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Cleaning For Health: A Comparison of Cleaning Methods



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Definition of Terms

Soil – for the purpose of this technical document, is defined as unwanted matter which can harbor and therefore increase the growth and spreading of bacteria and other microorganisms.

Urine residue – for the purpose of this paper is defined as the presence of dried urine upon a surface and is measured by the creatinine concentration in milligrams per deciliter.

Creatinine – an organic compound produced in the human body as a part of normal metabolism, and excreted in the urine as metabolic waste. For the purpose of this paper, the measurement of the concentration of creatinine on a surface is used as a measure of the amount of urine, and therefore, soil present.

Surface roughness – the small-scale, microscopic variations in the height of a surface. It can cause friction losses or drag in fluid flow, or entrap tiny particles.

Fomite – a contaminated object that can transmit disease (1).

CFU – It is an acronym for Colony Forming Units. It is a unit of measure of bacteria concentration on a surface or within a fluid in the study of microbiology. A single colony forming unit on a substrate or Petrifilm represents a single bacterium.

Aerobic bacteria – bacteria that can grow and live in the presence of oxygen. Examples of aerobic bacteria are E. coli, coliforms, and salmonella.

Enteric bacteria – Gut flora, or intestinal bacteria, are the bacteria that normally live in the digestive tract. Some perform a number of useful functions involving digestion. Others such as E. coli or coliforms can spread infectious disease if they are transferred to another person.

Executive Overview

In the cleaning industry, there has been much in the way of anecdotal evidence and marketing claims concerning the optimum means of cleaning, or removing soils, most of which lack supporting scientific data. In fact, there has not even been a universally accepted definition of clean. Nor has there been agreement on the ultimate goal of cleaning – appearance vs. health.

Kaivac has long believed that clean is defined as the absence of soils, and further, that a clean environment promotes human health. To that end, in 1997 Kaivac developed a new high flow fluid extraction (HFFE) method of cleaning commercial restrooms, also called no-touch cleaning. Compared to traditional string mopping and flat microfiber mopping, this HFFE method not only produced a noticeable improvement in the visual appearance of restroom floors and fixtures, but it also reduced or eliminated sour, stubborn restroom odors. It was Kaivac's hypothesis, therefore, that its HFFE method was more effective than traditional and microfiber mopping at removing soils and associated microorganisms. Consequently, it was important to test this hypothesis by scientifically measuring and comparing the effectiveness of the three cleaning methods, and then, determine how that cleaning effectiveness affects human health. In other words, which cleaning method produces the healthiest indoor environment?

This investigation focused on measuring cleaning effectiveness on ceramic restroom floors. A measurement methodology was developed where the amount of urine residue (a primary soil on restroom floors) is quantified by the concentration of creatinine (a metabolite found in urine). Then, a series of tests and field studies was conducted to compare the soil removal values as defined by the amount of urine residue removed from a restroom floor. Following these tests and studies, additional experiments were conducted to study the correlation of soil removal with the removal of bacteria colonies on ceramic floors.

The test and field study results showed that a HFFE cleaning system is significantly more effective than traditional string mopping or flat microfiber mopping at removing urine residue and potentially harmful bacteria from the grout line and the tile surface of a restroom floor. The tests gave the benefit of the doubt to the mopping processes because only clean mops and fresh cleaning solutions were used, something rarely seen in the real world. Some of the findings include:

Effectiveness of Removing Urine Residue

- **Grouted Surface** - after cleaning with water, both string and flat mops left 30 times more urine residue than HFFE cleaning. This equates to a cleaning efficiency of 38% for string and flat mop cleaning compared to 98% for HFFE cleaning.
- **Tile Surface** - after cleaning with water, both string and flat mops left 12-13 times more urine residue than HFFE cleaning. This equates to a cleaning efficiency of 76% for string and flat mop cleaning and 98% for HFFE cleaning.

Effectiveness of Removing Bacteria from Grouted Surfaces

- After cleaning with an EPA registered disinfectant, flat mop cleaning left 35 times more residual bacteria than HFFE cleaning.

- These studies showed that HFFE cleaning removes significantly more soil which corresponds proportionally with bacteria removal.
- The study proved that removing urine residue greatly reduced the odor emanating from the restroom floor, which can be considered sensory evidence of bacterial activity.

Effectiveness of Creatinine Test Strips for Measuring Urine Residue and Bacteria

- Creatinine test strips provide a simple and accurate means for the immediate measurement of the presence of urine residue on restroom floors.
- There was a clear relationship between measured creatinine levels and the presence of aerobic bacteria, which could include such harmful species as E. coli, salmonella and coliforms.

Why HFFE Performs Better

This investigation compared the entire process; therefore the cleaning steps were not individually evaluated to determine effect on cleaning effectiveness. The following process differences were noted concerning why the HFFE cleaning process is more effective than flat or string mop cleaning systems:

- The HFFE cleaning process includes built-in dwell time which is very important for the loosening and lifting of soils from the cleaning surface. Typically this dwell time is minimized during mopping due to the fact that the liquid application and the soil entanglement occur simultaneously.
- The high flow extraction of soils and liquid through the system's built-in wet vacuum ensures that contaminants are removed from the restroom floor, including the vulnerable grout lines, where the other cleaning methods fail to agitate, absorb, or lift soils. Also, minimal liquid is left after cleaning, which inhibits post-cleaning bacteria growth. Mopping processes leave behind a substantial residue of moisture, soil, water deposits and cleaning compounds along with an increased dry time.
- Finally, the HFFE cleaning process employs sound bio-waste management procedures by continuously applying fresh cleaning fluids, removing these wastes from targeted surfaces, and properly containing and quarantining these wastes in an isolated and safe compartment (the vacuum tank) for proper disposal. This minimizes cross-contamination throughout the restroom and to other areas of the building.

Introduction

Kaivac has long believed that clean is defined as the absence of soils, and Kaivac is not alone in this position. For example, Michael A. Berry, Ph.D., a member of the Scientific Advisory Council for the Cleaning Industry Research Institute (CIRI), recently defined clean as being “a condition free of unwanted matter that has the potential to cause an adverse or undesirable effect” (May 11, 2006 CIRI online seminar).

Consequently a key design consideration when developing a cleaning system is the ability to efficiently remove soils and other bio-waste materials, and to properly contain these soils to avoid cross-contamination to other areas of the building. This is critical for “Cleaning for Health” where the focus centers on creating a clean environment free of disease-causing bacteria (2).

Over the years at Kaivac, anecdotal feedback from users about its high flow fluid extraction (HFFE) cleaning system, also known as no-touch cleaning, has suggested that HFFE cleaning is a more effective cleaning system than a flat or string mop system. For example, customers of HFFE cleaning have stated that they had significant lingering odor problems in their restrooms prior to their adoption of HFFE cleaning. However, after cleaning their restrooms with their HFFE cleaning system, they noticed that the lingering malodor would go away. In addition, soils that had accumulated in grout lines and other surfaces began to disappear and grout lines would often whiten with time. Interestingly, this was usually accomplished without the use of disinfectants or disinfectant cleaners.

On December 1, 2004 in a report called “Bathroom Cleanliness” by Fox 10 News @ Nine KSAZ-TV Phoenix, Arizona, a television news crew led by Rob Piercy examined three school districts for the presence of urine on restroom surfaces. They swabbed a variety of restroom surfaces while the schools were in session. The swabs were then taken to an independent laboratory, Lab Express, for evaluation by lab technician, Scott Ferrell. They reported finding evidence of urine on virtually every surface in two of the three districts. While some splatter is inevitable in a school restroom, the samples for these schools were taken in the morning – prior to heavy use.

The third district fared much better in the test, with urine present only on the floor around the toilet and on door handles. Incidentally, the third district’s restrooms were tested in the afternoon, not in the morning. This was significant because it was expected that the restroom surfaces would be even more soiled, more contaminated, and show more evidence of urine after continued use. In searching for the reasons why these restrooms showed less evidence of urine than the other two districts, the television crew discovered that this district had incorporated a Kaivac HFFE cleaning system, while the other districts were using conventional methods (Kaivac had no prior knowledge of this news story until after it was aired).

Although this anecdotal and circumstantial information was good, it was not enough to validate and prove the cleaning effectiveness of a HFFE cleaning system. There was a lack of definitive scientific data to support the hypothesis that HFFE cleaning is a more effective cleaning system than flat or string mop cleaning. Therefore, it was desired to conduct testing to scientifically evaluate the cleaning effectiveness of these three cleaning methods.

But why is cleaning effectiveness so important? Ultimately the goal of Cleaning for Health is to produce an environment free of disease-causing bacteria, such as E. coli and Salmonella, to avoid the spread of infectious diseases. This idea of cleaning goes beyond cleaning for appearance only and focuses on properly killing and removing bacteria, molds, parasites, allergens, and viruses. In 2006 an E. coli epidemic was traced to contaminated spinach and other epidemics like it have raised the importance of Cleaning for Health to reduce one's exposure to harmful diseases. Kennedy, Enriquez, and Gerba (3), in their investigation of coliforms and E. coli in public restrooms, found that, "Coliforms were most often isolated on the floor in front of the toilet. Coliforms were isolated more than 50% of the time at three sites, i.e., floor in front of the toilet, drain of the sink basin, and the sanitary napkin disposal...E. coli was also isolated 20% of the time inside the urinals." Also, Gerba, Wallis, and Melnick (4) demonstrated a phenomenon referred to as the "toilet sneeze". They explained how fecal matter and other enteric bacteria get from the toilet to other restroom surfaces. They showed that the flushing of a toilet spews tiny droplets containing fecal matter, urine and bacteria into the air and then eventually onto floor surfaces throughout the restroom. The presence of these types of bacteria indicates high exposure to potentially infectious diseases. Fomites, such as the soles of a shoe, a purse, backpack, or a person's hands, can spread these infectious bacteria to other areas of a building.

Therefore, the purpose of this paper and investigation is to apply a scientific methodology to measure and compare the cleaning effectiveness of three cleaning processes—flat microfiber mop cleaning, string mop cleaning, and HFFE cleaning. Based on this information, this investigation will focus on the effectiveness of each cleaning method at removing soils, specifically urine residue and bacteria, from restroom floors around toilets and urinals which is critical for producing a healthy indoor environment.

The hypothesis of this investigation is that if a cleaning method is able to remove urine from these high concentration areas, it will remove urine and other soils from additional locations as well. It is hypothesized that these cleaning results could be duplicated at other cleaning areas such as a kitchen or school hallway.

Methodologies

Measurement Technique for Quantifying Urine Residue

The first step in comparing cleaning methods was to develop a valid measurement methodology to quantify cleaning effectiveness. The criteria for this measurement methodology were:

- It must quantify the amount of soil present before and after cleaning.
- It must be accurate and repeatable.
- It must be objective and not subjective, based on the user's opinion.
- It must provide immediate feedback to the user on cleaning effectiveness.
- It can be used to measure cleaning effectiveness in any restroom.

One potential method considered was to test the sites with swabs, which would then be sent to an offsite laboratory for results. While this is an accurate method, it requires three to five days to receive data, and therefore, does not provide immediate feedback, making it

impractical for field testing. Another common method, black light testing, proved to be too inaccurate and very subjective.

The measuring of urine was investigated as a means of quantifying cleaning effectiveness for the following reasons. Urine is the most common and prevalent soil of any restroom. A restaurant restroom may have grease-based soils, but also urine. A factory restroom may have different oils present, but also urine. Urine is a common denominator of a restroom facility. Secondly, the presence of urine can also indicate the presence of other harmful soils and contaminants which facilitate the growth of bacteria and other micro-organisms that cause harmful diseases. Thirdly, urine detection was the means of measuring cleaning effectiveness by Fox 10 News in the above stated example. Finally, other Kaivac research indicates that foul restroom odors come from urine residue that remains when cleaning is only partially effective. This is a prevalent problem of the cleaning industry. While fresh urine from a healthy individual is usually considered to be sterile, it contains urea, which acts as a nutrient for many types of bacteria. In fact, urea is a powerful fertilizer that has surpassed and nearly replaced ammonium nitrate as a fertilizer. Attracted to this rich food source, bacteria soon begin to break down the urea, giving off ammonia and unpleasant odors. Over time, the residual urine that is not removed--along with the related colonies of bacteria--produces the stubborn foul odor associated with unclean restrooms. Therefore, it was hypothesized that the quantifying of urine would be a good indicator for measuring cleaning effectiveness on a restroom floor.

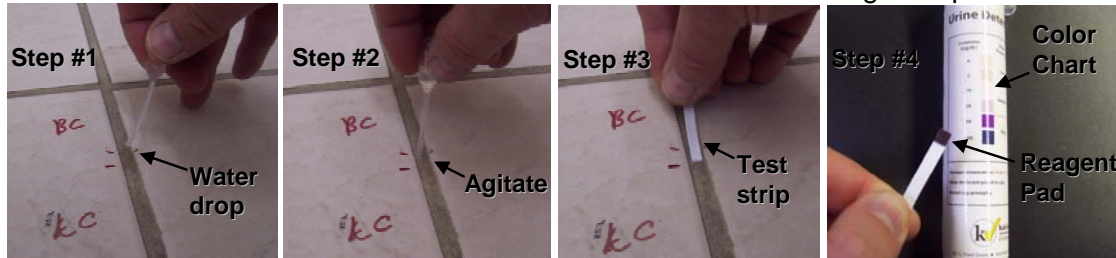
Based on this rationale, research was conducted in the area of urine testing. A common urine test used in the area of healthcare and urine specimen validation was found which measures a metabolite called creatinine. American Heritage Dictionaries defines creatinine as, "creatinine anhydride, $C_4H_7N_3O$, formed by the metabolism of creatine, that is found in muscle tissue and blood and normally excreted in the urine as a metabolic waste." In this testing technique, a small thin plastic test strip with a reagent pad is dipped into a urine sample. The color change on the pad determines the concentration of creatinine. Therefore it was hypothesized that a creatinine measuring technique could be developed that would quantify the amount of urine residue on a surface.

The testing and research of this investigation proved the following:

- The presence of creatinine equates to the presence of urine.
- Creatinine remains present in urine residue after it has been dry for several months.
- Creatinine concentration does not increase or decrease with time.
- Creatinine concentration varies by individual and has a normal range of 20 to 100 mg/dL.
- Although the creatinine concentration varies by individual, creatinine concentration increases proportionally with increased applications of urine.
- Finally, for a given amount of urine residue with a given creatinine concentration upon a surface, a reduction in creatinine concentration equates to a proportional reduction in urine residue.

These results show that the measure of creatinine concentration on a floor surface meets the criteria necessary for quantifying cleaning effectiveness.

Following is the creatinine measurement methodology which was developed and optimized via scientific testing and repetition (refer to Pictorial 1). First, a drop (approximately 0.024 milliliter) of tap water is placed on the floor using a 1.2 milliliter pipette. The fluid is then allowed to sit for 15 seconds and then agitated using the tip of the pipette in order to bring urine residue into the solution. Then the urine test strip reagent pad is placed into the fluid for 10 seconds and removed. After 60 seconds, the color of the test strip is compared to a calibrated color chart to read the creatinine concentration level in milligrams per deciliter.



Pictorial 1: Urine Detection Kit Procedure

String and Flat Mop Cleaning Method

Following is the string and flat mop cleaning procedures implemented throughout this investigation:

- For this investigation, fresh tap water and a fresh never-used mop head was used for each cleaning application. In the real world, this is not usually the case.
- For string mop cleaning, a conventional cotton string mop was used with multiple strands of cloth ranging from 12 to 18 inches in length.
- For flat mop cleaning, a polyester microfiber pad manufactured by an industrial leader in the cleaning industry was used.
- The mops were thoroughly wetted and wrung out in a mop-bucket wringer resulting in a dampened mop.
- The test area was then cleaned by making a first pass of the mop across the area and then making a second pass in the opposite direction. For each pass across the floor, a slight downward pressure was applied to the mop via the mop handle (refer to Pictorial 2).



Pictorial 2: String Mop & Flat Mop Cleaning Techniques

High Flow Fluid Extraction (HFFE) Cleaning Method

Following is the HFFE cleaning process implemented throughout this investigation:

- A KaiZen cleaning machine by Kaivac, Inc. was used which consists of an indoor pressure washer (500 psi) with low and high pressure settings for applying chemical and rinsing, automated chemical injection system, fresh water tank (15 gallons), wet vacuum (20 in H₂O of lift) system for high flow fluid extraction, and Vac tank for containing soils (refer to Pictorial 3).
- First the test area was flooded with the cleaning solution from the spray gun of the KaiZen with the nozzle in the low pressure mode.
- The cleaning solution was allowed to dwell for five minutes.
- Then the solution was vacuumed via high flow fluid extraction using the “Vac tool and Squeegee” assembly. A first pass was made across the area and then a second pass was made in the opposite direction.



Pictorial 3: HFFE Cleaning Process

Cleaning Methods Comparison Studies

Experiment # 1: Removal of Urine Residue by Various Cleaning Methods

Purpose

An experiment was designed to compare the effectiveness of string mopping, flat mopping and HFFE cleaning in removing urine residue from the grout line and from the tile surface of a restroom floor.

Methods

This experiment was performed using the grouted ceramic-tile floor of one of the restrooms at the Kaivac corporate office. The restroom floor was sectioned off into test areas – one area for each of the three cleaning methods being evaluated. Each area was identical in size, and included two grout line intersections. In addition, each area was remote from the other two, so that there would be no flow of liquids or solutions from one area to another. Each test area was equally soiled with fresh urine by holding a fine-mist spray bottle 12 inches above the first grout line intersection, aiming the bottle toward the intersection, and spraying 1 gram of urine downward onto the floor (refer to Pictorial 2). This same procedure was repeated at the second grout line intersection. The urine then was allowed to dry. The urine application was repeated until a sufficient level of urine residue build up produced a 50 milligrams per deciliter (mg/dL) creatinine reading as described later.



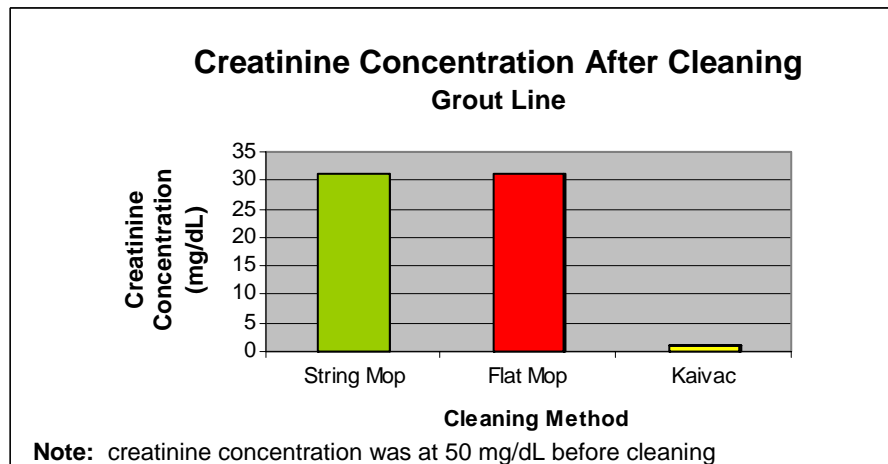
Pictorial 2: Spray application of urine solution

The test areas were cleaned using cold tap water and the designated cleaning method—string mop cleaning, flat mop cleaning, and HFFE cleaning as described previously in the “Methodologies” section. For these initial tests, cleaning chemicals were not used to avoid any possibility of influencing the results.

After cleaning, they were tested for creatinine concentrations using the urine test strips. For each test area, both the grout line intersection and the surface of the ceramic tiles were tested. At the grout line intersection, measurements were taken in all four directions to capture data in parallel and perpendicular to the cleaning direction.

Finally the data was recorded and statistical analysis completed. Statistics were performed with the Stata package, version 6.0 (Stata, College Station, TX). Individual comparisons for all variables between the string mop, flat mop and HFFE cleaning methods were made using the t-test for all numerical variables and the chi-square test for all categorical variables, as the samples were deemed independent. Statistical significance was set at $p < 0.05$, with two-tailed testing.

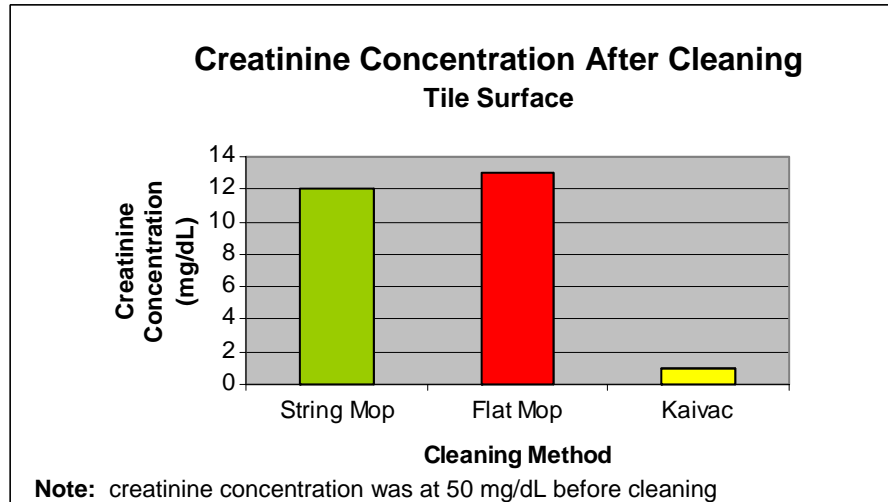
Results



Graph 1: Creatinine Concentration After Cleaning For Grout Line

Graph 1 shows the average creatinine concentration in milligrams per deciliter (mg/dL) detected on the grout line test site of each of the areas after cleaning based. Prior to cleaning all the test sites had creatinine concentrations of 50 milligrams per deciliter (mg/dL). The vertical axis shows the creatinine concentration after cleaning. The horizontal axis

shows the three cleaning methods tested – string mop cleaning, flat mop cleaning, and HFFE cleaning with a Kaivac machine. As may be seen in the graph, the average creatinine concentration detected at the grout line was 31 mg/dL (38% cleaning efficiency) for both string and flat mop cleaning, and 1 mg/dL (98% cleaning efficiency) for HFFE cleaning (P-value was 0.000 for comparison of the string and flat mop cleaning to HFFE cleaning, n=11).



Graph 2: Creatinine Concentration After Cleaning For Tile Surface

Graph 2 shows the average creatinine concentration results similar to Graph 1 but on the tile surfaces after cleaning (data found to be statistically significant). Once again, prior to cleaning all the test sites had creatinine concentrations of 50 mg/dL. As may be seen in the graph, the average creatinine concentration on the tile surfaces was: 12 mg/dL (76% cleaning efficiency) for string mop cleaning; 13 mg/dL (74% cleaning efficiency) for flat mop cleaning; and 1 mg/dL (98% cleaning efficiency) for HFFE cleaning (P-value was 0.000 for comparison of the string and flat mop cleaning to HFFE cleaning, n=11).

Conclusions

Based on the results of this experiment, the following conclusions were made:

First of all, HFFE cleaning is significantly more effective at removing soils, specifically urine residue, from restroom floor surfaces than string or flat mop cleaning. It is hypothesized that the following characteristics of the HFFE cleaning process contribute to these results. The fresh fluids and built-in dwell time of the HFFE process appeared to be significant factors for loosening and lifting soils from the cleaning surface. This dwell time is minimized during mopping due to the fact that the liquid application and the soil entanglement occur simultaneously. Also high flow extraction of soils through the HFFE wet vacuum process appeared to be more effective at soil removal than the entanglement process of the string or flat mop. This can especially be seen at the grout line where the string and flat mop cleaning process left 30 times more urine residue than HFFE cleaning.

Secondly, the grout line is significantly more difficult to clean than the tile surface. The string and flat mop cleaning was approximately twice as effective at cleaning the tile surface compared to the grout line (76% and 74% cleaning efficiency compared to 38% on the grout

line). HFFE cleaning did not have this same difficulty demonstrating a cleaning efficiency for tile and grout surfaces at 98%.

It is hypothesized that the reasons for these results are as follows. The string and flat mop fibers appeared to have difficulty making contact with the grouted surfaces due to the concave shape of the grout line. Secondly the grout line is difficult to clean due to the higher surface roughness as compared to the smooth tile surface. This higher surface roughness results in surface irregularities where dirt soils get trapped and become difficult to remove. Based on these results the future tests focus on the cleaning efficiency of the grout line.

Field Study # 1: Field Study of Urine Residue Levels Pre- and Post- Cleaning--for Two Different Cleaning Programs--Conducted by a National FSP

Purpose

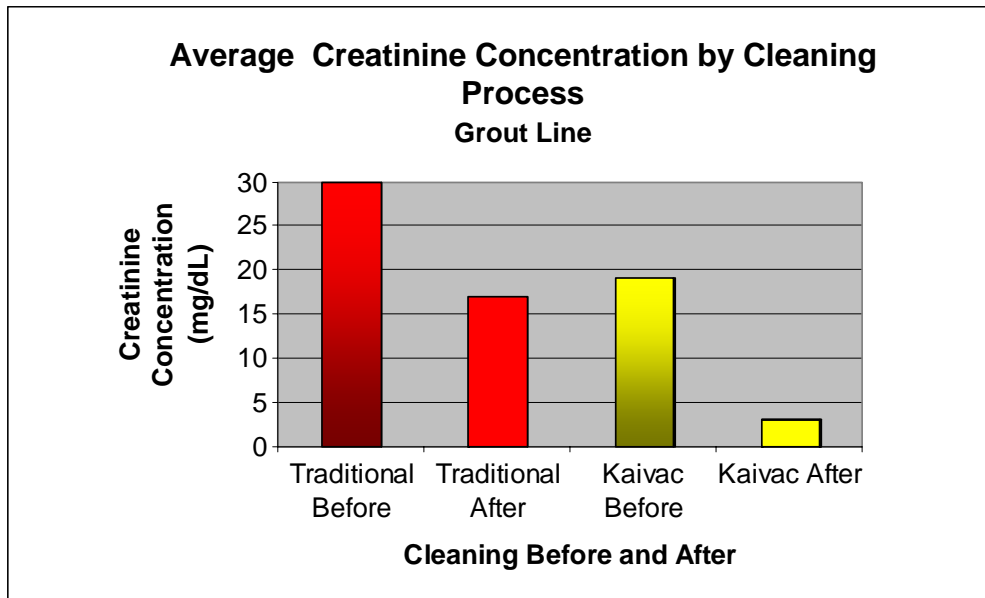
An experiment was designed to find out how much urine residue is present in the grout line, on the restroom floors of a wide variety of public, commercial, and industrial facilities. In particular, it was desired to determine how much residue was present before and after cleaning using two different types of cleaning programs. The first program involved traditional periodic in-house string mopping of the restroom floors. The second program is one in which a national facilities service provider (i.e. FSP) used a Kaivac HFFE cleaning system to clean their clients' restrooms, including the floors, every other week. In between those FSP visits, the client organizations usually performed their own typical unstructured string mopping.

Methods

Using the urine detection strip measuring technique mentioned above, before and after cleaning measurements were obtained from the facilities that performed their own in-house cleaning using mops.

For facilities using the second program, a few of the FSP cleaning professionals were trained to perform urine detection testing with the urine test strips. They then went to a variety of customer sites and tested the grout line prior to cleaning. After that, they performed the every-other-week HFFE cleaning service followed by a second test at the same grout line location.

Results



Graph 3: Average Creatinine Concentration by Cleaning Process

Graph 3 shows the average creatinine concentration in mg/dL at the grout line before and after cleaning for both cleaning programs. The vertical axis shows the creatinine concentration and the horizontal axis shows the cleaning methods before and after cleaning where “Traditional” refers to the periodic in-house string mopping and “Kaivac” refers to the every-other-week HFFE cleaning with a Kaivac machine by a trained FSP, with periodic string mopping by the customer in between service visits.

As can be seen in Graph 3, for the “Traditional” program, the average creatinine concentration detected at the grout-line before cleaning was 30 mg/dL and after cleaning was 17 mg/dL. This equates to an average cleaning efficiency of 43%.

For the HFFE cleaning program, the average creatinine concentration detected at the grout-line before cleaning was 19 mg/dL, and after cleaning was 3 mg/dL. This equates to an average cleaning efficiency of 84%.

Conclusions

First of all, this field testing confirms the conclusions of the controlled tests in Experiment #1 that HFFE cleaning is significantly more effective at removing soils than string or flat mop cleaning. Secondly, based on the results of this experiment, a program that incorporates a HFFE cleaning system is not only far more effective at removing urine from the restroom floor than a program that relies on mopping (84% cleaning efficiency as compared to 43%). But also, there is far less urine build-up on the floor. In fact, facilities that are cleaned only with a mop have nearly as much urine present after cleaning as those that incorporate HFFE cleaning had prior to cleaning.

The above results were achieved in facilities that incorporate HFFE cleaning as infrequently as every other week. Based on these results, it is projected that facilities incorporating HFFE cleaning on a more frequent basis, such as daily or weekly would experience even better cleaning efficiencies that would approach the 98% cleaning efficiency of the controlled tests in Experiment #1.

Experiment # 2: Removal of Bacteria and Urine Residue—Flat Mop versus HFFE

Purpose

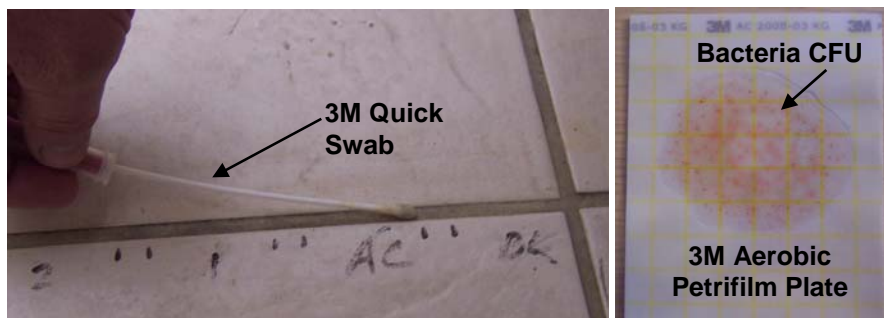
Experiment #1 and Field Study #1 focused on cleaning effectiveness at removing urine residue. But how does removing urine residue equate with bacteria removal on a restroom floor surface? It was shown that flat mop cleaning and string mop cleaning produce similar results for grouted surfaces. Secondly, it was shown that the grout line surface is the most difficult surface to clean due to the concave crevices and surface roughness. Thirdly, HFFE cleaning was more efficient than string or flat mop cleaning when using only water. But how do these cleaning methods compare using an EPA registered disinfectant at removing and killing bacteria? Therefore this experiment compares flat mop cleaning with HFFE cleaning on grouted surfaces of a restroom floor when using an EPA registered disinfectant to understand how urine residue removal equates with bacteria removal.

Methods

These tests were performed using the grouted ceramic-tile floor of two of the restrooms at the Kaivac corporate office. Each restroom floor was sectioned off into test areas. The first restroom had test areas for HFFE cleaning including brushing. The second restroom had test areas for flat mop cleaning. Both cleaning methods utilized an EPA registered quaternary ammonia disinfectant, EPA Reg #8155-23.

Next each test area was soiled with a solution consisting of ½ teaspoon of human fecal matter and tap water. The solution was applied by holding a fine-mist spray bottle 12 inches above the grout line and spraying 3 pumps for every 12 inches of grout line, allowed to dry, and then the application was repeated. Next urine was applied using the same spraying technique, allowed to dry, and then the application was repeated.

Four different grout lines were measured for each restroom. Creatinine concentrations were measured, and then total aerobic bacteria samples were taken using a 3M Quick Swab, Aerobic Bacteria Petrifilm Plate, according to the wet swabbing method described in “3M Quick Swab Procedure” for these items (refer to Pictorial 5). The bacteria samples were taken on a square inch of grout line area.



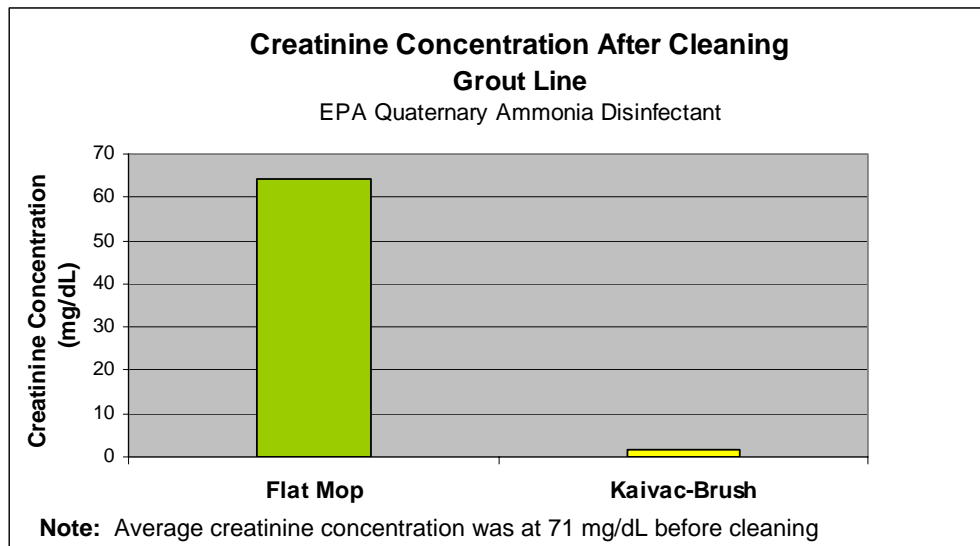
Pictorial 5: Bacteria CFU Sampling Equipment

The test areas were cleaned using the corresponding cleaning method and cleaning processes described previously. In addition, the HFFE test areas were brushed during the dwell time, with a firm-bristled brush supplied by Kaivac, Inc. using a two-pass back-and-forth motion.

Ten minutes after the test areas had been cleaned and dried, they were tested again for creatinine and bacteria concentrations. The Aerobic Bacteria Petrifilm Plates were then placed in an incubator at 30°C. After 48 hours, the bacteria data was counted and recorded per the “3M Interpretation Guide”.

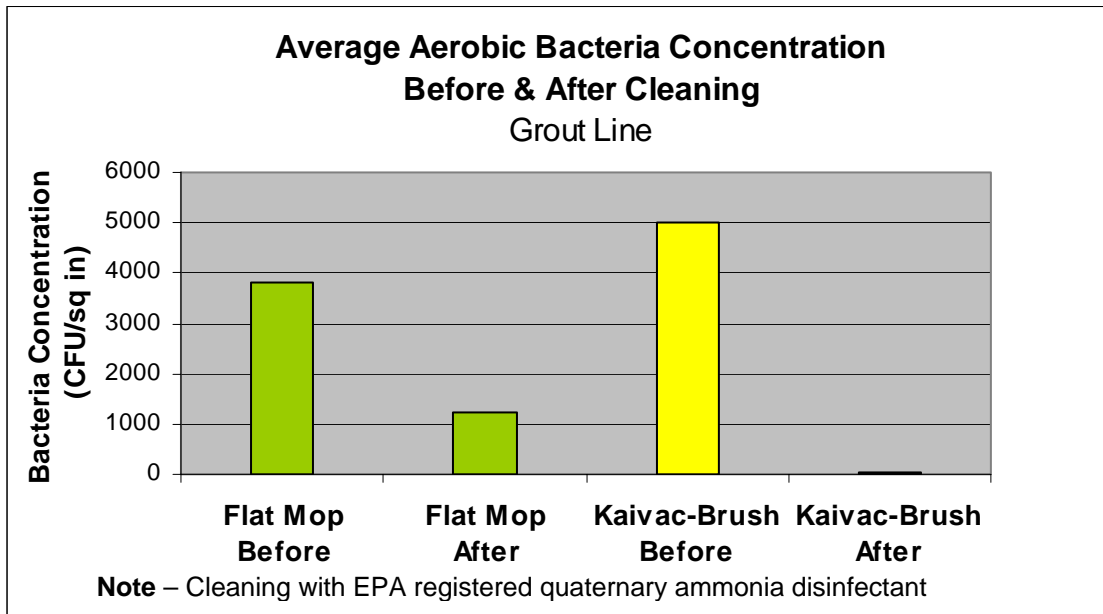
Finally the data was recorded and statistical analysis completed. Statistics were performed with the Stata package, version 6.0 (Stata, College Station, TX). Individual comparisons for all variables between the string mop, flat mop and HFFE cleaning methods were made using the t-test for all numerical variables and the chi-square test for all categorical variables, as the samples were deemed independent. Statistical significance was set at $p < 0.05$, with two-tailed testing.

Results



Graph 4: Creatinine Concentration After Cleaning Using Disinfectant

Graph 4 shows the average creatinine concentration (mg/dL) at the grout lines after cleaning for each of the restrooms. The average creatinine concentration before cleaning was 71 mg/dL (P-value was 0.0013 for comparison of the flat mop cleaning to HFFE cleaning, $n=4$). As in the prior tests, the HFFE cleaning was more effective at removing urine residue. But the key factor of this test was to compare the creatinine and bacteria concentrations before and after cleaning.



Graph 5: Aerobic Bacteria Concentration Using Disinfectant

Graph 5 shows the average aerobic bacteria concentrations measured in CFU (colony forming units) per square inch. The measurements were taken at the grout lines of the restrooms before and after cleaning with the disinfectant (data was found to be statistically significant). There was a noticeable foul odor in both restrooms before cleaning appearing to indicate a high bacteria concentration on the restroom surfaces. HFFE cleaning with brushing after cleaning had an average of 35 CFU per square inch. Flat mop after cleaning had an average of 1235 CFU per square inch (P-value was 0.0043 for comparison of the flat mop cleaning to HFFE cleaning, n=4). Therefore flat mop cleaning left 35 times more bacteria than the HFFE cleaning process.

Conclusions

In Experiment #1, cleaning efficiency was compared using tap water as the solvent solution, and HFFE cleaning demonstrated superior results. In this experiment an EPA registered quaternary ammonia disinfectant was introduced which is typical for any mop disinfecting process. The HFFE cleaning process repeatedly demonstrated superior cleaning efficiency at removing soils and urine residue. This experiment also showed that the soil removal equates to bacteria removal and therefore resulting in a healthy environment. The HFFE cleaning process left 35 CFU per square inch of grout line, which was 35 times less than flat mop cleaning. Based on the results of this experiment, the HFFE cleaning process is significantly more effective than flat mop cleaning at removing soils and likewise reducing bacteria concentrations on restroom floor surfaces.

Another conclusion from these results is that the creatinine concentration after cleaning is a good measure not only of soil removal but also bacteria removal. For the HFFE cleaning process, the creatinine concentrations after cleaning showed a cleaning efficiency of 97.6% which resulted in very low bacteria concentrations after cleaning. Therefore if a cleaning process removes soil then it is a good indication that it is removing bacteria. On the other hand, the flat mop cleaning had a low cleaning efficiency of 8% and only reduced the

bacteria down to approximately a third the concentration. Therefore, leaving significant quantities of soil can indicate that potentially harmful bacteria have not been removed.

Conclusions

Cleaning Effectiveness at Removing Soils

First it was shown from this investigation that HFFE cleaning was the most effective cleaning method for removing urine residue. On grouted surfaces after cleaning with water, both string and flat mops left 30 times more urine residue than HFFE cleaning. This equates to a cleaning efficiency of 38% for string and flat mop cleaning compared to 98% for HFFE cleaning. On tile surfaces after cleaning with water, both string and flat mops left 12-13 times more urine residue than HFFE cleaning. This equates to a cleaning efficiency of 76% for string and flat mop cleaning and 98% for HFFE cleaning. These results in cleaning effectiveness were further confirmed by field data from active restrooms.

Cleaning Effectiveness at Removing Bacteria from Grouted Surfaces

Secondly, this investigation revealed that HFFE effectiveness at removing soils corresponds proportionally with bacteria removal. After cleaning with an EPA registered disinfectant, HFFE cleaning took bacteria concentrations from roughly 5000 down to 35 CFU per square inch. Along with these results, the study proved that removing urine residue greatly reduced the odor emanating from the restroom floor, which can be considered sensory evidence of bacterial activity.

Overall Cleaning Effectiveness Conclusions

These results demonstrated that the HFFE cleaning is not only better than flat microfiber and string mop cleaning at removing soils and bacteria, but also producing superior cleaning effectiveness down to true sanitization results. These results came from critical sites of a restroom floor with high concentrations of soil and bacteria. Based on these outcomes, it is hypothesized that these cleaning results are inherent qualities of the cleaning process. Therefore it is hypothesized that similar results would occur with other soils and other cleaning locations throughout a building such as the kitchen or the hallway. This will be a point for further investigations.

Effectiveness of Creatinine Test Strips for Measuring Urine Residue and Bacteria

This investigation showed that creatinine test strips provide a simple and accurate means for the immediate measurement of the presence of urine residue on restroom floors. Also demonstrated was a clear relationship between measured creatinine levels and the presence of aerobic bacteria, which could include such harmful species as E. coli, salmonella and coliforms. These results show that the measure of creatinine concentration meets the criteria necessary for accurately quantifying cleaning effectiveness on a restroom floor surface.

The Significance of Grout

This investigation revealed that grout is a more difficult surface for removing soil and bacteria as compared to the flat, smooth tile surface of a restroom floor. The string and flat mop cleaning was approximately twice as effective at cleaning the tile surface compared to the grout line (76% and 74% cleaning efficiency compared to 38% on the grout line). HFFE cleaning did not have this same difficulty demonstrating a cleaning efficiency for tile and grout surfaces at 98%.

It is hypothesized that the reasons for these results are as follows. The string and flat mop fibers appeared to have difficulty making contact with the grouted surfaces due to the concave shape of the grout line. Secondly the grout line is difficult to clean due to the higher surface roughness as compared to the smooth tile surface. This higher surface roughness results in surface irregularities where dirt soils get trapped and become difficult to remove. When evaluating a cleaning effectiveness of a tiled surface with grout lines, it is very important to measure the grouted surfaces to ensure accurate measurements. It is hypothesized that the lack of adequate cleaning of the grouted surfaces of restrooms is the cause of restroom malodors and high bacteria growth and dispersion.

Why Was High Flow Fluid Extraction Cleaning More Effective?

According to ISSA (International Sanitary Supply Association), there are three primary components in the process of cleaning with a room temperature cleaning solution: agitation, chemical, and time. These three components are usually known as the acronym ACT. They all work together in direct relationship with one another to accomplish a level of cleaning; if one is changed, one or both of the others must change as well to maintain cleaning effectiveness. For example, if dwell time is decreased, then either agitation or chemical strength must be increased to compensate.

For sound bio-waste management there are two more additional components for truly effective cleaning that are vital in the HFFE cleaning process. They are fresh ingredients (including water) which are flooded upon the surface, and suctioning away of unwanted contaminants and soils. These added components expand the cleaning acronym to FACTS.

The results of this investigation show that HFFE cleaning process which implements the FACTS components of cleaning is superior to flat microfiber mop cleaning or string mop cleaning. Even though the cleaning steps were not individually tested, it is hypothesized that the HFFE process produced optimum results based on the FACTS differences cited in the table below:

		HFFE	Flat Microfiber Mop	String Mop
F	Fresh	Continuously applying and using fresh cleaning solution and rinse water reduces risk of cross-contamination throughout the restroom and to other areas of a building.	Periodically uses fresh mop heads, but reuses water and cleaning solutions which increases the risk of cross-contamination.	Does not use fresh mop and reuses water and cleaning solutions which increases the risk of cross-contamination.

	Flood	Pressure system supplies ample cleaning fluid (1 gpm) to the floor surface and is more effective at lifting soils into the solution for removal.	Uses damp mop which only supplies a film of fluid.	Uses damp mop which only supplies a film of fluid.
A	Agitate	Standard process incorporates brushing during the dwell time to agitate and lift soils from the surface.	Typically only two strokes with mop per surface which minimizes agitation.	Typically only two strokes with mop per surface which minimizes agitation.
C	Chemical	Pressure system has adjustable flow rates to ensure proper chemical dispensing and achieving proper quantities of chemical per cleaning surface area.	Applies chemical at same flow rate.	Applies chemical at same flow rate.
T	Time	Process has built-in dwell time which is very important for the loosening and lifting of soils from the cleaning surface (typically 5 minutes)	Typically dwell time is minimized due to the fact that the liquid application and the soil entanglement occur simultaneously.	Typically dwell time is minimized due to the fact that the liquid application and the soil entanglement occur simultaneously.
S	Suction	Suctions away bio-wastes through the wet vacuum high flow extraction and contains them in the vacuum tank system. The 20 inches of H ₂ O lift enables it to suction soils from concave grout lines. Leaves floors virtually dry.	No suction. Soil removal occurs through entanglement of the soil in the mop fibers. Microfibers have more surface area than string mops for soil entanglement, but proved to be inadequate for soil removal of crevices and concave grout lines. Leaves floors damp.	No suction. Soil removal occurs through entanglement of the soil in the mop fibers. Proved to be inadequate for soil removal of crevices and concave grout lines. Leaves floors damp.

It is recognized that it may be theoretically possible to obtain similar results with a traditional mop or microfiber mop as the HFFE cleaning system. However, based on these findings, this would be possible only by supplementing those methods with more aggressive agitation, as with a brush, longer dwell time for the cleaning solution, or an increased duration of mopping and rinsing. All of these changes would have a great impact on the cleaning productivity.

Future Studies

Although anecdotal information and theoretical ideas are good, alone they are not sufficient for validating cleaning methods and accurately quantifying cleaning effectiveness. It is important for cleaning industries to pursue science in order to educate communities on the importance of cleaning and its impact on health. It is critical to understand the science of cleaning and disinfecting, as well as the science of microbiology and epidemiology (the study of the spread of germs and diseases).

Therefore future testing and research will consist of experiments and field studies of cleaning efficiency at removing soil and bacteria from other areas of a building such as kitchens, hallways, and classrooms.

Finally future work will also entail supporting research programs through CIRI which plays a key role in the science of cleaning for the cleaning industry.

Conduct Your Own Research

An important aspect of the scientific method is sharing results and procedures for review and validation. For more information to conduct research with the Urine Detection Kit or purchasing and using the Urine Detection Kit, please call 1-800-287-1136 (option3) for inquiries.

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