Characteristics of Medical and Surgical Suction Systems. The Microbiology and Nosocomial Hazards of Collection Vessels

Thomas R. Neblett, Ph.D.
Harold W. Rossmoore, Ph.D.
John W. Wireman, Ph.D.

Emptying the suction canister is a routine duty performed by hospital personnel which may have certain associated bio-hazards. Laboratory investigations of such hazards have included (1) bacterial growth rate within the canister and species recoverable, (2) bacterial population acquired on workers' hands while emptying canisters, and (3) airborne bacteria released when canisters were emptied, and the relationship of their numbers to population within the canister. Bacterial population within the suctioned material was found to increase the longer a canister remains in place. Microorganisms on the hands increased after dumping the populated canister. A higher bacterial population within the canister produced proportionately greater hand population during emptying. Hand populations remained higher than anticipated following a single postdumping handwash. Numbers of airborne bacteria above the dumping site increased in direct relation to the microbial content of the canister. The results suggest that the act of emptying a canister can lead to increased bacterial contamination of hospital personnel and environment.

Thomas R. Neblett, Ph.D.

Harold W. Rossmoore, Ph.D.

John W. Wireman, Ph.D.

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Thomas R. Neblett, Ph.D.

Dr. Thomas R. Neblett is a clinical microbiologist who has had more than 25 years experience in his chosen field. He holds a Ph.D. degree in Microbiology and Public Health from Michigan State University, a M. S. degree in Biology with specialization in Bacteriology from Wayne State University and an undergraduate (B.A.) divisional degree in Biological Sciences from Michigan State College (now MSU). Dr. Neblett's professional background includes major medical center and community hospital type microbiology and infection control practises experiences. He was employed for 22 years at Henry Ford Hospital, Detroit, Michigan where he directed clinical Serology and Microbiology. For three years he was Chief Microbiologist for Flint Clinical Pathologists, P.C., serving St. Joseph and McLaren Hospitals in Flint, Michigan. His specialized scientific interests have included applications of fluorescent antibody methods to diagnostic immunology and bacteriology, urinary tract microbiology, clinically significant anaerobic bacteria, *Legionella* and most recently, the microbiology of medical suctioning equipment and procedures. He was a member of the Infections Control Committees in each of those hospitals where he has served as Director of Microbiology.

Dr. Neblett is a member of numerous regional and national professional societies. As a member of the American Society of Microbiology he has been active in continuing education programs, as chairman of a travelling anaerobic bacteriology workshop and as convenor of numerous workshop programs offered at the ASM and other professional society annual meetings. His experiences as a speaker and workshop presenter have included travels throughout the United States and to Canada, Europe and Mexico. His audiences have included microbiologists, physicians, medical technologists, practitioners of infection control and nursing groups. His most recent activities include a one-day lecture workshop on the microbiology and infectious hazards associated with medical suction devices.

Dr. Neblett is currently self-employed as a microbiology consultant to Biosan Laboratories of Ferndale, Michigan and to Medivac Corporation of Abilene, Texas. He may be reached at his Farmington Hills, Michigan office, 313-471-5480, or by mail or phone at Biosan Laboratories, 10657 Galaxie Ave., Ferndale, Michigan, 313-544-0042 or through Medivac Corporation, 442 Cedar St., Abilene, Texas, 800-351-1360.

Harold W. Rossmoore, Ph.D.

Dr. H. W. Rossmoore is currently Professor of Biological Sciences and Adjunct Professor of Occupational and Environmental Health at Wayne State University, Detroit. He also is President and Founder of Biosan Laboratories, Ferndale, Michigan. He attended the University of Michigan where he earned degrees in Pharmacy, Chemistry, and the Ph.D. in Microbiology.

During his microbiological career he has published widely in the field of contamination control, including more than 50 original articles and one patent, and presented his research at numerous international meetings. In 1964-65 he as a recipient of a Fulbright Professorship and a National Science Foundation Fellowship for studies at the University of Madrid, Spain, and at the Laboratory of Insect Pathology of the Institute of Entomology, also in Spain. His book, "The Microbes, Our Unseen Friends," written for popular consumption was given an award by the New York Academy of Sciences in 1979.

He is a member of numerous professional and scientific societies and has been elected a fellow of the Royal Society of Health (U.K.). Some of his affiliations include American Association for the Advancement of Science, Society for Industrial Microbiology, American Society for Microbiology, Biodeterioration Society (London), Society of Invertebrate Pathology, National Association of Corrosion Engineers, American Society of Lubrication Engineers, and the American Society for Testing and Materials.

John W. Wireman, Ph.D.

Dr. John W. Wireman is currently Senior Consultant in Industrial and Applied Microbiology at Biosan Laboratories, Ferndale, Michigan. He also is an Adjunct Professor of Biological Sciences at Wayne State University, Detroit. Dr. Wireman received his Ph.D. in Biochemistry and Microbiology from the University of Illinois, Urbana.

He was a National Institutes of Health Postdoctoral Fellow at the University of Minnesota Medical School before joining the faculty at Wayne State University. Some of his professional affiliations include the American Association for the Advancement of Science, Society for Industrial Microbiology, and American Society for Microbiology.

Dr. Wireman's research interests have included work on Ehrlich Ascites Tumor cells, plant and bacterial virology, and the physiology and developmental biology of bacteria. Currently his research involves the microbial influence on geochemical processes, microbial contamination control in industrial environments, and studies of the population biology of microorganisms involved in metal corrosion.

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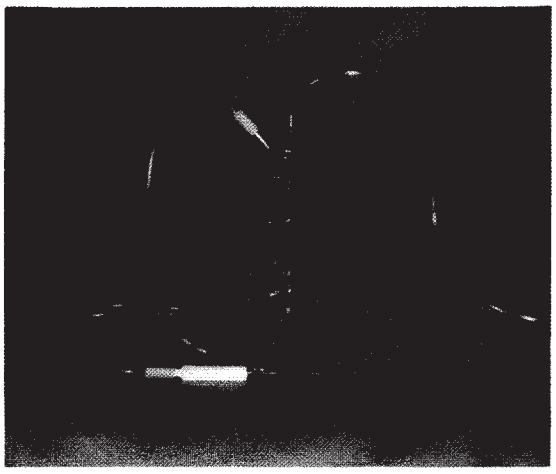
The experimental research reported in this monograph was conducted at Biosan Laboratories, Inc., 10657 Galaxie Ave., Ferndale, Michigan 48220 where the authors may be contacted for further information pertaining to this and related work. The authors gratefully acknowledge the able technical assistance, advice and interest of Carolyn Young and Leonard A. Rossmoore. Without cooperation from industry, and because of reductions in available governmental funding, time consuming and costly research of this type is often left undone. The authors wish to thank the Medi-Vac Corporation for the grant-in-aide which funded this project.

I. Introduction

Suctioning is a process by which materials are caused to flow from one place to another through a tube by means of negative atmospheric pressure differential.[1] Load is pushed from a source at higher atmospheric pressure toward a location having lower pressure. In all systems the receiving vessel becomes the immediate repository for suctioned load. Harmful characteristics of suctioning include possible traumatization of delicate tissues, asphyxia due to airway evacuation, and contribution toward or direct responsibility for infection.

The process of medical and surgical suction finds many applications within the modern health care facility. Surgical and obstetrics departments, emergency rooms, intensive care sections, oral surgery departments, and general patient care areas all have daily need for suctioning capabilities. Beneficial aspects of clinical suction include the removal of load, mainly liquids, small solids, combinations of unwanted tissues, mucopurulent matter, and air-foam or froth. Load is removed from a location harmful to the patient into a convenient, microbially safe receiving vessel where it may ultimately undergo examination, evaluation, and measurement prior to final aseptic disposal.

The clinical suction system characteristically aspirates a higher ratio of room air to liquid, so the suction load collector needs to be designed to permit gaseous flow (air) to pass freely onward in the direction of the vacuum source and to retain the non-gaseous load within the collector. The air phase moves on into the system and pump, finally to be discharged beyond the pump.



Typical suction set-up including patient connecting tube and tip.

II. Components

All clinical suction systems have common components. A suction tip, sometimes referred to as the sucker or catheter, is applied to the patient and is connected via tubing to the inlet side of the collection vessel. The collection vessel serves as the immediate source of vacuum which receives aspirated material and allows air passage through its exit portal. It is connected to the vacuum source via tubing and may pass the air through some form of pressure regulating device. Presence of a float shut-off to prevent liquid being drawn through the exhaust opening is a desirable component and should be fabricated to reduce any possibility of user removal or product non-function through user misconnection.

III. Microorganisms Involved

Any substance which originates from the human body must be considered as potentially capable of containing (and thereby of transmitting) microorganisms associated with body flora. Within a

Close-up of material inside used suction collection vessel which can serve as growth substrate for bacteria.

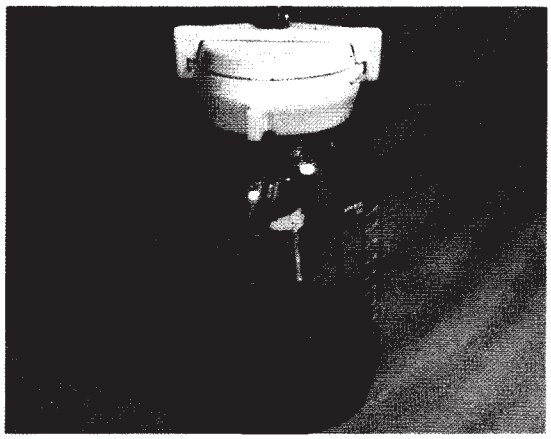
receiving vessel organic body substances can serve as growth substrate if allowed to incubate, thereby increasing bacterial population within the vessel. Extent of such overgrowth will depend, of course, upon how long the collector is allowed to stand at room temperature prior to emptying it. Investigation of this principle and data to support it follow in a subsequent section.

From pathologic body sites, the microbial content of suction load may be quite high and contain significant pathogens. Bacterial content of abscesses can include *Clostridium*, *Bacteroides*, and

Straphylococcus. The respiratory tract can contain *Streptococcus, Pseudomonas, Klebsiella, Serratia,* and a variety of gram negative commensal organisms. The female genito-urinary tract can contain a polymicrobic flora similar to that of the intestinal tract plus Herpes virus. According to the Joint Commission on Accreditation of Hospitals (JCAH), any blood or serous fluid must be considered as potentially hazardous[2], and capable of transmitting hepatitis virus. If not adequately contained, the material aspirated from the human body has distinct infectious potential when not properly handled.

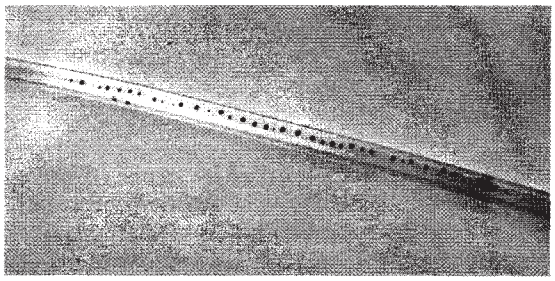
IV. Mechanics of Suctioning

During the process of patient suctioning, load and air enter at the suction tip and are drawn toward the collector. For short intervals, load may consist totally of fluid, mucus, or pus. The tip may become momentarily occluded and when cleared can allow air to enter the system quite abruptly. More commonly, the tubing conducts air and liquid together, without total occlusion. Under any of these circumstances, flow and velocity build up to create splashing and shearing forces across the heavier liquid within the container. Droplets



Splash particles collected on interior surfaces of vessel.

tend to form from the mixture of air and fluid, and heavier material and particles fall to the bottom of the container. Smaller droplets and minute particles tend to remain suspended in the air which makes its way, in a high state of tubulence, toward the exit portal of the collector. Aerosolized material is free to deposit on any surface it contacts from that point onward.

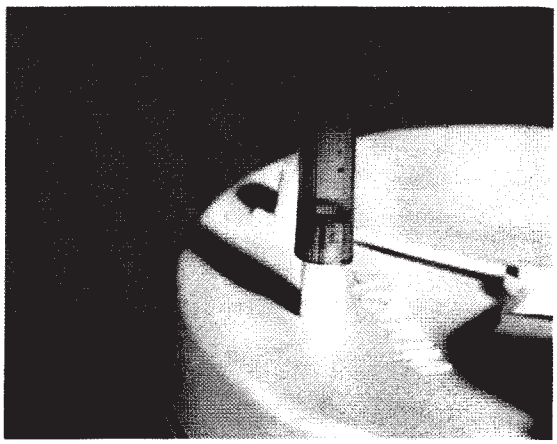


Close-up of coalesced aerosol particles inside vacuum connecting tube.

Work by Ranger and O'Grady demonstrated that as negative pressure increased, so did the numbers of microorganisms released by aerosolization.[3] They also established that the splash turbulence created when an occluded interval ended caused the level of aerosolized particle release to be highest, irrespective of level. Clearly, the need exists for a filter to be installed at the exhaust portal of medical suction collectors capable of entrapping microorganisms and a certain amount of moisture.[4] Ranger and O'Grady's work was performed on portable equipment, and they successfully prevented organism discharge into patient environments by means of a filter installed on the vacuum pump outlet. Rees found a filter placed between the collector and the vacuum pump to be effective in preventing such aerosol spread into the pump.[5]

V. Epidemiological and Nosocomial Significance of the Suction Canister and Aerosolized Particles

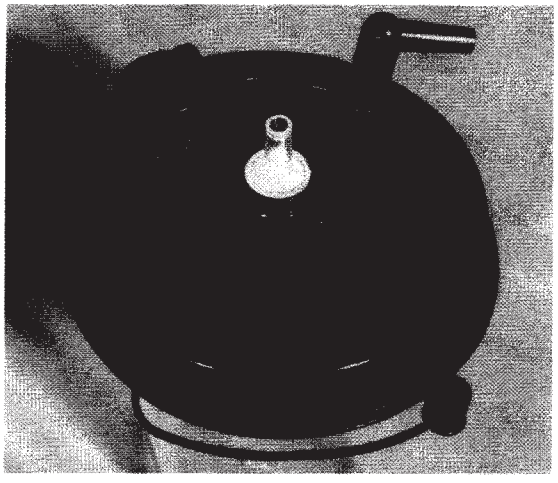
Handwashing must be practiced after handling suction apparati. An operator's hands can become contaminated in several ways, and touch spread of microorganisms thereby becomes possible. Organisms can be shed from the collector to deposit in tubing, regulators, and throughout a system if their escape through the exit portal is not impeded by a filter. The act of disconnecting tubing through which aerosolized patient contaminants have passed presents a distinct potential for hand contamination. Handling a canister containing microbially laden material during the disposal process can add to the flora of the hands. This



Heavy contamination at point-of-connection between collection vessel and tubing.

is possible through the act of removing the snap-fit lid on a disposable type collector. Material within the vessel can easily splash about as the lid comes off, and great care must be exercised to prevent contaminating hands by this procedure. As either a disposable or re-usable collection vessel is emptied, an aerosol is generated and the bacterial population of hands is increased proportional to the numbers of organisms harbored within the canister load. Failure to perform recommended handwashing procedures can result in the transmission of contaminating microorganisms throughout a patient care area.

A filter placed between the collector and the vacuum source will enhance the microbiological safety of the system. Likewise, if the collector can be discarded without going through the opening and pouring steps, a significant source of microbial contamination will be



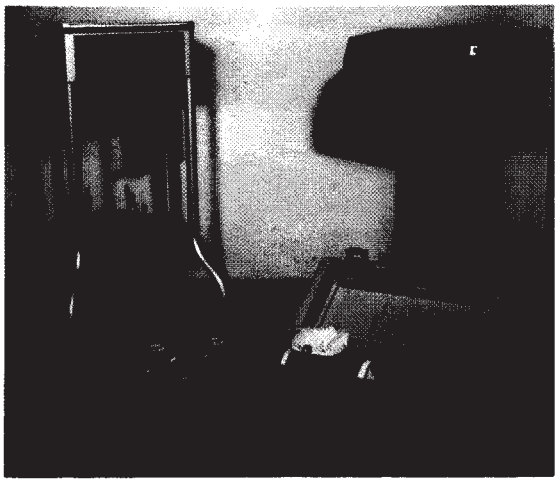
Some collection vessels build the aerosol retaining filter into the product as a non-removable part.

eliminated. Since the collector is responsible for receiving and retaining all of the aspirated load, all means possible should be observed to insure its function as a site from which nothing escapes.

VI. Portable and Central Vacuum Systems Compared

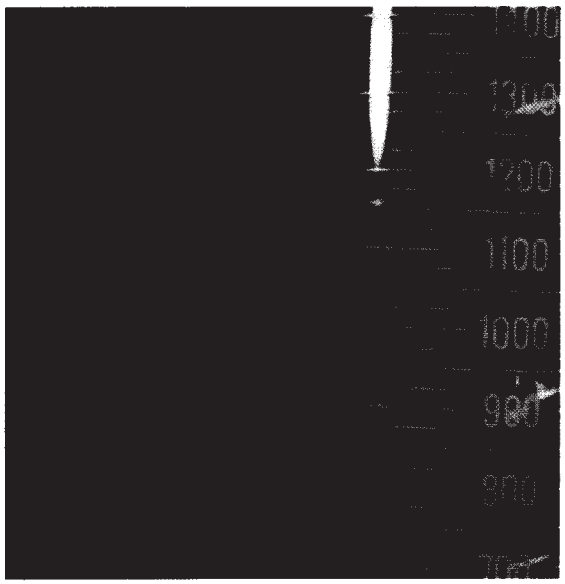
Clinical suction systems can be divided into two main categories: portable and central. Certain differences between the two merit consideration.

A. *Portable Systems*



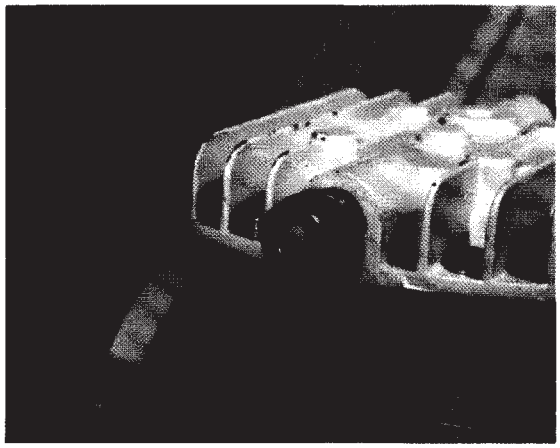
Shown here is a group of portable vacuum pumps typically used in patient care areas.

The portable system may be taken from room to room and only depends upon building facilities for its electrical power. It is otherwise self-contained. Suction from the unit's own vacuum pump may be applied directly to a rigid collection vessel, or it may be applied to a rigid chamber within which is contained a disposable plastic collection liner. Culture data indicate that units of the liner type, which do not have bacterial retentive filters on the outlet, allow aerosols (generated within the liner) to escape into the outer reusable chamber, collect on the surface of the bag, and pass through the tube connecting the outer chamber to the vacuum pump. With the absence of a shut-off valve, the additional possibility also exists for the bag to overflow into its outer chamber, grossly contaminating it. Other brands of portable suction units have rigid reusable collectors which must be handled, emptied, and sterilized prior to use.

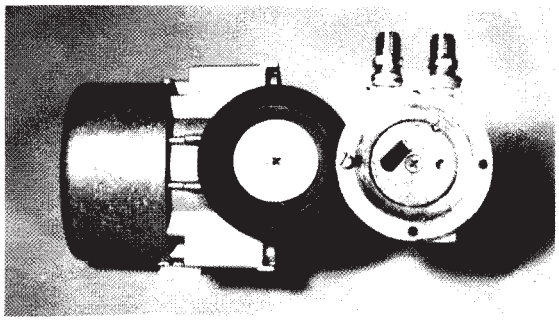


Notice the space between the interior lining and the outside reusable container. Here in this space contaminants can accumulate if a filtering device is not provided.

A common problem of portable suction units is the capability of discharging any microorganisms aspirated from present or past patients back into room space where the unit is in use. One pump manufacturer recognized this potential hazard and equipped the discharge tube end beyond the pump with a disposable fiber filter. With reuse, the filter will eventually pass microorganisms, but it represents an improvement over untreated discharge. Pumps are able to retain ubiquitous bacteria within the pump mechanism. These bacteria become deposited within the pump as aerosols from the collector and remain to be distributed into another patient room next time the portable pump is used. Routine central service procedures for processing portable units do not include gas sterilization of the entire unit or passage of formalin vapor through the pump as a decontaminating process. We have found as many as six different colony-forming types of bacteria and molds discharged from pump units which had been cleaned, serviced, draped, and were awaiting distribution to some other patient care area.



This picture shows the exhaust portion of a portable vacuum pump.

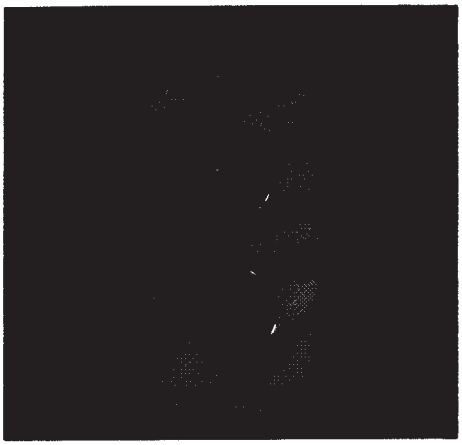


The interior of this portable vacuum pump is heavily contaminated, although disassembly is the only method of disclosing the presence of this contamination.

The need for a filtered collector on a portable pump is, therefore, two-fold. First, collection and containment of biologically active aerosols prevents the pump from becoming a source of widespread, inter-patient contamination; second, filtered collectors are needed to extend the life and performance of portable vacuum pumps.

B. *Central Systems*

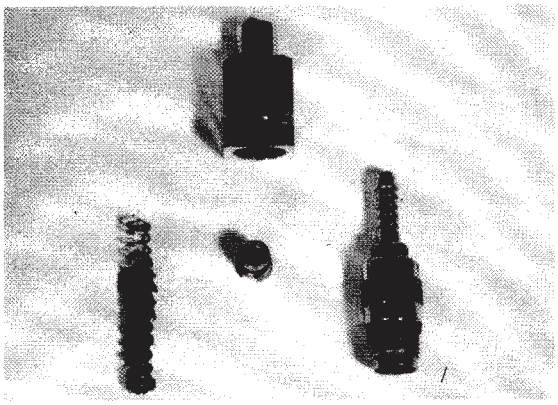
Vacuum systems employ built-in piping which leads from wall regulator attachment sites variously located within the hospital such as



A picture of a typical vacuum wall quick disconnect.

operating suites, delivery rooms, intensive care units, and often in a hospital's clinical laboratories. The network of piping usually leads to a large volume tank or chamber which has vacuum pulled on it by an alternating pair of pumps. The driving vacuum for the system is maintained somewhere around 12-15 inches of mercury at the most distant point in the system. Usually, capacity of the driving tank is large in order to maintain stable negative pressure support for an entire wing or building. Reliability is insured by having a pair of pumps which alternate automatically, actuated by pressure switches having upper and lower limits.

Any substance which is able to exit the collection vessel has the potential to enter and become a problem within the built-in system. Continuous exposure of regulator or pump mechanisms to the moisture of human secretions can result in corrosion or clogging which leads to erroneous vacuum level readings or outright failure of the mechanism. Although no epidemiologic rationale for the use of a filtered collector has yet been reported, circumstantial evidence is quite clear. Moreoever, the control of aerosols is an effort to extend the life of central vacuum components and to reduce the expenditures of routine maintenance and repair.



A disassembled quick dosconnect showing heavy contamination due to accumulations of aerosol particles, lint, and other foreign debris sucked into the outlet.

The discharge point of the system can be a problem of potential contamination since microorganisms drawn into the system are able to find their way into the reservoir chamber, past the pumps and out the discharge. Ideally, the discharge should be a closed one, connecting directly into the municipal sewerage system. However, this is not always the case and central vacuum discharges can be found opening into hospital basements, to the atmosphere at ground level (usually near a patient parking area), or onto the roof near a building air intake. Filters will, therefore, reduce the contamination of both portable and central vacuum systems.

VII. Studies to Examine the Microbiological Character of Medical Suction Collection Vessels

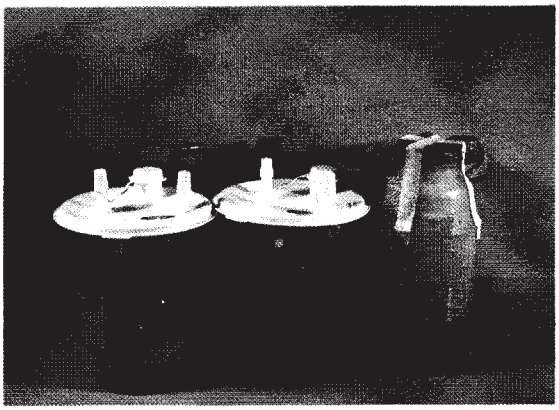
Three aspects of the microbiological characteristics of medical suction collection canisters have been investigated: (1) a canister populations study to determine rate of bacterial growth within the canister at room temperature, numbers of bacteria and identities recovered, (2) study of the bacterial population changes on operator's hands created by handling and dumping canisters, and (3) measurement of bacterial aerosols generated over the area where canisters are emptied.

A. *Methods*

1. *Canister Populations Study*

Scant information has existed about microbial growth which takes place within a suction collector while attached to the patient. The collector remains at room temperature while performing its function of receiving material aspirated from the patient. While room temperature is not optimal for the growth of bacteria, total cell numbers would seemingly increase significantly within the vessel due to the multiplication of organisms drawn in with organic body wastes early during its usage, and subsequent evacuations from the patient would add supplemental inoculum to that already present. The net result, depending upon how long the canister remained in its function, would likely be an increasingly populated content which would have greater potentially infectious hazard as the collection vessel continued in use. The following experiments were undertaken in order to acquire data on the rate of bacterial increase within a suction collector at room temperature and what indentities of potentially pathogenic and commensal microorganisms might be recovered.

Suction collection vessels of an intended disposable type were obtained from patients confined within critical care sections of a large



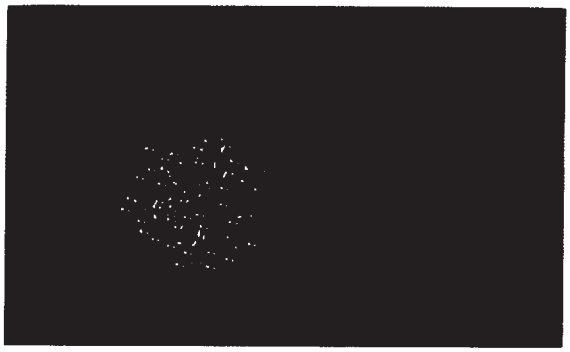
Grouping of contaminated vessels taken from the hospital.

hospital which handles long-term and acute care cases. Canisters were collected in groups of five to expedite the extensive microbiological culture procedures which were anticipated. The time and date each canister was placed onto the patient and when it was removed was recorded. Clinical data for each patient included: age, diagnosis, major surgical procedures performed, presence of infection, report of previous clinical microbiology laboratory results, and history of antimicrobic therapy. Immediately upon receipt in the laboratory, canister contents were diluted serially, and each dilution increment was droplet inoculated[6,7] in duplicate onto Columbia blood and MacConkey agar culture media. Contents were examined microscopically, and bacterial types observed were recorded. Canisters were sampled at 0, 4, 8, 12, 24, and 48 hours. All were held (incubated) at laboratory room temperature during the sampling to approximate patient room conditions. Culture

Contaminated vessels awaiting sampling.

plates were incubated at 35°C for 18-24 hours and populations were determined as numbers of colony-forming units of bacteria per ml (CFU/ml) undiluted canister contents. Identifications of bacteria isolated were made by conventional clinical microbiology laboratory methods.[8]

MacConkey plate with growth.



Blood agar plate with growth.

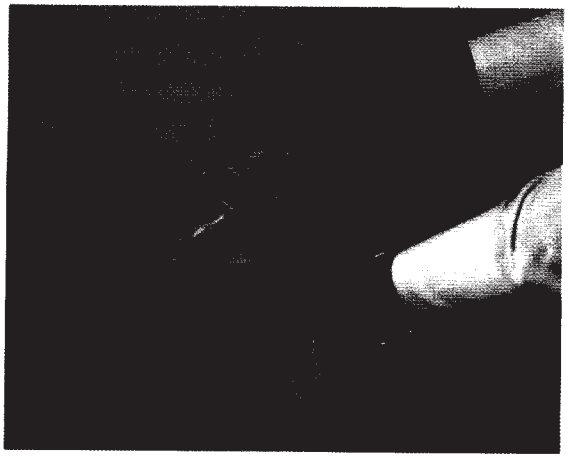
Canister populations in CFU/ml were converted to $\log_{10}$ to construct graphic representation of the changes which took place under the experimental conditions.

2. *Hand Contamination Study*

Experiments were conducted to measure the extent to which operator hands became bacterially contaminated as a result of handling suction canisters during the disposal process. One must be cognizant that such contamination could result from opening and handling the canister and from the aerosol generated during the disposal event.

A volunteer's hands were subjected to two one-minute thorough washes using a bland hand soap in order to leave no antibacterial residue on the subject's hands. Bacterial population was measured by the glove-fluid procedure[9] in which the subject donned a sterile

Insertion of hand into glove for the Glove-fluid Procedure.

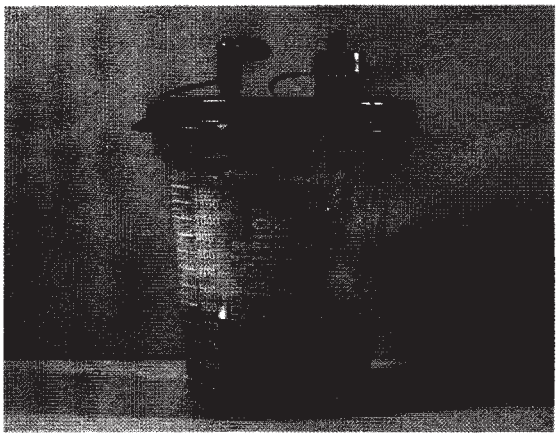


Adding the buffered solution to the sterile glove.

examination glove (Pharmaseal #8822, Lot L S1P142), and 75 ml of a phosphate buffered solution containing 0.01% Tween-80[10] were added to the glove. Subject's gloved hand was massaged thoroughly for one minute, and 10 ml were removed aseptically by means of a sterile disposable plastic syringe fitted with a sterile catheter. Serial ten-fold dilutions were made in half-strength Tween-80 buffer, and these were droplet plate inoculated in duplicate onto two agar media as described previously.

Canisters containing patient material, positive control canisters containing contrived load, and two negative control canister sets (one containing sterile BHI broth and another which contained sterilized patient material, respectively) were dumped individually into a deep laboratory sink to approximate procedure used in many hospitals. All canister volumes had been equalized to 500 ml with sterile water prior to the disposal experiments. Immediately following the dumping procedure, subject's test hand was sampled again by the glove-fluid technique. The hand was then given a single "normal" wash to approximae the procedure which is likely to be used in patient care units, and a final bacterial population determination was made via the glove-fluid method. The purpose was to determine if contamination acquired during handling and dumping the canister would be influenced by the second wash.

Additional controls (N = 22) were applied to determine whether any reduction in hand bacterial count following emptying of the canisters was due to the second "normal" washing or to removal by the

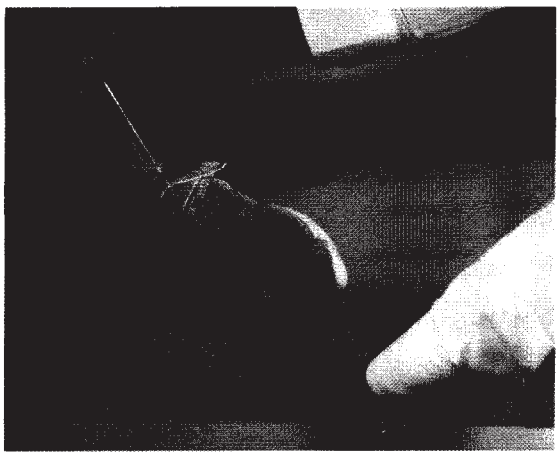


Contaminated vessel equalized to 500 ml.

glove-fluid sampling method employed to measure hand contamination level following dumping procedure. For each of the 22 canisters which had been inoculated with a polymicrobic mixture, the subject underwent a 2X one-minute thorough hand wash using a bland soap followed by glove-fluid sampling to determine initial hand population. Canisters were then dumped as previously described.

For 11 (Group A) of the total 22, a glove-fluid sampling was performed after canister disposal. The hand was then given a single "normal" wash, and a final population determination was made via the glove-fluid method. Therefore, for this group the final post-wash microbial population on the hand represents the residue after a glove sampling and the normal hand wash.

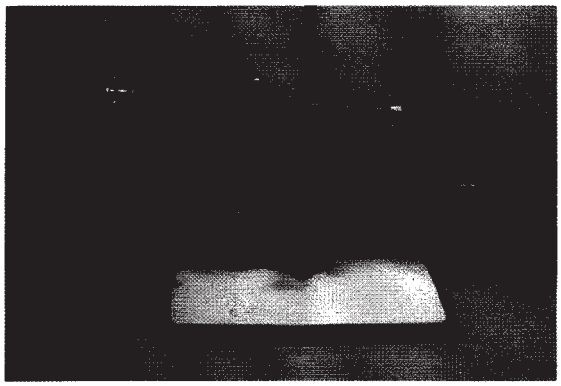
The other 11 (Group B) were not glove-fluid sampled after the canister dump. The hand subjected immediately to a normal wash followed by a bacterial population determination via the glove-fluid method. Thus, a comparison was achieved between one set of hands that were glove-fluid sampled and washed prior to final population determination (A) and the other set (B) which were only washed prior to final population determination.



Withdrawing sample during Glove-fluid Procedure.

3. *Measurement of Bacterial Aerosols Generated During Canister Disposal Procedure*

During each canister disposal operation, a portable battery-operated centifugal type air sampler (Biotest Reuter Centrifugal Sampler (RCS), Folex-Biotest-Schleussner, Inc., Moonachie, New Jersey)[11] was clamped to a ring stand 18 inches above the top edge of the sink which received each canister's contents. The device sampled at a fixed flow of 40 liters of air per minute. Airborne bacteria were impinged centrifugally onto an agar strip inserted peripherally around the sampler's rotary head. Sampling was performed for one minute immediately following



Biotest Reuter Centrifugal Sampler.

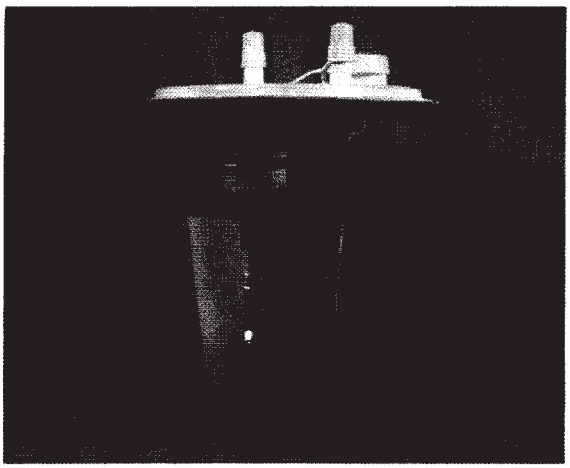
each canister's disposal. Baseline populations of room air were determined prior to commencing a series (ten canisters) of dumping experiments, midway through a series (5 canister set) and 90 minutes after completion of a series. Counts are expressed as colony-forming units (CFU) of bacteria per cubic foot of room air.

B. *Results*

1. *Canister Population Study*

(a) *Diagnostic Categories*

Patients from whom suction canisters were removed were all male with an average age of 66 years. Their age range was 51-90 years. All fell into one of the following diagnostic categories given in their order of frequency: malignant disease, cardiac, cardiovascular or vascular



Contaminated unit taken from one of the study objects.

disease, bowel obstruction, pneumonia, hyptertension, bleeding ulcers, plus a variety of miscellaneous medical problems. All were attached to an in-house central suction system. No canisters were studied from portable pump type systems.

(b) *Patient Canister Groupings*

Patients were divided into groups by the duration of applied suction time. Group I had been undergoing suctioning 8 hours or less when the canisters were removed. Group II had been attached more than 8 hours but less than 72 hours, while Group III had been undergoing suctioning for more than 72 hours. One or more antibiotics were being administered to 21 of the 31 patients at the time canisters were removed.

(c) *Bacterial Isolates Recovered*

From one to five bacterial isolates were recovered per patient with a mean of 3.22 isolates. Patients on antibiotics averaged 3.0 isolates per

canister, while those not receiving antibiotics averaged 3.8 isolates per canister. Bacterial identities isolated included 23 commensal and clinically recognized varieties. The 10 most common were:

Alpha hemolytic *Streptococcus*	*Klebsiella pneumoniae*
Staphylococcus aureus	*Bacillus* sp.
Pseudomonas aeruginosa	*Enterobacter cloacae*
Pseudomonas fluorescens	*Proteus mirabilis*
Neisseria sp.	*Serratia liquefaciens*

(d) *Quantitative Canister Data*

Canisters belonging to Group I (N = 24; 8 hours old or less) had the lowest average initial bacterial populations and underwent the greatest increase in numbers at room temperature during 48 hours. On Columbia blood agar, a general purpose medium to support the growth of most clinical pathogens, the average initial population was 8.9×10^6 CFU per ml of undiluted canister contents, or 8,900,000 bacterial cell units capable of forming colonies. Within 48 hours, the mean population had increased to 1.9×10^8 (190,000,000) CFU per ml, a 21.2-fold increase. On MacConkey agar, a medium which inhibits the growth of most gram positive bacteria and permits growth of most gram negative bacteria, Group I canisters averaged 1.7×10^7 (17,000,000) CFU per ml initially. Within 48 hours, these had increased to an average 6.3×10^7 (63,000,000) CFU per ml, or a 3.7-fold increase. These relative rates of increase may be seen in Figure 1.

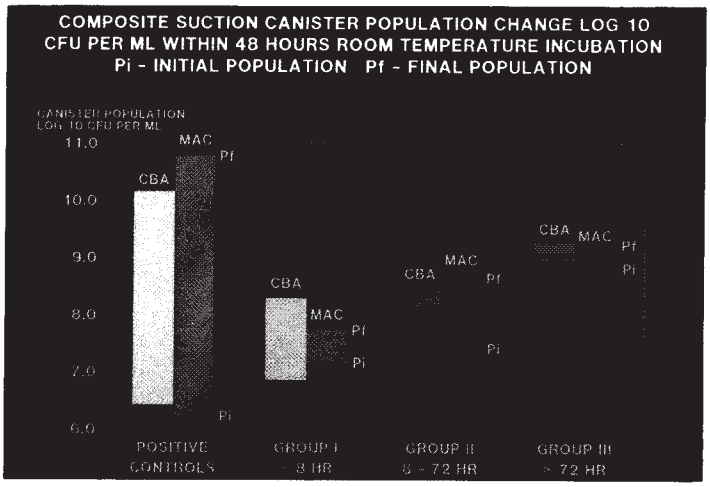


Figure 1.

Group II canisters (N = 5; 8-72 hours old) had a mean initial population of 1.2×10^8 (120,000,000) CFU per ml original contents on Columbia blood agar and a final mean population after 48 hours of 4.4×10^8 (440,000,000) CFU per ml, which amounted to a 3.8-fold population increase. On MacConkey agar, the initial mean population was 2.5×10^7 (25,000,000) CFU per ml original canister contents, and the final population detectable after 48 hours was 8.0×10^8 (800,000,000) CFU per ml, to give a 31.8-fold increase in numbers (see Figure 1).

Group III canisters (N = 2; attached to patients more than 72 hours) had a mean initial population of 1.2×10^9 (1,200,000,000) CFU per ml detectable on Columbia blood agar and a final mean population of 1.9×10^9 (1,900,000,000) CFU per ml, for a 1.51-fold increase in numbers for the period. On MacConkey agar, the initial mean population was 9.3×10^8 (930,000,000) CFU per ml, and the final mean population was 1.4×10^9 (1,400,000,000) CFU per ml, also a 1.51-fold increase in bacterial numbers (see Figure 1). More canisters within this category should be studied because of low numbers available when these were evaluated.

Positive control canisters produced an initial mean population of 2.8×10^6 (2,800,000) CFU per ml on Columbia blood agar and a final population average after 48 hours of 1.6×10^{10} (16,000,000,000) CFU per ml, to produce a 5,662-fold increase in numbers. The initial mean population detected on MacConkey agar was 1.8×10^6 (1,800,000) CFU per ml, and the final average was 1.2×10^{10} (12,000,000,000) CFU per ml after 48 hours. This was a 6,823-fold increase in numbers. Figures 2 and 3 show graphically these trends for all canister groups on blood and MacConkey agars. Population values are summarized in Table 1.

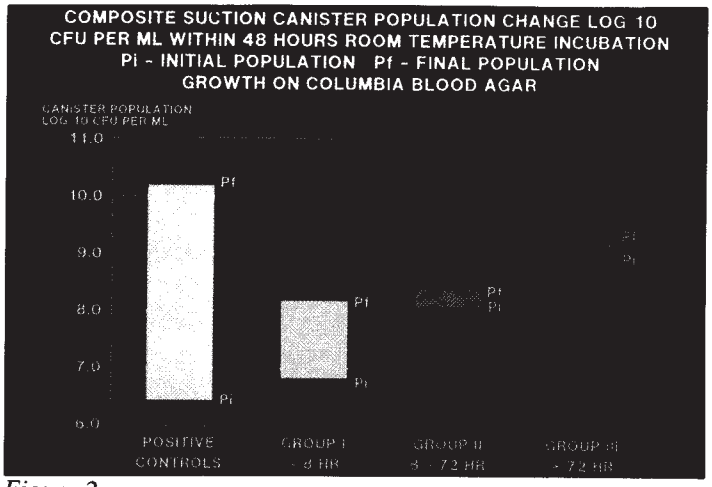


Figure 2.

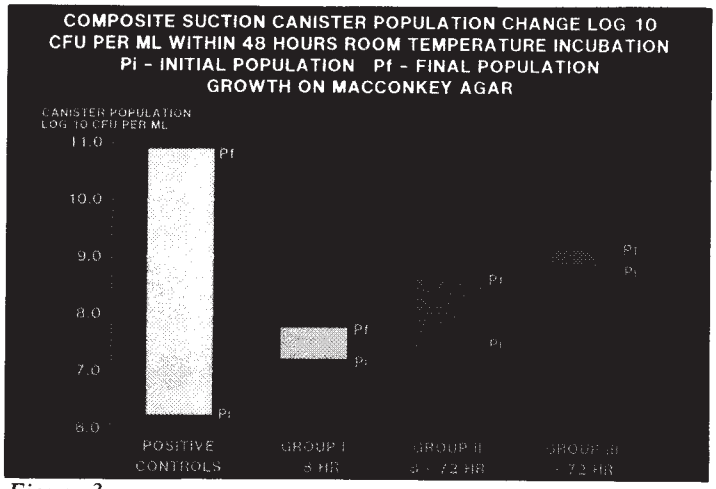


Figure 3.

SUMMARY OF INITIAL AND FINAL BACTERIAL POPULATIONS RECOVERED FROM SUCTION CANISTERS

		INITIAL	FINAL	INCREASE
GROUP I	CBA	8.9×10^6	1.9×10^8	21.2 X
	MAC			
GROUP II				
GROUP III				
POSITIVE CONTROLS	CBA	2.8×10^6	1.6×10^{10}	5,662 X

Table 1.

The data indicate that as the canister remains attached to the patient, the initial population at laboratory "time zero" is higher, and population increases are lessened. The canisters having lowest initial populations were those which had been attached to patients the least amount of time. These showed the highest rates of bacterial number increase. On

Columbia blood agar, Group II canisters had a starting mean population 12.9X higher than Group I. Group III had a 10.8X higher starting population than Group II and a 139X higher initial population than Group I canisters. Final 48 hour mean populations ranked: Group II — 2.3X higher than Group I, and Group III — 4.3X higher than Group II and 9.9X higher than Group I. Because of the selective character of MacConkey agar for gram negative bacteria, similar comparisons given may not have comparable validity. However, the increase trends are essentially the same as determined on the non-selective medium.

These data establish that bacteria confined within suction canisters increase in numbers at room temperature in spite of nonoptimal conditions for their growth, plus the possible presence of antimicrobic agents shed from the patient in secretions drawn into the canisters. The data indicate further that the longer a canister remains attached to a patient, the greater becomes its bacterial load, suggesting that the hazard of microbial spread to operator hands, facilities, and premises thereby is increased as the contained population increases. Ample evidence exists to suggest that steps to minimize the hazard of increased microbial populations are in the best interests of patient care and staff well-being.

2. *Hand Population Study*

Since ungloved, unwashed hands which contain resident and transitory microorganisms represent a prime means to spread infection within a patient care setting, the possibility of hands becoming microbially soiled by handling suction canisters during their disposal is a matter of utmost concern. Hands may become contaminated in at least two ways: by contact with canister load on the lip and underside of a lid as it is removed from a disposable type unit, and by the generation of an aerosol during the procedure of dumping the canister into a hopper or sink.

(a) *Bacterial Populations Recoverable*

The mean bacterial population recoverable from hands washed twice prior to dumping canisters (N = 30) was 5.6 × 10^3 (5,600) CFU per ml glove fluid. For convenience of data expression, these population values have been converted to $\log_{10}$ and are represented by the bar graphs of Figure 4. Approximate population recoverable from the entire

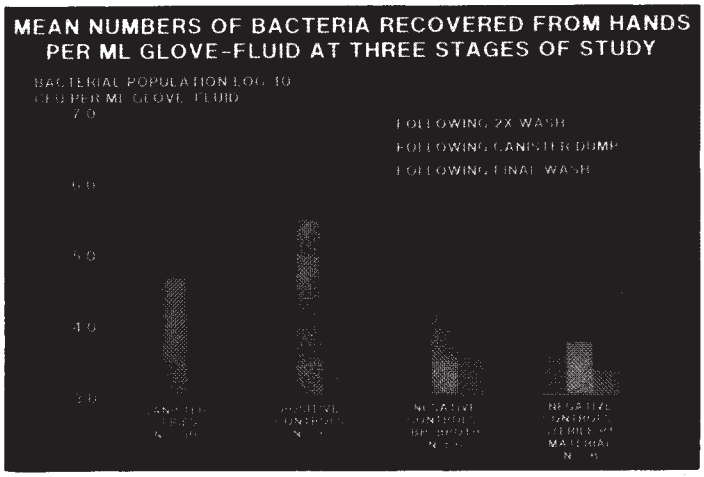


Figure 4.

hand may be arrived at by multiplying by 75, the total volume of fluid per glove in which the hand was immersed during sampling.

The mean population recoverable from hands immediately following dumping a canister rose to 5.3 × 10^4 (53,000) CFU per ml of glove fluid. This is an increase of $\log_{10}$ 0.976 or 9.5-fold numbers of bacteria acquired during the handling and dumping operation. Mean population after the final hand wash dropped to 3.4 × 10^3 (3,400) CFU per ml glove fluid.

Similar data were determined for six positive control canisters. The mean population recovered from hands was 6.5 × 10^3 (6,500) CFU per ml glove fluid following the 2X initial wash. The mean recoverable population became 3.3 × 10^5 (330,000) CFU per ml glove fluid following canister handling and disposition. This is a 1.7 $\log_{10}$ or 50.8-fold increase of bacterial numbers on the hands as a result of the handling and dumping of canisters containing known bacterial loads.

Six control canisters containing only sterile BHI broth produced a pre-dump mean population of 7.6 × 10^3 (7,600) CFU per ml glove fluid, a post-dump population of 1.4 × 10^4 (14,000) CFU per ml (a 1.8-fold increase — not statistically different from pre-dump), and a mean population following the final wash of 4.0 × 10^3 (4,000) CFU per ml glove fluid. Six negative control canisters containing sterilized patient material had a mean pre-dump population of 7.3 × 10^3 (7,300) CFU per ml, a post-dump population of 5.6 × 10^3 (5,600) CFU per ml, and a population of 2.3 × 10^3 (2,300) CFU per ml following the final hand wash.

(b) *Relationship Between Bacteria on Hands and Canister Population*

Figure 5 is a plot of the relationship between canister population and hand population after the dumping procedure for the 30 patient

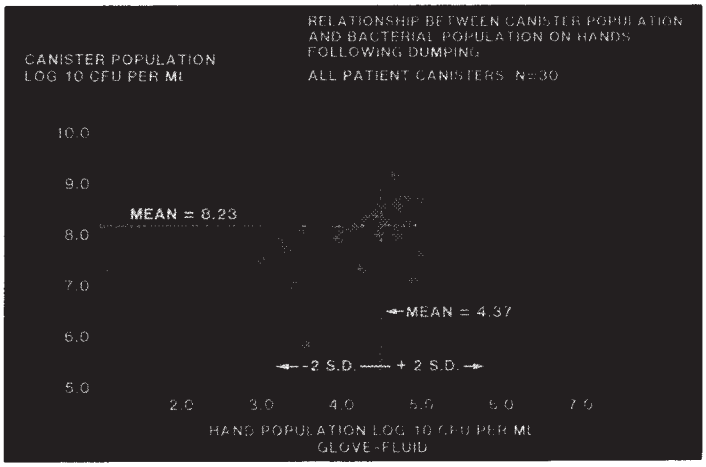


Figure 5.

canisters. Mean canister population was determined to be 1.70 × 10^8 (170,000,000) CFU per ml, and mean hand population was determined as 2.3 × 10^4 (23,000) CFU per ml glove fluid.

Figure 6 is a similar plot of the relationship between canister populations and hand populations following disposal for all positive control canisters (N = 18). These data include also those canisters to be described in the next section as additional controls. Mean canister

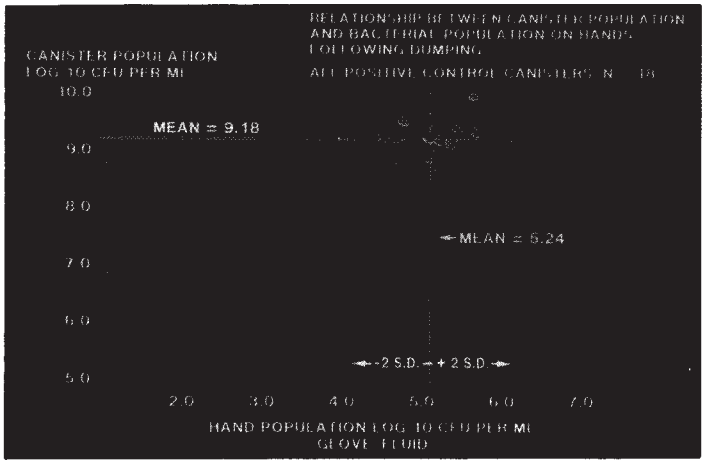


Figure 6.

population for this group was 1.5×10^9 (1,500,000,000) CFU per ml, and mean hand recoverable population was 1.7×10^5 (170,000) CFU per ml glove fluid.

(c) *Linearity of Hand Population Increase to Canister Population*

Figure 7 shows the two groups combined in an effort to ascertain an approximate linear relationship between canister population and hand

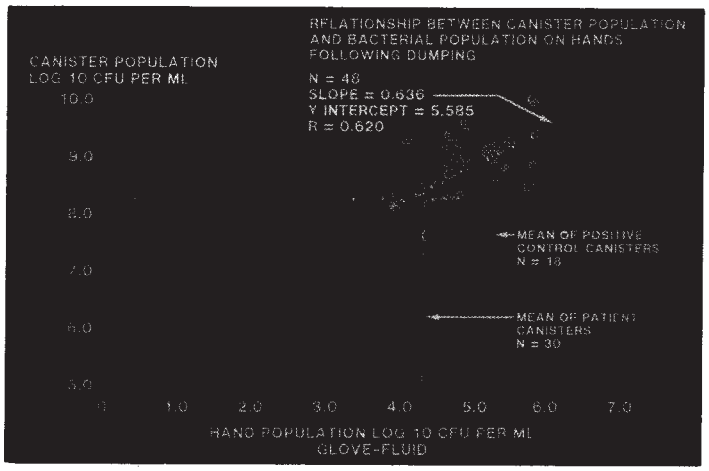


Figure 7.

population resulting from dumping a canister. The most probable straight line fitted through the points has a slope of 0.64, a *y* axis intercept of 5.6 ($\log_{10}$ canister population below which no hand population increase may be considered likely to occur), and a correlation coefficient (R) of 0.62. Cautiously interpreted, these values mean that above a theoretical, calculated canister population of 385,000 CFU per ml the hand population in CFU per ml glove fluid may be expected to increase by 0.6 $\log_{10}$ units (4.3-fold) per $\log_{10}$ unit of canister population increase (10-fold). For an array of 48 canisters tested, the *R* value of 0.62 suggests moderately good positive correlation between canister increase and hand population increase (1.0 = complete positive correlation, and 0.0 = no correlation).

(d) *Additional Controls Studied*

Data from the additional control canisters are represented in Figure 8. The glove fluid procedure is an effective means to remove bacteria from

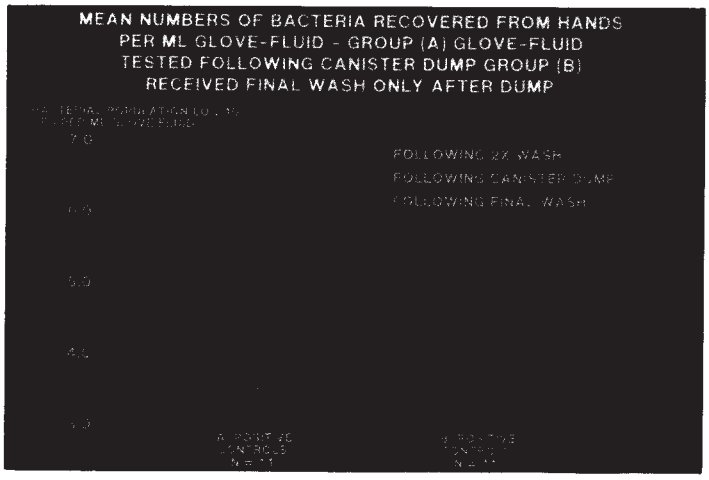


Figure 8.

the hands, and this series of controls was incorporated to learn the influence of the glove procedure on the final population determination which takes place after the second wash.

Group A consisted of those canisters which were dumped followed by an immediate glove fluid sampling to determine subject hand population. Group B were not glove sampled following the dump. Population means of hands following 2X pre-wash were comparable for both groups, 2.6×10^3 (2,600) CFU per ml for Group A and 1.8×10^3 (1,800) CFU per ml for Group B. The difference was not found to be statistically significant. The post-dump hand population mean for Group A increased to 3.9×10^5 (390,000) CFU per ml glove fluid, an average 149-fold increase. The Group B canisters were duplicates of Group A, therefore a similar magnitude of hand contamination was expected to result from disposal of both sets of canisters. However, the Group B hand contamination was measured after a final normal wash only. The mean final popluation for Group B was 1.7×10^4 (17,000) CFU per ml. glove fluid, compared to 9.6×10^3 (9,600) CFU per mil. for the comparable canisters in Group A. The average was 7.3×10^3 (7,300) CFU per ml. or 1.8-fold more organisms which remained on hands in Group B. This suggested that the glove fluid procedure plus final wash removed more bacteria than the final wash alone.

3. *Bacteria Aerosolized From Suction Canister Disposal Procedure*

Difficulty arises attempting to measure accurately which portion of the hand contamination acquired during canister disposal actually comes from contact with bacteria-laden surfaces of the device and which comes from aerosolization from the load. The data presented here resulted from an investigation conducted to relate microbial aerosol generated during the dumping procedure to canister population in much the same manner as hand population was shown to be related to numbers of bacteria contained within the canister contents.

(a) *Microbial Aerosols Released*

The mean of all bacterial aerosols generated during the 50 experiments was 59.2 CFU per cubic foot of room air. The range of bacteria released from the canister dumping experiments extended from 9.2 CFU to 156.4 per cubic foot. The mean background of bacteria already suspended in the air was 14.4 CFU per cubic foot at the beginning of an experimental series which usually consisted of five canisters. The mid-series mean sampled between canisters was 12.8 per cubic foot, while the mean airborne bacterial load measured 90 minutes after the last canister of a series was dumped amounted to 6.6 CFU per cubic foot. The mean bacterial aerosol created by dumping canisters amounted to 7.8 X initial background air load and 9 X mean final air load.

(b) *Linearity of Microbial Aerosol to Canister Population*

The relationship between aerosolized bacteria and collector population as their source is shown in Figure 9. The plot shows that

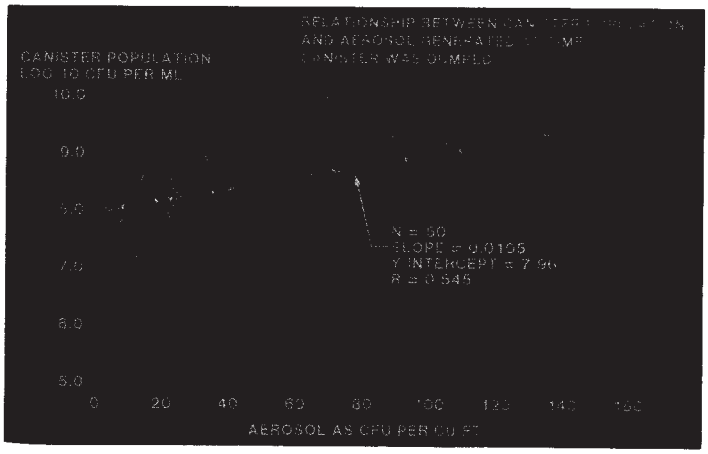


Figure 9.

distribution of liberated bacteria as colony-forming units per cubic foot of air is approximately linearly related to canister population. The data measured permit mathematic fitting of the most probable straight line through the points plotted. The calculated line based upon 50 determinations indicates that for each ten-fold (one $\log_{10}$ unit) increase

in canister population, one might anticipate an increase of 100 CFU bacterial population (within the distance sampled) per cubic foot of air.

These results provide reasonably clear evidence that considrable bacterial population is released into the air space immediately above the adjacent site of a canister dumping. Considering the number of canisters measured, the correlation coefficient (R) of 0.545 suggests a significant positive relationship between canister population and the bacterial load released into the air by the pouring steps (i.e., that the two tend to vary in the same [increasing] direction).

Elevation of bacterial content of the air above a canister dumping site to a level eight to nine times the background airborne population brings several considerations forward. The aerosolized bacteria are able to settle on operator's hands and clothing and onto the premises within the immediate vicinity and perhaps for some distance beyond. They may be transported away from the dump site, depending upon confines of room size and layout and air currents created by the building's ventilating sysem and personnel movements. The overall potential for contact spread is increased as is the possibility of shed from laden clothing. The microbial aerosol liberation discussed here could not exist if no contaminated canister were emptied in the first place. These data and others relating to airborne microbial spread confirm that absence of a source is a good means to prevent spread.[12,13]

C. *Summary of Investigative Findings*

Bacteria drawn into suction collectors as part of pathogenic or commensal flora along with blood, pus, mucus, and respiratory secretions are able to multiply on these body substances as nutritive substrates and can achieve populations exceeding one billion (10^9) viable organisms per ml of canister content within 48 hours at room temperature. Suction collection vessels are excellent incubators of bacteria if the microorganisms are able to receive adequate nutrients.

Canisters which remain undiscarded for up to about 72 hours demonstrate significant microbial population increases whether attached to patients or not. Those which have been attached to patients for 8 hours or less had lower initial populations but increased rapidly. Those older than 72 hours had the highest populations, hence demonstrated the least increase in numbers of viable bacteria upon further storage. The practical interpretation of this finding is that a canister should not remain attached to a patient any longer than is practicable.

Unprotected hands which handle loaded canisters undergo increases in skin surface bacterial numbers to a degree related to the numbers of bacteria contained within the canister.

Opening and pouring a suction collection vessel containing large numbers of bacteria into an open-top sink or hopper generates microbial aerosols above the receptacle proportionate to microbial population of the collector's load.

VIII. Discussion — Post-Usage Handling of Suction Collection Vessels

Once patient material has been aspirated into a collection vessel, microbiologically safe procedures should be followed when disposing of the unit. Body substances withdrawn from patients have been designated as potentially hazardous, and the data presented earlier in this paper have indicated that organisms capable of growth upon non-living organic material will multiply, thereby increasing the hazard in terms of numbers. Care must be exercised when handling the collector and its load, and standardized procedures should be established by which hospital personnel are to handle such contaminated containers.

In most institutions, the establishment and promulgation of such standardized procedures lies within the functions of the Infections Control Committee. Both the Food and Drug Administration (FDA) and the Joint Commission for the Accreditation of Hospitals (JCAH) recommend procedures to minimize the possibility that personnel or patient environment become compromised by improperly handled microbial contaminants.[14] Certain basic principles of safe handling and good practice should be incorporated into such procedures:

1. Disposable units should be discarded when full or when removed from a patient. They should not be emptied, rinsed, and placed back into service. FDA policy states that no disposable products be reused or reprocessed for use. The Centers for Disease Control (CDC) has declared:
   "Using reprocessed disposable items for patient care poses multiple potential risks to the patient."[15]
   Although many hospitals (approximately 80%) have switched to disposable suction collection vessels within recent years, glass and metal units are still widely used. Some institutions have only converted partially and have both systems in use. Some of those having switched to disposable containers still follow the procedure of emptying and rinsing their units and putting them back into service.

2. The same suction collector should not be used on more than one patient. Handling of collectors and associated tubing (which would be present in multi-patient application) should be avoided altogether. Levels of operator contamination are shown to be greatly increased and measures should be taken to prevent such occurences.

3. Removal of collection vessels from patient-use areas should be carried out in a sealed impervious container such as an autoclavable plastic Biohazard trash bag or autopsy specimen canister. Neither container should be transported unless sealed to prevent spillage or contamination of others enroute to its final disposition site. Accumulation of contaminated collector vessels for bulk disposal should be discouraged.

4. Once the protectively enclosed collector has reached a disposal area, its contents should be poured carefully by the most direct means into the municipal sewerage system. Personnel should be gowned, gloved, and masked. The protective apparel should not be worn outside the work area. If possible, the contents should be sterilized or have a bactericide added prior to emptying into the sewer. This is required in some European countries.

5. Incineration is a preferred disposal means for the non-reusable canisters. Burial in a land-fill is also acceptable. Although a properly functioning incinerator will pyrolize canisters completely, full units manufactured of a thick-wall polymer should not be incinerated because of the risk of explosive boiling. Certain thin-wall units pyrolize rapidly, and this is not a problem. However, certain major medical centers still have the requirements that no closed vessel filled with liquid may be disposed of in their pathologic specimen incinerator.

6. Reusable suction collectors should not be emptied and rinsed within a patient care area because of the aerosols generated by such a procedure and its ability to contaminate hands and immediate surroundings.

7. An institution should establish a standard interval for collection vessel changes. A period of 8, 12, or 24 hours is recommended.

8. Where the suction system employs reusable bottles, a sterilized replacement unit should always be available for immediate coupling to the unit from which the original was removed. When full, reusable collectors should be replaced. Contaminated units should be removed from patient care areas and emptied, rinsed, and terminally sterilized by live steam prior to being returned to service.

Adoption of these or similar precautionary practices for the handling of medical suction collectors may serve well to reduce liabilities in any possible litigation concerning nosocomial or self-infection by personnel while fostering an improved health care environment.

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