addition, individual house laterals are frequently blocked by rat activities.

Sewer rats constitute a disease hazard. Rats are the principal reservoir of the spirochete, Leptospira icterohemorrhagiae, which causes leptospiral jaundice, or Weil's disease, in man. The leptospires are shed in the rat's urine and are most easily transmitted to swimmers exposed to contaminated water, to sewer workers, and to abattoir and fish workers. Sewer rats also are carriers of various kinds of Salmonella, the organisms that cause food poisoning in man.

Damage caused by this reservoir of rats, whether economic or to health, can be reduced by holding the population below its maximum potential. Thus, it almost always pays to attempt control--even where complete elimination seems to be unattainable.

BRIEF HISTORY OF THE SEWER RAT

The Norway rat has been a denizen of underground drainage systems for several centuries and has richly earned the title of "sewer rat". The earlier history of this rat in Europe was one of living in the great storm drains in the larger cities. In the days prior to the early 19th century there were no sanitary sewers; the surface water and kitchen slop was all that was carried by the storm water drains. In this environment the sewer rat flourished and even was regarded as necessary to consume the large amounts of vegetable and animal matter that daily was thrown into the streets and the drains.

In the United States, innumerable storm-drainage systems existed even as far back as the 17th century. The use of these storm drains for the sanitary disposal of human wastes did not develop on a broad scale until about a hundred years ago. In England, Germany, and the United States the design of comprehensive sanitary sewers dates from about 1850 (Wolman, 1956). At first, many sewer systems were combined foul water and storm water drains, emptying usually into the nearest river or lake. Recently, we have seen the separation of sanitary sewer and storm water drain systems, with sewage treated before it is emptied into a river or lake. The sewer rat successfully made the shift from storm drains to the sanitary sewers. With the increased use of garbage grinders in today's homes, the sewer rat may be entering into a second golden age.

THE SEWER ENVIRONMENT

The physical conditions of sanitary sewers are apparently very conducive to rat life. The rat's two most important requirements, food and shelter, are usually available, but the presence of one is of little use if the other is lacking. Food, as just mentioned, is being supplied in increasing amounts where garbage grinders are installed. As a limiting factor, food is becoming relatively less important.

Shelter is probably the prime factor limiting rat populations in our urban sewer systems. The rat finds shelter in burrows excavated where any break in the sewer line can be found--in blind ends, unused laterals, and in dry or deteriorating manholes. Shelter is necessary for individual rats to escape from their fellows, and for females with young to rear their litter with safety because under crowded conditions mortality of unweaned young can be very high.

The sewer environment is characterized by darkness, high humidity, and seasonal temperatures that are generally warmer in the winter and cooler in the summer than temperatures at the surface. The seasonal temperature variation is, in fact, quite restricted, and this would lead one to suspect that the breeding rates of sewer rats would differ from surface populations. Surprisingly, this is not so. A sample of rats from the Liverpool sewers, collected over a period of a year, when compared with a sample from other sources showed no evidence that the breeding habits of the two were different (Perry, 1945).

CONTROL METHODS

A wide variety of control methods have been advocated to eliminate rats from sewers. The most practical method is the use of poison baits and this will be discussed in detail. A review of other methods will, however, be discussed first. Many of these methods have been applied to large diameter sewers in which the human operator has complete access; they may not be applicable to small bore sewers.

Sticky-boards coated with a water-resistant adhesive and a rodenticide (ANTU) have been used successfully in Stuttgart, Germany (Peters and Junghaus, 1951). This is, in a way, a variation of laying a poisonous dust. As a practical, large-scale technique, it could not be recommended.

Hovell (1924) says that in the Paris sewers, rats have been electrocuted by a live wire strung about 4 inches above the level on which the rats travel; bait was hung at intervals close above the live wire. A rat, on attempting to reach the bait, touches the live wire and is killed.

Gassing appears to be an attractive method at first glance. However, as Mehl (1954) points out, the danger of leakage into buildings on the surface by way of drains precludes the use of highly toxic gases in sewers. This strictly limits the number of gases that may be considered. Among these, sulfur dioxide and flue gas have been used in Germany to drive rats out of drains into the sewers. The hazard to be considered when using any gas is that of containing it within the sewer.

Flooding short sections of sewer is sometimes an effective way of getting rid of rats. The difficulty of reaching all burrows and laterals with water can be appreciated, however. Sewers which are surcharged with tidal flow are self-cleansing in this respect.

Hovell (1924) recommends driving rats (in large sewers) into specially constructed bags. A man enters the sewer and drives rats ahead of him into the expanded bag which completely blocks the sewers, excepting the water. They are then killed inside the bag.

The poison-foam method of Schürmeyer is a German invention (Mehl, 1954). The foam is produced under high pressure from several cylinders which can be carried around strapped to the back. The foam emerges from the nozzle as a flat ribbon of indefinite length, about 2 inches in width, which resembles a thin bread-mash. The foam is applied in sausage-shaped lengths to manhole ledges where it remains stable for two or three days. During this time any rats that run through it may pick up enough on their feet and fur to ensure their death when they clean themselves. The rodenticide used is Promurit, a trade name for a highly toxic compound, parachloro-phenyl-diazoamino-thiourea.

The method has several disadvantages: the original equipment is expensive; one cylinder of Promurit lasts only 8 to 10 minutes when used continuously; and the equipment is complicated and subject to breakdown. The danger to fish should be considered when using the foam in sewers if the poison is not adequately diluted on discharge. This method so far has not found application outside of Germany.

Trapping has been mentioned (Hovell, 1924) as a means of controlling sewer rats. He recommends permanent traps at the ends of sewers where they enter main thoroughfares or leave special areas.

POISON BAITS

Poison baits are the only known practical means of controlling rat populations in sewers. Normally, these are laid on the manhole ledges. In larger sewers which can be walked, baits can be placed along their length on available ledges or on specially installed bait trays.

The bait bases which have given best results are various cereal grains, ground horse meat, and ground fish. Oats, barley, and corn meal all appear to be well-accepted grains in sewers in California communities. Horse meat decays very rapidly and is recommended primarily where a quick kill of a resistant pocket is desired. It is well to determine which bait is most acceptable in each local situation.

Rodenticides that are in common use can be divided into acute poisons and chronic poisons. The acute poisons consist of sodium fluoroacetate (1080), fluoroacetamide, and zinc phosphide. Sodium fluoroacetate at a concentration of 1:400, either in wet or dry baits, has given excellent control where used frequently enough. Used as a direct poison (i.e. without pre-baiting) in the hands of experienced personnel, it is capable of kills of about 90 percent or more. With pre-baiting, an even better kill could be obtained.

Sodium fluoroacetate shows virtually no hazard to fish life (King and Penfound, 1946; Bentley, et al., 1959) when used in sewers discharging into natural waters. If the operator is aware of, and guards against, the hazards of this material, he has one of the best rodenticides available for holding sewer rat populations at a minimum.

Fluoroacetamide is a moderately fast-acting fluoroacetic acid derivative with toxic actions very similar to that of sodium fluoroacetate. It has an acute toxicity to rats about one-fourth that of sodium fluoroacetate and is considered a safer material to handle and manufacture (Chapman and Phillips, 1955). A recent study by Bentley and Greaves (1960) showed that fluoroacetamide is palatable to rats. Since the period of time before the onset of warning symptoms is fairly long, rats consumed an average of 18 to 100 LD_{50} equivalents. The period of onset of symptoms was longer than with sodium fluoroacetate; this appeared to offer a definite advantage in ensuring that all rats tested received a lethal dose before becoming distressed.

In their latest report (Bentley, et al., 1961) the British workers compared the efficiency of 0.25 percent sodium fluoroacetate with 2 percent fluoroacetamide in paired field trials against sewer rats. They found that fluoroacetamide significantly outperformed sodium fluoroacetate and on the basis of these field trials they are prepared to back fluoroacetamide against sodium fluoroacetate. Fluoroacetamide is a material certainly worthy of consideration by American workers for sewer rat control. With its lower toxicity, longer period before onset of symptoms, lesser handling hazards, and proven field efficiency, it is a strong contender with sodium fluoroacetate as a direct acute poison in sewers.

The third acute rodenticide in common use against sewer rats is zinc phosphide. It is usually used at a concentration of 1 to 2½ percent. It can be mixed with cereal grains, using corn oil or peanut oil as a binder, or with ground horse meat or ground fish. It rapidly decomposes in sewers, lasting only a few days. In general, it does not give the excellent direct kill results that can be expected of sodium fluoroacetate or fluoroacetamide.

Chronic poisons (anticoagulants) are coming into wide use against sewer rat populations. The three common ones are warfarin, pival and fumarin. Used with cereal grains and a mold-inhibitor they are proving to be very successful in cleaning up pockets of resistance and even compare favorably with acute poisons in large-scale control of rat populations. They do require a more frequent lifting of manhole covers, since a surplus of bait must be maintained during the treatment. Most treatments require at least three applications. Bentley (1960) recommends a 1-4-8 days schedule where infestations are heavy and a 1-8-15 sequence where light. Some operators use an even longer sequence (1-15-36) and apply two pounds of bait at each manhole.

The great advantage that chronic poisoning offers over direct acute poisoning is that the rats are conditioned to the bait base while they are being poisoned. An additional advantage is the fact that bait shyness, due to receiving a sub-lethal dose of rodenticide, rarely develops when using anticoagulants.

To achieve the best results with acute poisons it is necessary first to condition the animals to the base bait, a procedure known as pre-baiting. Unpoisoned bait is usually offered twice, followed by one application of poisoned bait. There are several advantages to this method. First, the animals are feeding freely on the bait base when the poison in introduced; consequently, they consume more of the poisoned bait than they would if directly poisoned. Secondly, it is known that some rats require several days in which to locate the bait (Bentley, et al., 1955) and these are more likely to be poisoned if pre-baited.

PARAFFIN BAITS

Moisture-proofing of baits by mixing them with paraffin has been a recent innovation (Ecke and Christofano, 1959; Marsh and Plesse, 1960). The solidified paraffin blocks of either acute or chronic poison baits have proven to be very versatile. Anticoagulant baits are usually mixed with paraffin in amounts of 1 quart to 1 gallon. The gallon amount, poured into a number 10 can, nailed to a heavy plank and placed on its side on the manhole ledge, provides enough bait to last for several weeks. The quart amount seems to be ideally suited to clean up a small pocket of resistance around one or two manholes. All containers should be anchored with wire to prevent their being swept into the sewer and to make inspection easier.

Permanent paraffin blocks utilizing acute poisons, such as sodium fluoroacetate or fluoroacetamide, are easily prepared. Dissolve 1 ounce of sodium fluoroacetate in 1 gallon of water and mix with 28 pounds of grain bait (keep the same ratio when using smaller amounts of bait) until the grains are wet. Spread the grain out on a tray to dry. The air-dried grain is then mixed with paraffin, using just as little paraffin as is required to hold the block together. Insert a wire, bent so that a loop rests on the bottom of the mold, into the mixture before adding the paraffin.

Permanent paraffin blocks with acute poisons are useful in cleaning up small pockets of resistance following an initial poisoning campaign. They can be used in preventing re-infestation into a branch of the sewer system which has been cleared. Acute poison blocks are placed in the manholes of the laterals that afford entrance into the entire upper system that has been cleared. Any animal attempting to move into the cleared system will be exposed to the poison point.

One other use of paraffin blocks might be mentioned. These could prove useful in manholes which are excessively wet or where splashing water would quickly wash away loose bait.

MOLD INHIBITORS

Semi-permanent baits can be prepared for sewer rat control by adding mold inhibitors such as paranitrophenol or dehydroacetic acid (or its sodium salt). Larthe (1957) recommends using paranitrophenol at a concentration of 0.25 percent; above this concentration acceptance of bait was greatly reduced. Dehydroacetic acid and its sodium salt are best used at concentrations of 0.1 percent and 0.15 percent, respectively. Moldiness in pinhead oatmeal treated with these materials did not appear until after exposure for 18 to 21 days in damp sewers.

Bentley (1960) gives the following formulations for using these preservatives: add 1/4 pound of paranitrophenol to every 100 pounds of bait (0.25 percent concentration) or add dehydroacetic acid at the rate of 1 ounce to 60 pounds of bait--approximately 0.1 percent (for the sodium salt add 1 ounce per 40 pounds of bait--0.15 percent).

The sodium salt of dehydroacetic acid is water soluble and so is para-nitrophenol if the water is warmed. Dissolve them first in the water with the rodenticide and then soak the grain in the usual way. If paranitrophenol or one of the other two preservatives is used with anticoagulants, they should be mixed at the same strengths as given above.

The advantages of mold-inhibited baits are obvious. Any kind of treatment that will prolong the life of the bait would increase the effectiveness of the one-shot per year poisoning program, or of any direct poisoning effort for that matter. This is due to the fact that not all rats locate the bait within a few days. In one sewer, for instance, Bentley, et al., (1955) found that the maximum bait take occurred only after nine days. Naturally, a bait that will persist in an acceptable state for up to three weeks guarantees that much more of the rat population will have a chance to find it.

BAITING METHODS

The simplest means of laying baits is to utilize the manhole benching. The benching should first be swept clean so that fresh rat sign can easily be seen. Virtually all baiting is done from the street surface because of its ease and speed. The most frequently used baiting tool is a large spoon. If the manholes are deep or the benchings hard to reach, another type of baiting device must be used. Bentley (1960) describes a bait depositor in the form of a box with a false floor that falls away when the string by which the depositor is lowered is slackened. This allows the operator to swing the bait onto a bench that would be impossible to hit with a spoon.

He also describes a telescopic metal or plastic tube, with a funnel-shaped upper end, through which the bait is poured when the lower end of the tube is properly positioned. Another useful device is a freely-swinging can, mounted at the end of a pole, which can be inverted by pulling a string.

In sewers with no benchings at the manholes, bait trays fastened to the side of the sewer above the level of flow are useful. A short length of 3-inch rope enables the rats to climb up to it. Some sewers may have a small step above the flow level, approximately 3 to 4 inches wide. A plank may be placed across the sewer, resting on both steps. Both sides should be baited near the sewer wall since rats may habitually travel along only one side. Worcester (1959) describes a floating bait station for use in manholes subject to extreme fluctuations in sewage level. He mounts quart ice cream containers on 14-inch sections of bridge plank. These are secured to the manhole ladders with stove pipe wire, allowing enough slack to compensate for rise and fall.

Moist baits, which might scatter excessively when applied with a spoon, could be spooned into waxed-paper sandwich bags and tossed onto the benching intact. Rats will not hesitate to rip into the bag.

The amount of poison-bait laid in each manhole will depend somewhat on the sign observed and on how much is known of its past history. Usually 2 ounces of acute poison bait will suffice; heavy infestations may require 4 ounces. If chronic poisons are being used and the bait sequence is short, 8 to 16 ounces for each manhole will probably suffice. If a longer bait sequence is being used, then 1½ to 2 pounds per manhole per baiting would be needed. In any case, where all, or almost all, of the bait is taken between baitings, the amount laid should be doubled.

ENVIRONMENTAL CONTROL

Other control measures can be aimed at reducing the two main elements necessary to rat life in sewers--food and shelter. Communities with obviously old and deteriorating sewer mains carrying a maximum flow should not permit the installation of garbage grinders unless new sewers are installed capable of handling the increased load.

Orangeburg and ordinary clay sewer pipe cannot be recommended, since neither is impervious to the gnawing of rats. A city code or ordinance should require plumbers to seal off abandoned service lines at the sewer main and not at the property line. Any time a building is abandoned, moved from the premises or destroyed, the sewer laterals should be capped at the sewer main. When the main line is tapped for a new service line, the break should be rat-proofed. Rat control problems are greatly eased if the storm water drains and sanitary sewers are two separate systems with no crossovers.

THE CONTROL PROGRAM

Knowledge of the distribution and extent of rat infestation in the sewer system is basic to any good control program. As information is gathered it should be transferred to a large map of the sewer system that shows the location of every manhole and the sewer mains and their direction of flow.

Information on rat infestation will come from several sources. Some of the best information is gained by a visual inspection of the manholes, noting the presence or absence of rat sign and the approximate amount of sign. A sample of the city's manholes, perhaps 10 percent, selected at random should give an indication of the pattern of rat distribution and suggest areas in need of treatment.

Surface rat complaints often give a good clue to the presence of an underground reservoir population. Areas of chronic complaint, where investigation shows rat burrows under sidewalks, driveways, or in front yards are almost certain to show a sewer infestation.

Sewer maintenance crews should report the finding of rat-infested manholes to the agency doing control work. Conversely, the control agency should notify the sewer maintenance personnel of any poisoning operations, the specific manholes involved and the type of rodenticide being used.

Since rat sign is not an infallible indicator of the presence or absence of rats, Bentley (1960) recommends placing "token baits" of several ounces of barley or oats on the manhole ledges, whether rat droppings are present or not. The manholes are rechecked 5 to 7 days later and the take of bait recorded. This gives excellent data on the presence of rats but involves two liftings of the manholes. However, it can be tied into the control program by poison baiting at the time of re-inspection.

A method of using smoke to spot rodent burrows connected with either the main sewer or individual house laterals has been described by Bruce and Pomeroy (1956), Rea (1957) and Stacy (1961). Smoke is forced into the sewer main and by noting its emergence from under sidewalks, driveways, flower beds, front yards, water meter boxes, etc., rat activity can be detected. With the use of such a technique, the health department has a mass survey method that can easily locate trouble spots before excessive rat activity can cause damage or complaints.

The materials used are easily obtainable and simple to operate. Smoke bombs, yellow or red variety, are available from pyrotechnic companies. A Homelite portable blower, Model 20B, has been used to satisfactorily force the smoke through the system. This blower is capable of moving 1500 cubic feet of air per minute, more than adequate for several blocks of sewer main. The blower is connected by either an 8-inch flexible hose or a canvas air duct to a plywood disc about three feet in diameter. This disc has a ring of sponge rubber around its underside to act as a seal. Several sand bags are used to hold the plywood disc fast to the manhole.

In operation, the plywood disc is fitted over the open manhole and the flexible blower hose is fastened to it. The blower is started and allowed to run about 30 seconds to establish an air flow in the sewer. The smoke bomb is lit and quickly placed in the intake of the blower.

In about 30 seconds smoke can be observed coming from plumbing vent stacks on houses. It will also emerge from any other place where there is a break in the sewer leading to the surface. The area covered is generally about a block in both directions from the manhole that is smoked. The smoke is visible for about 5 minutes.

The uses of the technique are several and include locating potential or actual rodent burrows, finding crossovers between the sanitary sewers and storm water drains, spotting illegal connections to the sanitary sewer, finding leaky sections of sewer line that allow excessive infiltration of storm water, and as a check on the general condition of the sewer mains. Its greatest value to the health department lies in locating areas of rat activity that require prompt control procedures. The method can be initiated as a routine maintenance procedure by the street department to check on sewer condition and reports of rodent activity could be forwarded to the health department for prompt action.

Once the distribution of the rat populations in the sewer system is established, the actual control program can be initiated. If rats are found to be distributed city-wide, a reasonable start can be made by baiting every accessible manhole with one of the acute rodenticides. During the course of poisoning, data should be taken on the condition (wet, dry, flooded) of manholes and the rat sign (fresh or old rat droppings, burrows, dead rats) found at each manhole. The ledges should be swept clear so that fresh sign can be quickly spotted. A follow-up survey of the treated manholes can be made 2 to 3 weeks after poisoning. Any manhole showing fresh sign should be again treated with an acute rodenticide but with a different bait base. Thereafter, a routine operation using an acute poison could be carried out at six-month intervals.

If, however, real progress is to be made in clearing the sewer system of rats, a more imaginative approach will be necessary. The survivors of an initial poisoning operation, or for that matter the pockets of resistance following periodic control operations, are discontinuously distributed in the sewer system. If the system is to be permanently cleared, then an attack on each of these relatively self-contained populations is called for. Assuming that reliable records have been kept during the pre-poisoning survey and during the poisoning operation, it should be fairly easy to spot the survivors on the sewer map. Eash branch of the sewer system that is infested should be worked until it is clear. This is probably best done by baiting with an anticoagulant until no further takes are observed.

Then to provide additional guarantee that the branch will remain clear, several acute poison paraffin blocks may be fixed in each of the several manholes that tie the branch into the main system. For re-invasion of this branch to take place from the main sewer system, rats will have to pass the manholes with poison blocks. These permanent poison points have a very good chance of stopping any invaders. Similarly, when a new sewer line ties into the main sewer, permanent poison blocks can be installed in the entry manholes to cut down the survival of invading rats. Frequent, periodic inspection is an important element in the success of these poison points.

Assessing the kill is one of the important problems we have not solved. Counting the number killed is of little value since it is the survivors we have to contend with. Bentley (1960) advises placing "test-baits" every six months at the manholes previously treated. Enough bait should be placed to serve as a pre-bait for 2 or 3 days--follow this with the same bait base but with poison. The pre-bait take will give reliable figures on survivors at each manhole and while involving an extra lifting of the manhole covers, results in a more efficient poisoning operation.

The economics of sewer rat control quite frequently demand that only one lifting of manholes per year be made. The current costs of poisoning per manhole in several California communities has ranged from approximately $0.50 to $1.20. This figure includes labor, vehicle and materials. Considering these costs, a twice-yearly baiting of the chronically-infested areas with an acute rodenticide is suggested as a minimum control program for any city.

LITERATURE CITED

Bentley, E. W. 1960. Control of rats in sewers. Minist. Agric., Fish and Food Tech. Bull. No. 10, 22 p.

Bentley, E. W., J. S. Alabaster and Eileen Taylor. 1959. The use of sodium fluoroacetate against rats living in sewers discharging into natural waters. Sanitarian 67:309-310.

Bentley, E. W., A. H. Bathard and L. E. Hammond. 1955. Some observations on a rat population in a sewer. Ann. Appl. Biol. 43:485-494.

Bentley, E. W. and J. H. Greaves. 1960. Some properties of fluoroacetamide as a rodenticide. J. Hyg., Camb. 58(2):125-132.

Bentley, E. W., L. E. Hammond, A. H. Bathard and J. H. Greaves. 1961. Sodium fluoroacetate and fluoroacetamide as 'direct' poisons for the control of rats in sewers. J. Hyg., Camb. 59(4):413-417.

Bruce, D. and R. Pomeroy. 1956. Smoking out trouble in sewers is Santa Cruz technique. Western City 32(4):40.

Chapman, C. and M. A. Phillips. 1955. Fluoroacetamide as a rodenticide. J. Sci. Food and Agric. 6(5):231-232.

Ecke, D. H. and S. M. Cristofano. 1959. City-county team wins war on rats. Amer. City 74(10):104-105.

Hovell, M. 1924. Rats and how to destroy them. Wm. Wood and Co., New York. 465 p.

King, J. E. and W. T. Penfound. 1946. Effects of new herbicides on fish. Science 103:487.

Larthe, Y. 1957. The preservation of baits with special reference to the control of rats in sewers. Sanitarian 65:276-281.

Marsh, R. E. and L. F. Plesse. 1960. Semipermanent anticoagulant baits. Calif. Dept. Agric. Bull. 49(3):195-197.

Mehl, S. 1954. Die Bekämpfung der Ratten in der Kanalisation. Merkbl. Nr. 12, Bayer. Landesanst. f. Pflzb. u. Pflzsch. Munich, 4 p.

Perry, J. S. 1945. The reproduction of the wild brown rat (<u>Rattus norvegicus</u> Erxleben). Proc. Zool. Soc. Lond. 115:19-46.

Peters, H. and L. Junghaus. 1951. Über die Brauchbarkeit von Giftleim zur Rattenbekämpfung in der Kanalisation. Städthygiene 11:305-306.

Rea, A. N. 1957. Sewer problems and serendipity. Calif. Vector Views 4(12):76.

Stacy, C. E. 1961. Locating leaky sewers with smoke. Publ. Works 92(11):133.

Wolman, A. 1956. Disposal of man's wastes, p. 807-816. In W. L. Thomas, Jr. [ed.], Man's role in changing the face of the earth, Univ. Chicago Press, Chicago.

Worcester, M. D. 1959. Rat control in small sewers. Pest Control 27(8): 21-22.