Safer Alternatives to Current Floor Wax Strippers for Schools and Public Buildings

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DISCLAIMER

This report was prepared as a result of work sponsored by the University of Nevada Reno (UNR) and the Western Sustainability and Poluution Prevention Network with a grant from the United States Environmental Protection Agency Region IX (EPA), the Bay Area Air Quality Management District (BAAQMD) and the Institute for Research and Technical Assistance. The opinions, findings, conclusions, and recommendations are those of the author and do not necessarily represent the views of UNR, EPA and BAAQMD. UNR, EPA and BAAQMD, their officers, employees, contractors and subcontractors make no warranty, expressed or implied, and approved or disapproved in this report, nor has UNR, EPA or BAAQMD passed upon the accuracy or adequacy of the information contained herein.

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EXECUTIVE SUMMARY

Most schools and public buildings have historically used a flooring called vinyl composition tile (VCT) in their hallways, classrooms and public areas. The VCT requires a significant amount of maintenance to maintain a shiny, polished look. The flooring is waxed frequently and periodically it is stripped and several new coats of wax are applied. The floor wax strippers that have been used for many years contain volatile organic compounds (VOCs) that contribute to photochemical smog, they often contain toxic components and they have high pH. So-called green strippers with lower pH have been developed in recent years but some have high VOC content, they all contain solvents and they all contain amines. Monoethanolamine, the most common amine in floor strippers, can cause asthma and it is a sensitizer. Maintenance staff, teachers, students and the public can be exposed to these materials which pose a risk.

This document summarizes the results of a project sponsored by the University of Nevada Reno and the Western Sustainability and Pollution Prevention Network (WSPPN) with funding from EPA Region IX, the Bay Area Air Quality Management District and the Institute for Research and Technical Assistance (IRTA). The aim of the project was to identify, develop, test and demonstrate safer alternative floor wax strippers. The project was conducted by IRTA, a small technical environmental nonprofit organization. Although IRTA's initial focus was on developing and demonstrating alternative floor wax strippers, the project was broadened to include other methods of reducing or eliminating the use of high-VOC content, toxic floor wax strippers. As part of the project, IRTA examined three strategies which included:

- Developing safer alternative floor wax strippers
- Applying coatings over VCT that do not require waxing or stripping
- Installing alternative flooring in place of the VCT that does not require waxing or stripping

The results of the strategies are discussed below.

Developing Safer Alternative Floor Wax Strippers

IRTA worked with two formulators to develop, test and demonstrate alternative floor wax strippers that could substitute for the strippers used today. In California, the California Air Resources Board (CARB) regulates the VOC content of consumer and institutional products, including floor strippers. The South Coast Air Quality Management District (SCAQMD) in southern California has a certification program for consumer products and has established a VOC limit for strippers which is much lower than the VOC limit set by CARB. During the project, IRTA and the formulators developed two alternative strippers that have zero VOC content in the CARB regulation and contain no amines, which are asthmagens and sensitizers. One of the strippers, called Green Innovations Solvent-Free Floor Finish Remover III-14C, contains no solvent and meets the stringent VOC limit set by SCAQMD. The other stripper, called Green Innovations Floor Finish Remover III-14A, does contain solvent but it still has a VOC content of zero in the CARB regulation.

IRTA conducted extensive testing at Riverside Unified School District (USD) to optimize the performance of the alternative strippers. The two best strippers were tested at a number of other locations in schools and public buildings to compare their performance with the strippers used by maintenance staff today. IRTA evaluated the cost of the alternative stripper and compared it to the cost of green and non-green strippers. Because the alternative strippers are not commercial products, IRTA estimated what their price might be based on a materials and blending cost. This cost would be marked up by the supplier by a factor of 1.3 to 2, depending on the circumstances. IRTA obtained estimates from a long-time industry source of the price ranges for green and non-green strippers used today. Table E-1 summarizes the results of the cost comparison for the marked up price of the alternative safer strippers and those that are currently used. The values show that the prices of the alternative strippers are lower than the prices of other green strippers even with a markup of 2. The price of the solvent-free alternative stripper is also lower than the price of non-green strippers and the price of the alternative stripper containing solvent is in the middle of the range of the prices for non-green strippers.

Table E-1
Price Comparison for Alternative Strippers and Currently Used Strippers
(Per Gallon)

Stripper	Materials/Blending Price	1.3 Markup Price	2.0 Markup Price	Market Price
Alternative III-14C (solvent-free)	$5.54	$7.20	$11.08	$7.20 to $11.80
Alternative III-14A (with solvent)	$8.41	$10.93	$16.82	$10.93 to $16.82
Typical non-green strippers	NA	NA	NA	$14 to $20
Typical green strippers	NA	NA	NA	$18 to $25

NA is not applicable

Using Coatings and Alternative Flooring

The second and third strategies employ pollution prevention methods that can eliminate the use of wax and wax stripping products altogether. For the second strategy, IRTA identified and tested three different types of coatings that could be used over VCT and would require no waxing or stripping. IRTA worked with the suppliers and Riverside USD to apply the three types of coatings to the VCT flooring in a busy hallway at a Riverside school. These included a vinyl seal, a polyurethane coating and a UV urethane acrylic coating. The coatings were maintained with simple dry and wet mopping with no waxing or stripping. They were monitored for a school year to determine their performance. The polyurethane coating started wearing in certain recessed areas by the end of the school year. The vinyl seal and UV cured coating maintained their integrity and the school staff indicated they preferred the UV cured coating which had a very polished look.

For the third strategy, IRTA worked with manufacturers and suppliers to install three alternatives types of flooring in the same hallway system at the Riverside school; one other type of flooring was installed in a second school. Two additional types of flooring had been installed in the same hallway system and at a third school. All six of these flooring types were tested and monitored for the school year. One additional type of flooring which was not tested was evaluated in the cost analysis. All of the alternative flooring types require no waxing and stripping. The seven total types of flooring are:

- Optima IQ, a homogeneous vinyl sheet flooring
- EcoPure, a natural linoleum flooring with cork backing
- Omni Sports, a heterogeneous vinyl flooring with closed cell cushion backing
- Centiva Contour, a heterogeneous hardened vinyl plank flooring
- Centiva Mineral Chip, a homogeneous hardened vinyl tile flooring with a terrazzo look
- Powerbond, a resilient nylon flooring with closed cell cushion backing
- Mondo, a blend of natural and synthetic rubber flooring

IRTA performed a cost analysis and comparison of using the VCT with waxing and stripping on the one hand and using the three coatings with no waxing and stripping on the other hand. IRTA also compared the cost of using VCT with waxing and stripping and using the seven types of alternative flooring with no waxing and stripping. The approach involved annualizing the materials and application/installation cost of the coatings and flooring over their warranty life and adding it to the maintenance cost to determine an annual cost of using the coating or flooring. Table E-2 presents the results of the cost comparison on a per square foot basis for a number of scenarios.

Table E-2
Annual Cost Comparison of VCT, Coatings and Alternative Flooring
(Per Square Foot)

Flooring/Coating Type	Annual Cost of Using Alternative Option
VCT	
New	$3.39
Replacement	$3.65
Coatings	
Vinyl Seal Over VCT (12 month life)	$2.72 (over old VCT); $2.11 (over new VCT)
Vinyl Seal Over VCT (18 month life)	$2.23 (over old VCT); $1.80 (over new VCT)
Vinyl Seal Reapplication	$1.90 (12 month life); $1.66 (18 month life)
Polyurethane Coating Over VCT	$2.40 (two year life); $1.96 (three year life)
Polyurethane Coating Reapplication	$1.93 (two year life); $1.65 (three year life)
UV Cured Coating Over VCT	$2.14 (three year life); $1.72 (five year life)
UV Cured Coating Reapplication	$1.82 (three year life); $1.53 (five year life)
Alternative Flooring Types	
Optima IQ	$2.17 (no demolition); $2.43 (demolition)
Ecopure (linoleum)	$1.94 (no demolition); $2.10 (demolition)
Omni Sports	$1.54 (no demolition); $1.63 (demolition)
Centiva Contour	$1.43 (no demolition); $1.49 (demolition)
Centiva Mineral Chip	$1.56 (no demolition); $1.63 (demolition)
Powerbond	$0.66 (no demolition); $0.68 (demolition)
Mondo	$2.06 (no demolition); $2.19 (demolition)

The results of the analysis indicate it is less costly on an annual basis to use all three of the coatings over VCT and all seven types of flooring in place of the VCT than it is to use VCT. In some cases, as indicated in the table, the coatings have a variable warranty life. After they are applied initially, the coatings can be applied over themselves and this is less costly than the initial application. When the flooring is replaced, demolition of the existing flooring may be required if VCT is being replaced; in new buildings, no demolition is required.

<u>Conclusions</u>

The results of the project indicate that using VCT flooring in new buildings is not a good option. Building owners and architects should select alternative flooring and the alternatives are less costly to use over the life of the flooring in all cases. The results also show that for existing buildings, when old flooring is being removed and replaced, using new VCT is not a good option. Again, all other types of flooring evaluated are a better option. In buildings where VCT still has a useful life, a good option is to use a coating over the VCT. In cases where VCT is still being used, alternative safer wax strippers should be used to improve air quality and minimize the risk to maintenance staff, teachers, students and the public.

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I. Introduction and Background

There are thousands of new and existing schools and public buildings in the United States that require flooring of various types for different purposes. The most common type of flooring encountered in schools and public buildings today is vinyl composition tile (VCT). This flooring requires substantial on-going maintenance and it must be waxed and stripped routinely to maintain a glossy rich appearance. Many of the wax strippers on the market today contain Volatile Organic Compounds (VOCs) which contribute to smog and toxic components that can expose maintenance workers, teachers, students and the general public.

In California, the California Air Resources Board (CARB) regulates the VOC content of consumer products, including floor wax strippers. Several years ago, CARB estimated that VOC emissions of floor wax strippers in California amount to about eight tons per day. CARB is currently conducting a survey of all consumer product categories and a more updated estimate should be available shortly. The South Coast Air Quality Management District (SCAQMD) has established a voluntary certification program for janitorial products and that program also covers floor wax strippers. The SCAQMD program has more restrictive standards than CARB's regulations and there are no products in the stripper category that meet the VOC certification standard. U.S. EPA's Safer Choice Program (formerly the Design for the Environment Program) provides a list of floor wax strippers that can carry the Safer Choice label.

Virtually all of the floor wax strippers on the market today contain monoethanolamine, including those that comply with the CARB VOC limits and are approved to carry the EPA Safer Choice label. This chemical can cause asthma which is becoming an increasingly serious problem in the U.S. and it is a sensitizer. Some contain other amines that may have similar problems. Many of the strippers also contain solvents that are VOCs which contribute to smog and/or are toxic. Examples are glycol ethers; these are VOCs and some have toxicity endpoints. Some of the strippers are highly alkaline with very high pH which can cause acute exposure problems for workers and others in the buildings.

The Institute for Research and Technical Assistance (IRTA), a nonprofit organization, was established in 1989 to identify, develop, test and demonstrate safer alternatives in industrial and consumer product applications. IRTA's work has a heavy focus on solvent alternatives. IRTA staff have worked with hundreds of facilities in California to find and implement low-VOC, low toxicity alternatives.

IRTA received a subgrant from the University of Nevada Reno under the Western Sustainability and Pollution Prevention Network (WSPPN) which was sponsored by a U.S. EPA pollution prevention grant to conduct a research project on alternative floor wax strippers. The Bay Area Air Quality Management District (BAAQMD) also provided support to IRTA for the project. IRTA also provided a substantial in-kind contribution to the work. The purpose of the project was to develop, test and demonstrate low-VOC, low toxicity alternative wax strippers that can be used in maintaining the floors and to find and investigate other methods of minimizing or eliminating the use of wax strippers.

IRTA recruited several school districts and public building entities to assist in the project. In some cases, the facilities demonstrated and explained their floor stripping process and in others, they assisted IRTA by conducting testing of the potential alternative wax strippers and other approaches to reducing or eliminating the need for the strippers. The participating entities included:

- Riverside Unified School District (Riverside USD)
- Irvine Unified School District (Irvine USD)
- San Francisco public buildings

- SCAQMD public building
- San Francisco Unified School District
- City of Santa Monica School District
- Santa Monica public buildings

As part of the project, IRTA worked with two formulators, eChem and DuraChem, to develop and test the safer alternative floor wax strippers. The aim was to make strippers that did not contain any amines including monoethanolamine; had zero VOC content under the CARB regulations; met the lower VOC content requirements of the SCAQMD janitorial products certification program if possible; and had a reasonably low pH. IRTA and the two formulators developed and tested two strippers that satisfied some or all of these restrictions.

Also as part of the project, IRTA tested three different types of coatings that can be applied to VCT; these coatings do not require waxing or stripping so much of the on-going maintenance for the VCT can be avoided. The suppliers IRTA worked with, NeverStrip and DFS Flooring, provided three different types of coatings for testing. They are:

- Vinyl seal
- Polyurethane
- UV urethane acrylic

In addition to the tests of the coatings, IRTA worked with flooring suppliers, including Tandus Centiva, KYA Surfacing, Floor Tech America and Signature Commercial Floor Covering, to identify, install, test and evaluate flooring alternatives that do not require waxing or stripping. IRTA tested and/or evaluated seven different types of flooring during the project. The different types of flooring included:

- Optima IQ, a homogeneous vinyl sheet flooring
- Omni Sports, a heterogeneous vinyl sheet flooring
- EcoPure, a natural linoleum flooring with cork backing
- Centiva Contour, a heterogeneous hardened vinyl plank flooring
- Centiva Mineral Chip, a homogeneous hardened vinyl tile with a terrazzo look
- Powerbond, a resilient nylon flooring with closed cell cushion backing
- Mondo, a blend of natural and synthetic rubber flooring

IRTA conducted much of the preliminary testing of the alternative floor wax strippers with Riverside USD. All of the participating school systems and public buildings were willing either to demonstrate their current stripping process and discuss their practices or test the alternative strippers developed by IRTA and the formulators. When IRTA and the formulators finalized the best three strippers with Riverside USD, these three strippers were tested with the SCAQMD public buildings. The two best strippers were then tested with the San Francisco Public Buildings and Irvine USD. The coatings and alternative flooring were all tested at Riverside USD. None of the other project participants was willing to test the coatings or alternative flooring types so the experience at Riverside USD is the basis for many of the results presented here.

IRTA evaluated and compared the cost of three strategies for the floors. The first strategy was to continue using VCT flooring which requires waxing and stripping and this strategy served as the baseline for the analysis. As part of this strategy, IRTA compared the performance and cost of the currently used strippers with the performance and cost of the low-VOC, low toxicity strippers developed and tested during the project. The second strategy was to apply different types of coatings to the VCT and avoid the need for waxing and stripping. The third strategy was to install alternative flooring in place of the VCT most commonly used today and also avoid the need for waxing and stripping.

1.1 Project Approach

In general, the first step in the project was to visit the participating facilities to discuss the flooring, the waxing and stripping products they use and the practices they use for stripping. In some cases, IRTA watched the stripping operations to determine the important components of the process.

The second step was to recruit two formulators to assist IRTA in formulating alternative low-VOC, low toxicity strippers. Two formulators, Dura-Chem and eChem, agreed to work with IRTA on the project to formulate and conduct testing of the alternative floor wax strippers.

The third step was to investigate the different types of floor coatings to determine which types could be tested at Riverside USD. IRTA identified a supplier of three types of coatings, vinyl seal, polyurethane and UV urethane acrylic, that are all low-VOC content and suitable as floor coatings. The flooring supplier, NeverStrip, and an installer, DFS Flooring, worked with IRTA to apply these coatings at Riverside USD.

The fourth step was to investigate alternative types of flooring that could be used in place of VCT. IRTA identified a flooring manufacturer, Tandus Centiva, who coordinated with other suppliers to obtain the flooring and Signature Commercial Floor Covering installed most of the different types of flooring at Riverside USD. Two other types of flooring were already installed at Riverside USD and these were also included in the analysis.

The fifth step was to monitor the coatings and alternative flooring for about one school year to allow a comparison of their performance. The project team conducted monthly inspections to observe the coating and flooring performance during the testing phase and to identify and handle problems that arose in the course of the testing.

The sixth step was to test alternative strippers with Riverside USD and the other participating facilities to identify the best performing alternatives. This testing provided input for deciding on the two best low-VOC, low toxicity strippers.

The seventh step was to evaluate and compare the cost of using VCT with wax stripping maintenance on the one hand with using the coatings and alternative flooring with no wax stripping on the other hand. This step also involved examining some of the health and environmental implications of the current and newly developed strippers, the coatings and the alternative flooring that were tested.

The eighth step was to prepare a final report describing the results of the project.

1.2 Alternatives Performance

Performance of the low-VOC, low toxicity alternative strippers at the testing facilities was evaluated on a case-by-case basis. In all cases, the plant personnel judged the alternative stripper performance by comparing it to the stripper they use currently. The Riverside USD maintenance and environmental staff, as well as the suppliers and IRTA, made judgements about the performance of the coatings and alternative flooring based on the regular monthly inspections.

1.3 Cost Analysis

IRTA performed cost analysis for the safer alternative strippers and compared it to the cost of using the stripper currently used at Riverside USD and the cost of typical "green" and non-green strippers available on the market today. For the coatings and alternative flooring, IRTA evaluated the materials and installation cost and the on-going maintenance cost The cost analysis was performed for a case study of a typical school with 10 classrooms containing a total or 9,600 square feet and on a per square foot basis. The cost of the three scenarios, 1) using VCT with maintenance, 2) using VCT with coatings and little maintenance and 3) using alternative flooring with little maintenance, were compared for the case study and on the per square foot basis.

1.4. Health and Environmental Issues

As part of the project, IRTA noted some of the health and environmental issues that arise with use of the current and alternative strippers, the VCT and alternative flooring types and the coatings applied to the VCT. This analysis did not involve a comprehensive life cycle assessment of all the health and environmental factors. Rather, it focused more heavily on the in-use characteristics and impacts of the products.

1.5 Report Organization

Section II of this report provides detailed information on the approach IRTA used in developing safer alternative floor wax strippers and the results of the testing. This involved evaluating the regulations and certification and labeling programs and these are described in the section as well. Section III of the report provides background on the coatings that were tested at Riverside USD, including the regulations that apply in Southern and Northern California. It also describes the performance of the coatings during the school year. Section IV presents background information on the alternative flooring that was tested at Riverside USD and describes the performance during the school year. Section V of the report presents the cost analysis and comparison for the wax strippers, the VCT baseline, the coatings and the alternative flooring. Section VI includes a description of health and environmental issues. Finally Section VII summarizes the project findings. Appendix A includes Material Safety Data Sheets (MSDSs) or Safety Data Sheets (SDSs) for the currently used floor wax strippers and the alternative strippers that were tested during the project. Appendix B provides SDSs for the coatings that were tested and Appendix C presents a cost reconciliation of one of the coating types.

II. Alternative Floor Wax Strippers

2.1 Floor Wax Stripping Process

As discussed earlier, most schools and public buildings rely on the traditional VCT for their flooring. A major disadvantage of this flooring is that the maintenance requirements are resource intensive for ensuring the floor presents a glossy appearance. The floors must be waxed regularly and the wax has to be stripped and reapplied to the floor periodically. In order to maintain the appearance, the waxed surface also has to be burnished periodically.

During this project, IRTA worked intensively at several schools in the Riverside USD system, to perform the initial testing necessary for developing an effective alternative stripper. Riverside USD's waxing, burnishing and stripping practices are representative of the practices of all schools and public buildings. There may be some variation, however, depending on the policies the maintenance staff follows. Furthermore, because of funding constraints in recent years, many schools and public buildings have eliminated or reduced the frequency of some maintenance practices that are recommended for ensuring the VCT maintains its appearance. Thus the costs of maintenance for VCT evaluated for today are likely lower than the costs incurred for optimal maintenance historically.

In the past, Riverside USD burnished the VCT every six months; because of funding shortfalls, this practice has been discontinued altogether. The suppliers of VCT do recommend that the floors be burnished, however, so IRTA included the costs in the analysis. The burnishing process requires use of a natural hog hair pad on a floor machine run at 2,500 rpm. The high speed of the rotating pad heats up the floor finish (wax) and the burning of the top coat gives the floor a gloss. The burnishing process requires one worker and it takes about 15 minutes to burnish 1,000 square feet.

The maintenance staff strips the wax from the floor, rinses it and reapplies wax every seven months. It requires three workers for four hours each (12 person hours) to strip 1,000 square feet of VCT. The stripper is first diluted to the proper concentration which is often about four parts water to one part stripper. The stripper is applied to the floor with a mop and is allowed to work for five to 15 minutes. The stripper needs to penetrate the wax layers and, in some cases, there is a significant buildup. When the stripper begins to work, it bubbles up on the floor. A picture of the floor with the stripper applied is shown in Figure 2-1. A floor machine with an abrasive pad is then moved over the floor area to be stripped; it uses a rotary movement of the pad to accomplish the stripping. A picture of the floor machine stripping the floor is shown in Figure 2-2. The residue of the wax and stripper is sucked up with a wet vacuum. This process is shown in Figure 2-3. Finally, rinsewater is applied to the floor with a mop and the residue is again sucked up in the vacuum. The residue of the wax, stripper and rinsewater is put in a bucket and flushed to the sewer.

After stripping, a sealer and three coats of wax are applied to the floor. The first coat, the sealer coat, is used to seal the pores of the VCT. The maintenance people then apply three coats of wax. It takes about 20 minutes to apply the sealer and each coat of wax. It requires 20 minutes for each coat to dry before the next coat can be applied. Some of the facilities IRTA worked with do not use a sealer. The practice is more important for old and/or irregular VCT.

Figure 2-1. Stripper Applied to Floor

Figure 2-2. Floor Machine Stripping Wax

Figure 2-3. Wet Vacuum Handling Residue

In between the stripping events that occur every seven months, the maintenance staff top scrubs the floor twice. During a top scrub, the wax is removed with a neutral mild detergent but the sealer is not. Two coats of wax are then applied. The same wax used in the stripping process above is used for the top scrub. The top scrub process requires three workers for 45 minutes each for top scrubbing 1,000 square feet. The workers must wait an additional 20 minutes for each of the coats of wax to dry.

2.2. Floor Wax and Floor Wax Strippers

An SDS for a typical floor finish called Trendsetter is shown in Appendix A. Generally, floor finishes used on VCT contain acrylic copolymers and solvents of various kinds. The acrylic solids on the floor are the materials removed in the stripping process. The solids are softened when the stripper penetrates them for a period and, when the floor machine with a Hi-Pro black pad is rotated on the floor, the softened material is abraded. The wet vacuum is then used to suck up the liquid residue containing the solids.

An SDS for the stripper used by Riverside USD is shown in Appendix A. This stripper, called "Bombers Industrial Strength Stripper," contains potassium hydroxide, an amine and a glycol ether called 2-butoxy ethanol. The formulation has a high pH, between 12 and 14. The supplier recommendations indicate it should be diluted to six parts water to one part stripper for extreme buildups or 12 parts water to one part stripper for heavy to medium buildups. This dilution is required so the stripper can meet the VOC requirements (see below). It is a very aggressive stripper. Riverside USD dilutes the stripper with four parts water to one part stripper so it is actually used at higher concentration than recommended in practice.

An SDS for another stripper called "Waxie Green Floor Stripper" is also shown in Appendix A. This stripper is representative of the so-called green strippers used by some facilities. It contains two solvents; one is a glycol ether and the other is benzyl alcohol. It also contains monoethanolamine (called 2-amino ethanol on the SDS). In this case, the pH is lower than the pH of Bombers, at 10.9.

2.3. Regulations on Floor Wax Strippers

In California, the California Air Resources Board (CARB) has jurisdiction over air emissions from consumer products. The regulation in place since 2002 requires that nonaerosol strippers sold for California must meet a VOC content limit of 3% or less by weight for removing light or medium buildup. They must meet a VOC content limit of 12% by weight for heavy buildup. The labels on the strippers must specify the dilution ratio that meets these VOC limits.

The South Coast Air Quality Management District (SCAQMD) regulates air emissions from stationary sources in four counties in Southern California including all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties. The SCAQMD does not regulate air emissions from consumer products but the District does have a voluntary certification program for janitorial products. This program requires certified products to meet a very low VOC content limit of 10 grams per liter or about 1%. It also puts restrictions on the ingredients in strippers that are toxic or contribute to global warming or ozone depletion. The CARB regulation sets higher VOC limits of 3% and 12% for the strippers they regulate and the CARB definition of VOC is also less stringent than the definition used by SCAQMD. There are no floor wax strippers currently certified by SCAQMD because none of the strippers on the market meet the very low VOC limit established in the certification program.

EPA has a program called Safer Choice which was formerly called Design for the Environment. The Safer Choice program works collaboratively with industry to establish standards for safer products in certain industries. EPA worked with stripper suppliers to allow the Safer Choice label to be used on products that meet their criteria. The strippers that carry the label generally contain monoethanolamine or other amines, benzyl alcohol and/or glycol ethers of various types. These ingredients are the same as those in the "green" Waxie stripper discussed above. Even though these strippers may contain some ingredients that have toxicity issues, EPA considers the Safer Choice products to be the best state-of-the-art products available.

2.4. Safer Alternative Strippers

One of the aims of IRTA's project was to find alternative strippers that do not contain amines. Many amines, including monoethanolamine, are sensitizers and asthmagens. There is concern about increases in asthma in recent years so minimizing or eliminating the use of asthmagens is important. Another aim of the project was to develop alternative strippers that would have zero VOC content as defined in the CARB regulation and to meet the lower 10 gram per liter VOC limit of the SCAQMD Janitorial Products Certification program, if possible. Yet another aim was to develop strippers that would have a lower pH limit.

IRTA worked with two formulators to develop, test and demonstrate alternative strippers that met these aims. MSDSs for the strippers, called "Green Innovations Floor Finish Remover (III-14A)" and "Green Innovations Solvent-Free Floor Finish Remover (III-14C)," are shown in Appendix A. The first stripper, 14A, contains benzyl alcohol like other green strippers but it does not contain any amines. It has zero VOC content according to the CARB standards. The second stripper, 14C, contains no solvent and no amines. It also has zero VOC content according to the CARB standards. This second stripper would meet the SCAQMD 10 gram per liter VOC limit but the first stripper would not.

2.5. Tests of Alternative Strippers

An important factor in the performance of a stripper is the concentration that is applied to the floor. The CARB regulations require the dilution level to be specified by the suppliers and suppliers may recommend a different level depending on how heavy the wax buildup is. Often, suppliers pick the level of dilution based on the level that will meet the VOC content requirements. The higher the dilution level, the lower the VOC content of the stripper as applied.

When schools and public buildings use a particular stripper for a long time, they can judge the concentration of the stripper that is needed for a particular job. Often, when the buildup is high, two or more applications of the stripper may be required. Instead of applying the stripper twice for a heavy buildup of wax, the maintenance staff may simply increase the concentration. When the staff are familiar with a stripper, they rarely measure the concentration but instead they just judge how much stripper and water should be used for a specific job. Frequently, maintenance staff at most schools and public buildings ignores the supplier recommended dilution levels and use a higher concentration routinely.

When testing a new stripper, the maintenance staff does not know how it will perform. In that case, they do measure the concentration. When a stripper is new, like those developed here, it is not always obvious what concentration to recommend. In some cases, the alternative strippers may not work as well as the current stripper because the staff routinely uses the current stripper at a higher concentration. It is therefore difficult to tell how well the alternative stripper would perform if the staff were able to use it for a much longer period and develop a knowledge of the best concentration through experience.

Another important factor in the performance of a stripper is what kind of pad the staff uses in the floor machine during stripping. As discussed later, Riverside USD uses Hi-Pro pads which are very aggressive. Other schools and public buildings IRTA worked with may not use Hi-Pro pads and, as a result of using less aggressive pads, they may need to use a higher concentration of stripper or apply the stripper more times to achieve the desired result.

Yet another factor that must be considered when testing strippers is whether or not a sealer is used. Sealers are used to cover the VCT below which may be irregular so the finish looks even after it is applied. In many cases, schools and public buildings do not use sealer but, in some cases, they do use it and it makes the stripping more difficult.

During the testing, IRTA could not control all the variables, particularly when a larger amount of stripper was left with organizations to use at a later time. In addition, when some of the testing took place, the staff did not use their current stripper on the same waxed floor so there was not a good comparison. They often felt they were familiar enough to judge how their stripper would perform. This indicates that the stripper tests can provide good input on whether the strippers are viable products but not necessarily whether they perform well or poorly compared with other individual strippers.

2.5.1. Tests at Riverside USD

Earlier versions of the floor wax strippers were tested a number of times over the course of the project at Riverside USD. This was necessary to determine which floor wax stripper approaches would be most effective. It allowed IRTA and the formulators to compare the performance of different alternative strippers to the performance of an extremely aggressive stripper, Bombers. Pictures of some of the stripper tests are shown in Figures 2-4 through 2-8. Figure 2-4 shows the alternative strippers and Bombers applied to the floor during a test. Figure 2-5 and Figure 2-6 shows the floor machine with the Hi-Pro black pad rotating over the stripper and Figure 2-7 shows the wet vacuum collecting the residual stripper and wax after the stripping. Figure 2-8 shows the floor after stripping with the alternative strippers and Bombers. When the floor is still wet it is not obvious how well a stripper performed so it is necessary to wait for the floor to dry to see if all of the stripper and the sealer is removed.

The preliminary testing at Riverside USD of various different alternative stripping formulations allowed IRTA and the formulators to determine a few of the best approaches to making strippers with the health and environmental characteristics that would be safer and at the same time, perform effectively. This testing signaled which three strippers were the best strippers for selection and testing at other facilities.

2.5.2. Tests at SCAQMD Building

When the alternative stripper formulations had been developed based on the criteria for health and environmental characteristics and the performance data from the Riverside USD testing, three alternative strippers were tested at the SCAQMD building in Diamond Bar, California. SCAQMD was using a stripper from Waxie called "W-400 Heavy Duty Stripper" which, like Bombers, is not a green stripper. An SDS for this stripper is shown in Appendix A. It contains sodium hydroxide, an amine and 2-butyxy ethanol. The pH is listed as >12.5.

The strippers were tested in a small area in an elevator cove that had a buildup of four or five coats of wax. The strippers were applied and allowed to sit for a time so they could penetrate the coats of wax. Then the floor machine with the rotating Hi-Pro black pad was moved over the area. The wet vacuum was used to suck up the residue and the floors were allowed to dry.

Figure 2-4. Applying Strippers during Tests at Riverside USD


Figure 2-5. Floor Machine Stripping during Tests at Riverside USD


Figure 2-6. Hi-Pro Pad on Floor Machine during Tests at Riverside USD


Figure 2-7. Wet Vacuuming Residue during Tests at Riverside USD


Figure 2-8. Floor after Stripping Tests at Riverside USD

The results of the testing indicated that two of the three strippers performed well, at least as well as the stripper that was used currently. These were the III-14A and the III-14C strippers described above. The maintenance staff preferred one of the strippers, the III-14A stripper, so IRTA and the formulator provided five gallons of the stripper for stripping a hallway that had several coats of wax at a later time.

The stripper was tested at the SCAQMD building and the maintenance manager indicated the stripper performed well. He said the stripper was able to remove several coats of wax effectively. He noted that he particularly liked the stripper because it created a non-slip surface. This is in notable contrast to other strippers which become very slippery after they are applied. The non-slip characteristic indicates the stripper would be safer for maintenance staff to use. The staff had also given IRTA this feedback during the earlier tests of the three strippers in the alcove. Pictures of the larger scale testing are shown in Figures 2-9 and 2-10. They show the floor before and after the stripper was applied respectively.

2.5.3.Tests At San Francisco City Hall

The testing at the SCAQMD building demonstrated that the two best strippers were the III-14A and III-14C so these were the strippers that were tested at the San Francisco City Hall. The City Hall was using a stripper, Claire 316, called “Floor Finish Remover,” which is considered a “greener” stripper than Bombers, the stripper used at Riverside USD. An MSDS for this stripper is shown in Appendix A. It indicates that the stripper contains monoethanolamine and benzyl alcohol. The pH is relatively low, below about 11.5.

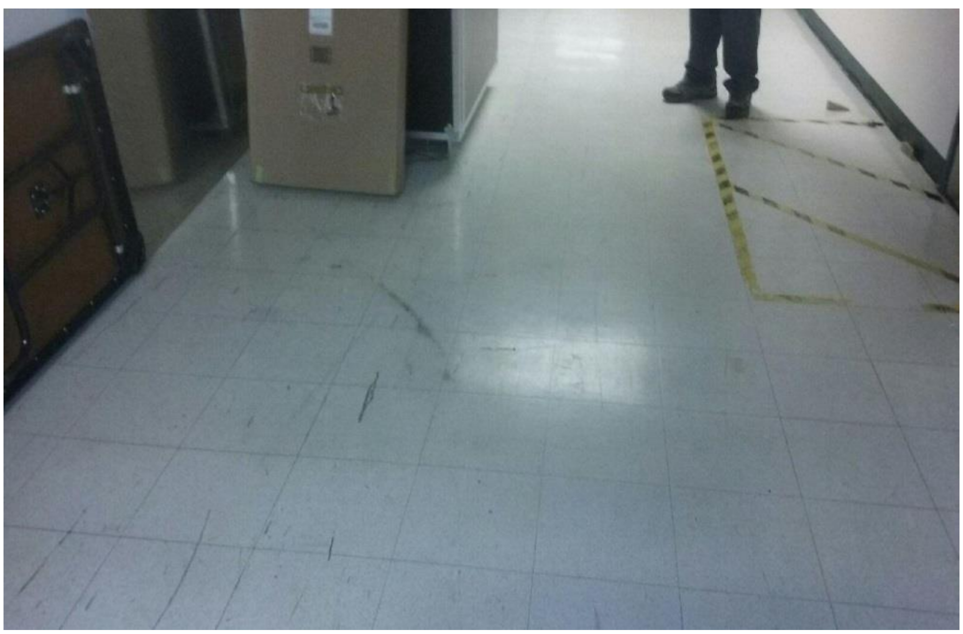

Figure 2-9. Floor before Stripper Application during Testing at SCAQMD Building

Figure 2-10. Floor after Stripper Application during Testing at SCAQMD Building

The maintenance people indicated that there were six or seven coats of wax on the floor which normally would require at least two separate applications of the stripper. The staff first tested the III-14A stripper, the stripper containing solvent. The stripper was applied twice, the floor machine was moved over the floor, the wet vacuum absorbed the residue and the floor was allowed to dry. The stripper had not stripped the wax. The staff started applying the second stripper when it was discovered that the pads that were being used were not Hi-Pro pads. The staff were able to find a Hi-Pro pad and the second stripper, the III-14C, was used with this pad with one application. It was able to strip all of the heavy wax buildup on the floor in one application. All of the III-14A stripper had been used so there was none left to try to strip the wax with the appropriate Hi-Pro pad. Pictures of the staff applying the III-14C stripper and removing the wax are shown in Figures 2-11 through 2-13.

The City Hall maintenance staff asked if they could have five gallons of each of the two strippers to test on larger areas. IRTA and the formulator agreed to send them the larger quantities. The two strippers were tested on a floor that probably had three of four coats of wax. Both strippers required two applications to completely remove the floor finish. Both apparently removed nearly all of the finish in one application. There were some recessed areas in the flooring where the finish was not completely removed in the first application. The staff used a four parts water to one part stripper concentration recommended by IRTA and the formulator. A slightly higher concentration, as discussed earlier, may have been needed to remove all of the finish in one application. In general, the stripper used currently at City Hall removes this type of wax buildup in one application. It is not clear what concentration the staff uses for the current stripper; they do not measure it accurately any longer since they are familiar with its performance.

The staff preferred the solvent containing alternative stripper, III-14A, and thought it worked slightly better than the other solvent-free stripper, III-14C. In general, however, the manager reported that he believed both strippers were viable products.

Figure 2-11. Applying Alternative Stripper during Testing at San Francisco City Hall

Figure 2-12. Using Floor Machine on Stripper during Testing at San Francisco City Hall

Figure 2-13. Using Wet Vacuuming System during Testing at San Francisco City Hall

2.5.4. Tests at Irvine USD

IRTA and the formulator tested the two strippers with the maintenance manager at Irvine USD. The manager indicated the test was not a good one because the staff had allowed a buildup of at least seven coats of wax and had burnished the floor. Burnishing generates heat and fuses the top wax layer to the next wax layer making it more difficult to remove. He indicated that the floor had obviously not been stripped for a long time, possibly years. The day before, he had stripped the floor in a classroom in the same building. He had applied his current stripper, which is Waxie W-400 Heavy Duty Stripper, three times and it still could not remove all of the wax on the floor. There were many patches of wax left on the floor.

In spite of the fact that the test conditions were not ideal, the testing went forward in a hallway alcove. The two alternative strippers were tested with a Hi-Pro pad IRTA provided for the testing. After three applications, the stripper containing solvent removed most, but not all, of the wax. The stripper Irvine is currently using was tested as well. It was less effective in removing the wax than the alternative stripper with the solvent. The test results for the other alternative stripper indicated it did not seem to perform as well as the alternative stripper containing solvent. The maintenance manager indicated he liked the stripper with solvent because it created a non-slip surface. This was the same comment made by the maintenance staff at SCAQMD.

A picture of the floor in the alcove where the stripping tests were conducted is shown in Figure 2-14. Pictures of the stripping process with the Hi-Pro pad are shown in Figures 2-15 through 2-18.

Prior to the testing, the manager was not aware of the capabilities of the Hi-Pro pad. The staff at Irvine USD use similar black pads with a tighter weave. They became clogged easily, however, with the wax they


Figure 2-14. Alcove Where Strippers Were Tested at Irvine USD


Figure 2-15. Applying Stripper during Testing at Irvine USD

Figure 2-16. Using Floor Machine during Testing at Irvine USD

Figure 2-17. Using Wet Vacuum during Testing at Irvine USD

Figure 2-18. Floor after Stripping During Testing at Irvine USD

removed and the wax laden pad could not cut through the additional wax; it slipped over the top of the floor. The manager much preferred the Hi-Pro pad. He indicated that the Hi-Pro pad could be washed out and recycled so it could be reused, perhaps several times. This is in contrast to the tighter weave black pads which had to be discarded after one use. A picture of the two pads after the alcove testing is shown in Figure 2-19. The pad on the left is the Hi-Pro pad and the one on the right is the standard black pad.

Figure 2-19. Picture of Hi-Pro and Regular Pad after Stripping at Irvine USD

Because the manager did not believe the floor where the testing was conducted was representative of a normal stripping job, he asked for more of the two alternative strippers and IRTA and the formulator provided him with one gallon each of the two strippers. The stripper containing the solvent was subsequently tested on a floor with a more typical wax buildup and the results indicated it performed well. This additional testing also allowed the manager to test the Hi-Pro pad that had been rinsed out after the earlier testing. The manager did not test the solvent free stripper again.

III. Floor Coatings

3.1 Floor Coatings Applied During Project

Three different types of coatings were applied to the VCT at University Middle School in Riverside USD in a four legged hallway. This hallway experiences very high foot traffic so it was a very demanding test for the coatings. The three types of coatings that were applied are:

- Vinyl seal
- Polyurethane
- UV urethane acrylic

The purpose of applying and testing the coatings was to evaluate an option where the use of floor wax strippers could be eliminated altogether. None of the three coatings requires waxing or stripping during their useful life.

IRTA selected the vinyl seal and polyurethane coatings because they have a history of use for coating floors, specifically VCT. Some floors have been coated with UV coatings but the application, in this case, is not yet standard. IRTA talked with several different coating suppliers to identify the types of coatings that should be tested. A company called NeverStrip supplied the coatings that were tested and a flooring company, called DFS Flooring, applied them to the flooring in the hallway. IRTA wanted to work with NeverStrip because the company provides coatings that meet the low VOC limits specified in California and, in this case, specifically Southern California.

A diagram showing the hallway system where the coatings were applied over the VCT is shown in Figure 3-1. The diagram indicates that the polyurethane coating (called urethane in the figure) was applied in a fairly short hallway between two entrances where alternative flooring was installed as discussed in the next section. The vinyl seal and UV urethane acrylic coatings (called UV cured) were applied in longer stretches of two hallways. At one end, in each case, alternative flooring was applied at the building entrances.

3.2. Regulations on Floor Coatings

In California, as discussed earlier, CARB has jurisdiction over air emissions from consumer products. There are a number of local air districts in the state and they are responsible for regulating air emissions from stationary sources. VOC emissions from coatings, like those applied here to the floors, are covered under the local air district regulations. SCAQMD is the largest air district in California and it has authority over about half the sources in the state. The Bay Area Air Quality Management District (BAAQMD) in Northern California has authority over an additional one-fourth of the state sources. Both of these air districts have regulations that affect floor coatings. The other air districts in the state often follow the lead of the two larger districts so the BAAQMD and the SCAQMD regulations are representative of the regulations in the state as a whole. Each of the regulations is discussed below.

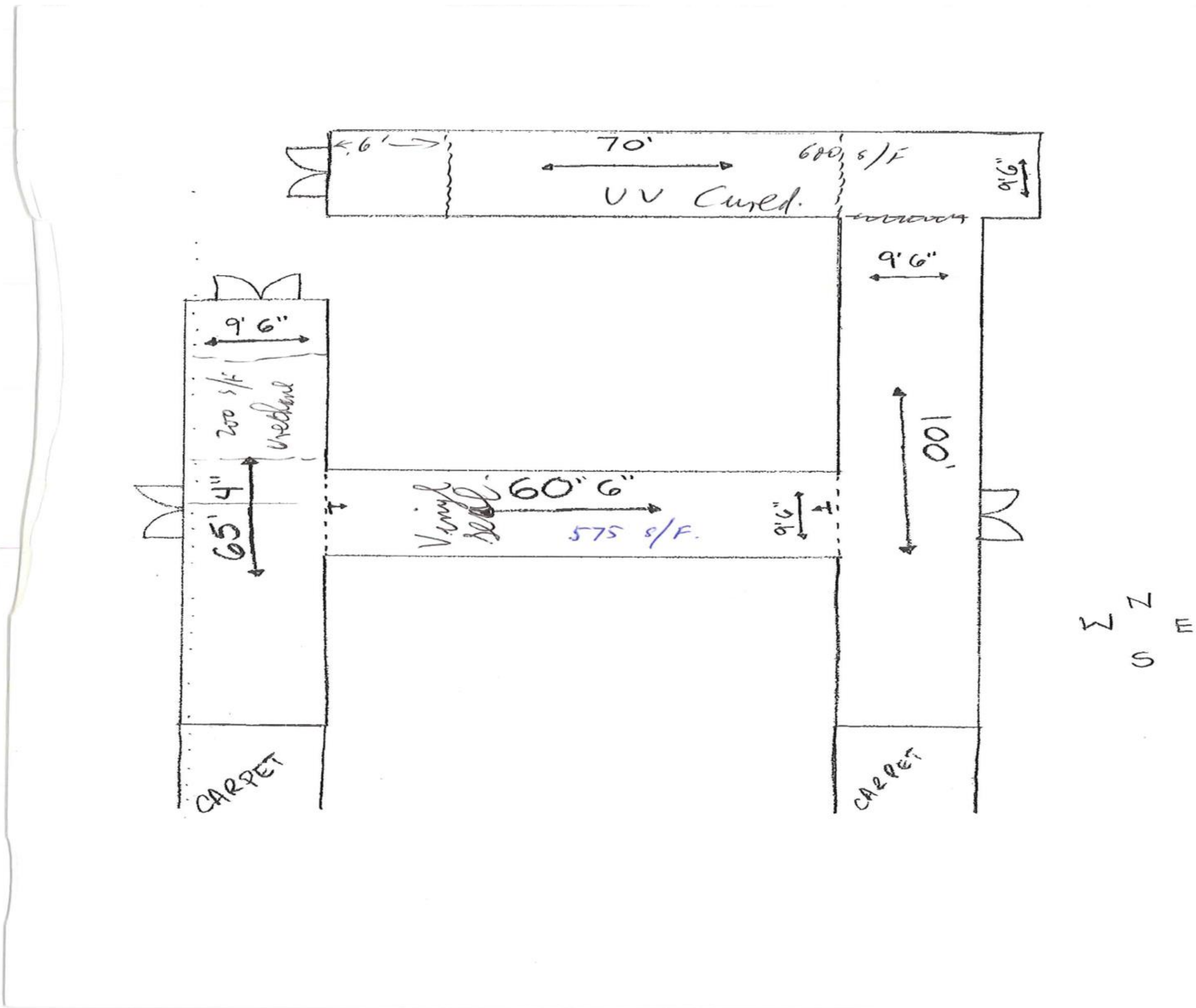

Figure 3-1. Drawing of Hallway System at Riverside School

3.2.1. SCAQMD Floor Coating Regulations

SCAQMD regulates floor coatings under SCAQMD Rule 1113 "Architectural Coatings." The current VOC limit for floor coatings in the regulation is 50 grams per liter. In some cases, SCAQMD defines floor coatings as Industrial Maintenance (IM) Coatings. These are cases where the floor coatings are used in chemical plants and related facilities where they will come in contact with aggressive chemicals and formulations. IM coatings have a higher allowed VOC limit of 100 grams per liter. In addition, IM coatings may be formulated with a solvent called tert-butyl acetate (TBAC) which is considered to be exempt from VOC regulations in the case of IM coatings. In nearly all cases where floor coatings are used in schools and public buildings, the coatings would not be interpreted by SCAQMD staff to be IM coatings. There is some confusion around where TBAC can and cannot be used, however. TBAC, as discussed later, is a carcinogen so IRTA did not test any coatings containing the solvent during this project.

3.2.2. BAAQMD Floor Coating Regulations

The BAAQMD regulates floor coatings under Regulation 8, Rule 3 "Architectural Coatings." The VOC limit on floor coatings is currently 100 grams per liter. The BAAQMD also defines IM coatings, similarly to SCAQMD. In contrast to SCAQMD, however, this agency does not exempt TBAC from VOC regulations for IM coatings.

3.3. Characteristics of Tested Coatings

The three types of coatings tested during this project are representative of the types of floor coatings that could be applied in a school or public building anywhere in the country. One of the coatings described below requires somewhat more maintenance than the other two types.

3.3.1. Vinyl Seal

An SDS for NeverStrip Vinyl Seal tested during the project is shown in Appendix B. It is a water-based coating with a VOC content of less than 50 grams per liter which meets the 50 gram per liter VOC limit required by SCAQMD and the 100 gram per liter VOC limit required by BAAQMD. Generally three coats of the vinyl seal are applied and the floor is burnished. The coating has a one hour dry time and seven days are required for a full cure. The coating is an extremely durable treatment that penetrates, seals and protects the floor. The maintenance regime for the coating is to clean the floor with a neutral cleaner containing no acids and a periodic burnishing. The warranty life of the coating is 12 to 18 months. When the coating wears, it can be reapplied over itself.

A picture of the coating application procedure is shown in Figure 3-2. A picture of the coating after application is shown in Figure 3-3. A picture of the coating in the school hallway just after the school year had ended is shown in Figure 3-4.

Figure 3-2. Workers Applying Vinyl Seal Coating


Figure 3-3. Hallway after Application of Vinyl Seal Coating


Figure 3-4. Vinyl Seal Coating at End of School Year

3.3.2. Polyurethane Coating

An SDS for the three part (Part A, Part B and Part C) water-based NeverStrip polyurethane coating, called NeverStrip Gloss Parts A-B-C, that was tested as part of the project is shown in Appendix B. The VOC content of the coating is less than 50 grams per liter. One or two coats are required and the floor can be used four to six hours after application. The maintenance regime for the coating is cleaning only. No burnishing is necessary. The warranty life of the coating is two to three years. When the coating wears, it can be applied over itself.

A picture of the workers applying the polyurethane coating is shown in Figure 3-5 and a picture after the coating was applied is shown in Figure 3-6. Note that this coating, like other polyurethane coatings, has an appearance of orange peel. This follows from the fact that the VCT underneath does not have a uniform surface appearance. Figure 3-7 shows a picture of the coating when the school year had ended.

Figure 3-5. Workers Applying Polyurethane Coating

3.3.3. UV Cured Urethane Acrylic Coating

An SDS for the NeverStrip UV coating, called NeverStrip UV Gloss, applied during the project is shown in Appendix B. The coating is 100% solids and the VOC content is less than 10 grams per liter. It is an extremely durable and shiny coating. It is cured with a floor machine with ultraviolet lights on the bottom and the floor can be used directly after curing. The maintenance regime for the coating is simply cleaning and no burnishing is required. The warranty life of the coating is three years. This coating was applied by the supplier for the first time to a floor during this project. UV cured coatings are very durable and the warranty life assigned to the coating is probably very conservative.

Figure 3-6. Hallway after Application of Polyurethane Coating

Figure 3-7. Polyurethane Coating at End of School Year

A picture of the UV coating application is shown in Figure 3-8. The floor machine with the UV lights on the bottom is shown in Figure 3-9. Figure 3-10 shows the coating after the application and Figure 3-11 shows the coating after the school year had ended.

Figure 3-8. Workers Applying UV Coating

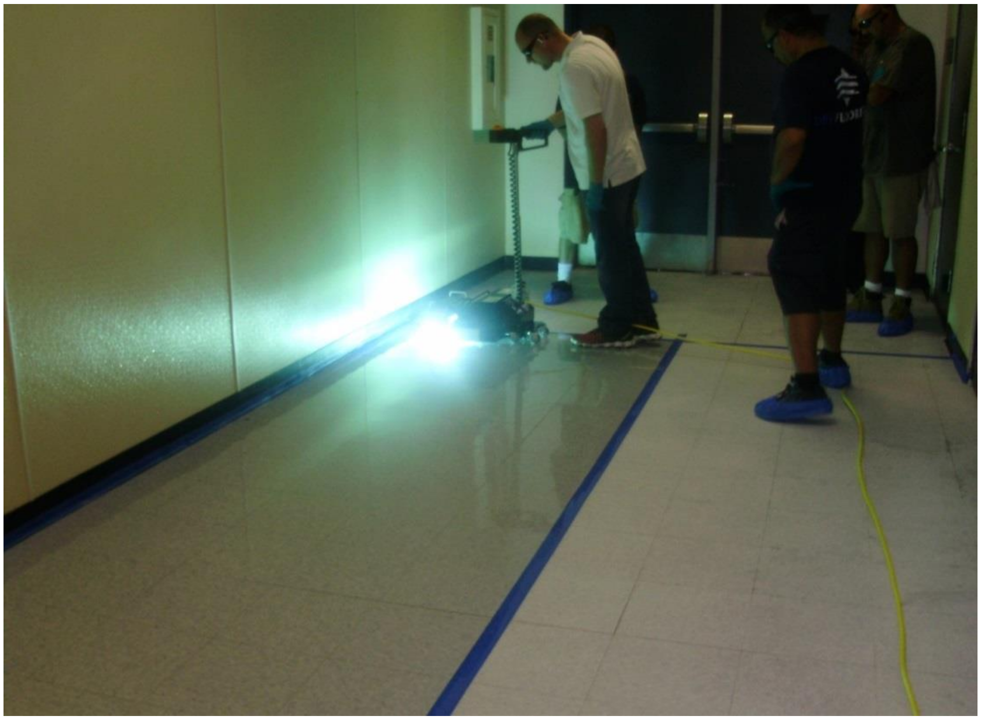

Figure 3-9. Floor Machine with UV Lights


Figure 3-10. Hallway after Application of UV Coating


Figure 3-11. UV Coating at End of School Year

3.4. Results of the Coating Tests

The hallway system where the coatings were applied and some of the alternative flooring was installed is in the only school in Riverside USD with a network of inside hallways. There is substantial foot traffic in this hallway system. About 850 students attend this school. The students go in and out of the school twice a day so the equivalent of 3,400 students go through the hallways each day.

As described later in the cost analysis, the maintenance regime for the coatings involves cleaning them regularly with a neutral cleaner. In the case of the vinyl seal, routine burnishing should also be performed. For all three coatings, no waxing or stripping is required at all.

As mentioned earlier, IRTA and the coating and flooring suppliers conducted monthly inspections to observe the performance of the coatings and flooring over the school year. During the first few inspections, it was noted that the vinyl seal appeared to be very yellow. It was not clear what the cause of this yellowing was. The maintenance staff were using a cleaner that had a neutral pH but contained citric acid. This acid is not compatible with the vinyl seal nor is it compatible with the vinyl flooring. Over time, continued use of the citric acid cleaner can degrade the vinyl seal and vinyl flooring more quickly than would otherwise be the case. It was not clear whether use of the citric acid cleaner led to the yellowing of the vinyl seal. The supplier burnished the vinyl seal and applied an additional topcoat and the yellowing disappeared. Throughout the rest of the inspections during the school year, the vinyl seal appeared to stand up very well and appeared glossy. The maintenance staff continued to use the citric acid containing cleaner and it had no additional discernible effect on the vinyl seal.

Near the end of the inspections during the school year, the polyurethane coating began showing some scratches and it became dull in the recessed areas of the uneven flooring below. This coating is near an entranceway where foot traffic is especially high. As indicated above, the vinyl seal was holding up very well and the appearance was good. The UV cured coating looked extremely shiny at the end of the inspection period and the teachers indicated they liked that coating the best.

IV. Alternative Flooring

4.1.Flooring Types Tested During Project

As part of the project, IRTA worked with flooring suppliers to test several different types of flooring alternatives. Like the coatings discussed in the last section, these flooring alternatives do not require waxing and stripping and schools and public buildings that decide to adopt them can eliminate the need to use floor wax strippers altogether. IRTA worked largely with one flooring manufacturer to install and/or monitor six of the seven types of flooring. Although the specific flooring used was the manufacturer's product, other manufacturers have similar products representing the product type as well. In that sense, the results are transferable.

IRTA arranged for installation and testing of four different types of flooring so their performance could be monitored during the course of the project. These included:

- Optima IQ, a homogeneous vinyl sheet flooring
- Omni Sports, a heterogeneous vinyl flooring with closed cell cushion backing
- EcoPure, a natural linoleum flooring with cork backing
- Centiva Contour, a heterogeneous hardened vinyl plank flooring

One other type of flooring, Mondo, a blend of natural and synthetic rubber flooring, was installed midway through the school year and another, Powerbond, a resilient nylon flooring with closed cell cushion backing, had been in place for several years. Both of these types of flooring were also included in the monitoring. Another type of flooring, Centiva Mineral Chip, was shipped for installation too late in the year to be monitored. The six types of flooring that were installed and the Centiva Mineral Chip, a homogeneous hardened vinyl tile with a terrazzo look, a total of seven alternative flooring types, were all included in the cost analysis and comparison presented in the next section.

4.2. Characteristics of Flooring Types

The different types of flooring evaluated during this project are targeted for specific applications but all of them can also be used for certain applications in schools and public buildings. Four of the flooring types are made of vinyl, one of the flooring types is woven synthetic material and two are made of natural materials. The processes for producing the different types of flooring are discussed briefly below. The descriptions are not for the specific brand of flooring tested here but rather apply to the types of flooring generally.

4.2.1. Vinyl Flooring

The VCT used historically for most flooring and four of the alternative flooring types are made from vinyl material and these include:

- Optima IQ
- Omni Sports
- Centiva Contour
- Centiva Mineral Chip

All vinyl flooring is made by combining polyvinyl chloride (PVC) resin with a range of different additives that give them various properties. Flooring formulations are different and almost always proprietary. The additives include plasticizers which soften and provide flexibility to the vinyl, stabilizers to slow discoloration and degradation from heat and light, pigments which provide color and fillers like clay and limestone. The amount of vinyl in flooring materials ranges from roughly 11% to 55%.

The resin and additives are combined to form what is referred to as vinyl compound which is in pellet form. These pellets are processed further to form vinyl tile or sheet vinyl flooring. Vinyl tile is made either by melt-compounding the ingredients at high temperature and molding the materials into the desired shape or by using a calendaring method. With this method, the components are mixed and passed through a series of rollers that squeeze the mix to the required thickness. The sheet is then coated to provide abrasion and stain resistance and is cut into tiles which are about 12 inches by 12 inches in size. In general, VCT contains less vinyl and more filler than solid and printed vinyl tiles.

In the case of sheet vinyl, the ingredients comprising the resin and additives are made into sheets by processing a thin layer onto a backing material. The product consists of a backing, a vinyl foam core, a decorative layer and a clear vinyl layer. This sheet is cured in an oven and, in certain cases, is coated with a thin layer of urethane. Two printing methods are used. First, the retrogravure printing method prints colors or patterns on the surface of the base layer. The second method is an inlaid method where the design goes all the way to the backing. The printed pattern is covered with a clear vinyl wear layer and the product is oven cured. The advantage of sheet tile over individual tiles is that the continuous sheets have few seams which collect dirt and moisture. The sheets are produced in widths of six feet or 12 feet. All four of the alternative vinyl flooring types examined during the project are sheet vinyl products.

The filler commonly used in the manufacture of VCT is limestone. Stabilizers are made of zinc, calcium and tin. A blend of two phthalate plasticizers, diisononyl phthalate and benzyl butyl phthalate is commonly used. As discussed later, some plasticizers, in recent years, have been identified as particularly toxic.

In vinyl flooring manufacturing facilities, internal recycling is common and up to 99% of the raw materials initially used in the process are used in the final product. In addition, vinyl flooring manufacturers often used recycled material from recovered flooring or other post-consumer waste. This prevents the material from being landfilled. Some of the vinyl waste product may be incinerated and this can lead to exposure to chlorine containing products like dioxins which are extremely toxic.

4.2.2.Natural Material Flooring

Two of the flooring types included in the testing and analysis during this project are made of natural materials. EcoPure is a linoleum which is made of linseed oil. The oil is mixed with rosin to form a cement. Other raw materials include limestone, cork and wood powder and pigments. The mixture is rolled out between cylinders onto a jute backing in the form of a sheet. It is cured in ovens and drying rooms until it becomes flexible and resilient. The flooring comes in a range of different colors and designs.

The Mondo rubber flooring tested during the project is called Harmoni and it was installed in a multipurpose room at Riverside USD. Harmoni is prefabricated rubber flooring, calendered and vulcanized with a base of natural and synthetic rubbers. Natural rubber is a latex material. The top layer of the flooring is virgin rubber and the bottom layer is recycled rubber. The recycled rubber comes from trimmings and blemished materials generated in the production process.

4.2.3.Powerbond

Powerbond, a carpet-like flooring material, was already installed in the major hallway system where three different flooring types were also installed specifically for this project. The Powerbond was evaluated as part of this project. Powerbond hybrid resilient sheet flooring is a heterogeneous construction of nylon and closed cell cushion foam. The cushion and nylon are fused together with heat and pressure to form an integral flooring. This type of flooring contains between 7% and 32% overall recycled content which includes a minimum of 7% post-consumer content. A water resistant fluoropolymer is applied to the flooring to impart bleach and stain resistance to dyed yarns. Some fully fluorinated materials, which could be present in the polymer matrix, have high global warming potential and these materials are being increasingly scrutinized as discussed later in the section on health and environmental effects.

4.3. Installation of Alternative Flooring Types

Figure 3-1, shown earlier in the last section, is a diagram with the positions of the three alternative types of coatings indicated. Three of the different types of resilient flooring and the Powerbond were applied in the same series of hallways where the coatings were applied. All three of the resilient flooring types were installed at entrances at the same time. The Powerbond was already installed and had been used for many years in two different parts of the hallway system farther away from the entrances than the resilient flooring or the VCT coatings. The Centiva Contour flooring was installed in the entrance hallway at another school at the same time as the other resilient flooring and the Mondo was installed in a multipurpose room in yet another school about three months later.

Figures 4-1 and 4-2 show the Optima IQ flooring at different stages of installation. Figures 4-3 and 4-4 show similar pictures for the EcoPure flooring. Installation of the Omni Sports flooring is shown in Figures 4-5 and 4-6. Pictures of the Centiva Contour flooring and the Mondo flooring installed at two other schools are shown in Figures 4-7 and 4-8 respectively. A picture of the Centiva Mineral Chip, which was not installed and tested but was included in the cost analysis, is shown in Figure 4-9.

4.4. Results of the Flooring Tests

Partway through the school year, the EcoPure flooring, which was located at one of the entranceways, was lifting up from the concrete below around the perimeter. The installer replaced the VCT surrounding it and injected additional adhesive between the concrete and the Eco Pure around the perimeter.

At the end of the monthly inspections of the coatings and alternative flooring, the Optima IQ had several scratches and the Centiva Contour flooring had one scratch. The Optima IQ was positioned at one of the busiest entrances and the Centiva Contour flooring was in the main hallway in another school where trucks made routine deliveries. All of the other flooring was in good shape. The staff at the school where the Centiva Contour flooring was installed in the hallway liked the flooring and wanted to have it installed throughout the school. The staff at the school where the Mondo was installed in a multipurpose room liked the flooring and thought it looked very good.

Figure 4-1. Workers Installing Optima IQ Flooring.

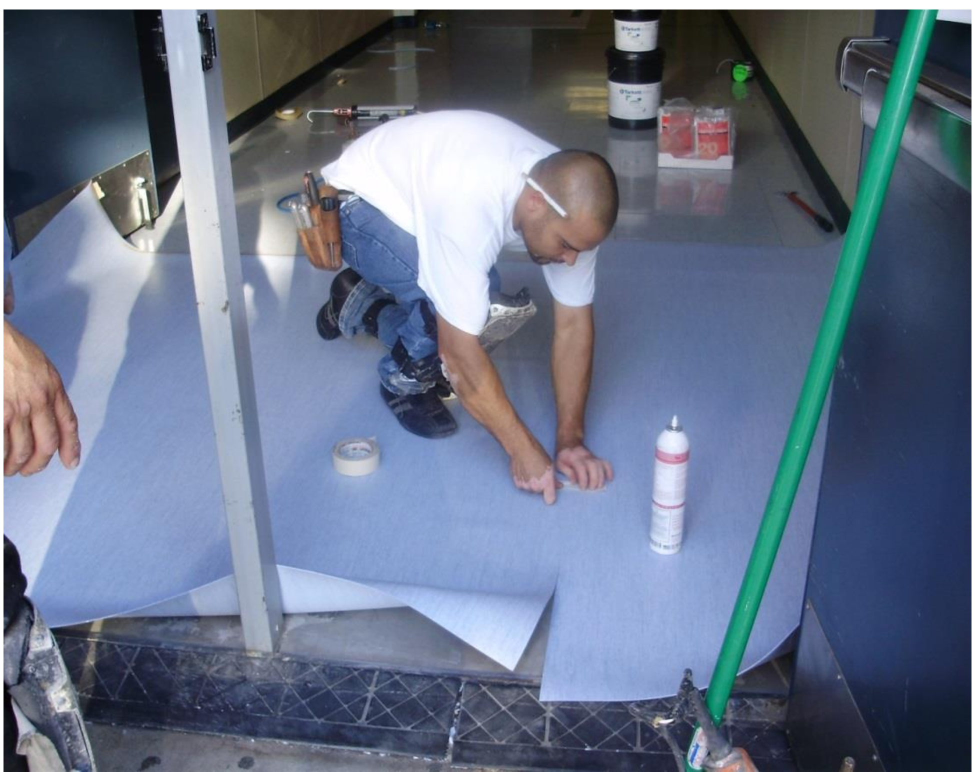

Figure 4-2. Another View of Workers Installing Optima IQ Flooring


Figure 4-3. Workers Installing EcoPure Flooring


Figure 4-4. EcoPure Flooring after Installation

Figure 4-5. Workers Installing Omni Sports Flooring

Figure 4-6. Omni Sports Flooring after Installation

Figure 4-7. Centiva Countour Flooring after Installation

Figure 4-8. Mondo Flooring after Installation

Figure 4-9. Centiva Mineral Chip Flooring Evaluated in Cost Analysis

V. Cost Analysis

5.1. Cost Analysis Scenarios

A project aim was to evaluate and compare the cost of using the VCT flooring found in nearly all schools and public buildings today with the cost of implementing alternative strategies for reducing or eliminating the use of toxic high VOC floor wax strippers used today. This section summarizes the cost analysis for four scenarios. These include:

- Estimated cost of using safer alternative strippers compared with using current strippers
- Continued use of VCT with routine waxing and stripping
- Application of coatings to VCT so no waxing or stripping is required
- Installation of alternative flooring in place of VCT so no waxing or stripping is required

The cost analysis for each scenario is described below. For the first scenario, IRTA analyzed and compared the cost of strippers used today with the cost of the two alternative strippers tested during the project. In the case of the last two scenarios, the cost of continued use of VCT is used as a baseline and the costs of implementing the strategies are compared with the baseline and with each of the other options.

5.2. Safer Alternative Wax Stripper Cost Analysis

5.2.1. Background

There are two types of wax strippers on the market today. The first type is conventional strippers which have been used for many years and are still widely used today. Conventional strippers, are generally highly alkaline strippers. They often contain amines, most commonly monoethanolamine. Very recently, some suppliers are starting to substitute other amines including 2-methyl-2-amino propanol (AMP) for monoethanolamine. The reason AMP is starting to be used more widely is that it has been deemed exempt from VOC regulations by EPA (see discussion in section VI). Often a glycol ether, 2-butoxy ethanol, is the solvent used in these conventional strippers. The second type of stripper, a so-called “green” stripper, generally also contains MEA or it may contain AMP. The pH of these strippers is lower than the pH of conventional strippers, generally less than 11.5. The green strippers may contain benzyl alcohol and/or glycol ethers other than 2-butoxy ethanol.

5.2.2. Cost Analysis

IRTA investigated the cost of these two different types of strippers. In doing this, it is necessary to take into account the dilution rate which can vary among strippers so the cost of using the strippers at their as-applied concentration can be compared. IRTA obtained the cost of the two alternative strippers tested during this project from a supplier. The strippers are not sold commercially so it was important to estimate a likely commercial price for these two strippers taking into account the raw materials cost and the markup for the profit to the blender and supplier. This price could then be compared with the price of the conventional strippers.

5.2.3. Alternative Stripper Price

During the project, IRTA worked with two formulators to develop safer alternative strippers as described in Section II. Both strippers contain no amines and have zero VOC content under the CARB regulations. One of the alternatives is solvent-free and the other contains solvent. The cost of the raw materials and blending for the solvent-free alternative stripper is $5.54 per gallon; the cost of the raw materials and blending for the solvent based stripper would be higher, at $8.41 per gallon. These costs are based on the premise that the stripper would be sold in individual one gallon containers or in a four one gallon container package. This is how most strippers are sold today to schools and public buildings.

Suppliers generally mark up the cost of the raw materials and blending by a factor 1.3 to 2. Assuming a markup of 30%, the supplier would charge $7.20 per gallon for the solvent-free stripper and $10.93 per gallon for the solvent based stripper. Assuming the higher markup of 2 times, the supplier would charge $11.08 per gallon for the solvent-free product and $16.82 per gallon for the product containing solvent.

During the project, IRTA obtained general industry cost information from a knowledgeable source who had been in the industry for more than 30 years. He indicated that the price range to the user for non-green strippers is $14 to $20 per gallon. The price for the green strippers is higher, ranging from $18 to $25. The price the supplier would charge for the solvent-free product even with a markup of a factor of 2 is well below the lower limit for green strippers. The price the supplier would charge for the alternative product containing solvent with a factor of 2 markup is also lower than the range for the price of green strippers. The price of the solvent-free product with a markup by a factor of 2 is even well below the lower limit of non-green strippers. The price of the alternative product with solvent with a markup of 2 is in the middle of the range of prices for the non-green strippers.

As discussed earlier, Riverside USD currently uses a stripper called Bombers which is not a green stripper. The dilution recommended for this stripper is one part stripper to six parts water for extreme buildup and one part stripper to ten parts water for heavy buildup. The recommendation for normal stripping is one part stripper to 10 parts water. Because virtually all schools and public buildings have reduced their stripping frequency, the buildup of wax is generally three to seven coats which would be considered heavy or extreme buildup. Riverside USD pays $21 per gallon for Bombers but dilutes it less than recommended. The dilution the staff uses is four parts water to one part stripper. When IRTA and the supplier tested the two alternative strippers with Riverside USD, the dilution that was used was also four parts water to one part stripper. If the supplier of the alternative strippers prices the strippers with a 1.3 to a 2.0 markup, the price of both alternative strippers would lower than the price Riverside USD is paying for Bombers, a non-green stripper.

At San Francisco City Hall, the maintenance staff uses a green stripper, Clair 316. The dilution rate they use is unknown. Clair recommends that the dilution rate of the 316 stripper should range from four parts water to one part stripper and six parts water to one part stripper. As discussed earlier, users often use a higher concentration than recommended in practice. When IRTA tested with City Hall, a dilution rate of four parts water to one part stripper was used for the two alternative strippers.

For purposes of analysis, IRTA assumed that the dilution of all the strippers would be the same. As discussed earlier, Riverside uses at four parts water to one part stripper dilution and the other facilities make judgements about what concentration to use from their experience. There is no way to accurately determine the dilution levels used by the population of schools and public buildings. As a consequence, IRTA simply compared the price of one gallon quantities of strippers in the analysis.

Table 5-1 shows a comparison of the prices of the alternative strippers assuming different markups. It shows a comparison with the price paid by Riverside USD for the Bombers non-green stripper and the price paid by San Francisco City Hall for Claire 316, a green stripper. The results of the cost analysis indicate that if the supplier priced the two alternative strippers with a very high markup of 2.0, their price would still be below the price range for other green strippers on the market today. Even at the higher markup, the nonsolvent alternative stripper would be priced far below the price range for non-green strippers. The solvent containing alternative stripper would be priced in the mid-range of the current price range for non-green strippers. The bottom line is that the two alternative strippers would be lower in price than other similar strippers on the market today.

Table 5-1
Price Comparison for Alternative Strippers and Currently Used Strippers

Stripper	Materials/Blending Price Per Gallon	1.3 Markup Price Per Gallon	2.0 Markup Price Per Gallon	Market Price Per Gallon
Alternative III-14C (solvent-free)	$5.54	$7.20	$11.08	$7.20 to $11.08
Alternative III-14A (with solvent)	$8.41	$10.93	$16.82	$10.93 to $16.82
Bombers Industrial Strength Stripper	NA	NA	NA	$21.00
Clair 316 Stripper	NA	NA	NA	$25.00
Typical non-green strippers	NA	NA	NA	$14 to $20
Typical green strippers	NA	NA	NA	$18 to $25

NA is not applicable

5.3. VCT Baseline Cost Analysis

5.3.1. Background

VCT is often installed in schools and public buildings reportedly because of its low initial cost. Architects specify it when they are planning the building and even if another type of flooring is specified, it is often changed because of cost overruns when the buildings are being constructed.

The warranty life of flooring is generally established by the manufacturer. It is often a lower bound for the length of time the flooring lasts. The manufacturers, understandably, are conservative in setting this life because they want to minimize their liability costs for failures. For VCT, the warranty life is five years. Most VCT is not replaced for 10 to 15 years, however, and in some cases, users keep the flooring for more than 20 years.

There are an estimated 10,000 schools in California. A typical elementary school has 30 classrooms, a junior high has 40 rooms and a high school has 50 or more rooms. A typical classroom has about 960 square feet and most classrooms in California currently have VCT flooring. Most school hallways also typically have VCT flooring. As discussed earlier, a considerable amount of maintenance is required to keep up the glossy appearance of the VCT and this maintenance involves frequent waxing and stripping.

5.3.2. Cost Analysis

IRTA's approach to the baseline cost analysis for the VCT was to evaluate the installation and operating costs associated with this type of flooring. The assumptions used for the cost analysis are described below.

5.3.2.1. Installation Cost

VCT is generally installed either over concrete or over wood. Permanent school structures are generally built with concrete flooring; portable structures, which are often used for many years, are generally built with wood flooring.

Suppliers of VCT indicate that the materials and installation cost for VCT over concrete or wood amounts to \$2.35 per square foot. This includes a freight charge of \$0.10 per square foot and a tax of 10%. After taking into account the tax and freight charges, the cost of installation is \$2.04 per square foot. The materials cost amounts to \$0.62 per square foot. The balance and majority of the cost is the labor cost; it amounts to \$1.42. Of the total cost of \$2.04 per square foot, labor accounts for 70% of the cost and materials account for 30%.

The cost of \$2.35 per square foot installed described above does not include a surface preparation cost for the floor. For both new and replacement cases, there is an additional cost of \$0.35 per square foot for preparing the surface. This can involve leveling the floor, scraping and cleaning the surface and patching it with filler to provide an even surface. This cost is almost exclusively a labor cost. There is an additional cost for demolition of the old flooring in the case where new VCT is replacing old VCT. This cost amounts to \$1.25 per square foot. For new VCT, the total cost of installed flooring is \$2.70 per square foot. In the case where old flooring is removed and demolition is required, the total installed cost is \$3.95 per square foot.

The materials component of the installation cost can be discounted for a purchase of 30,000 square feet or more. A large purchase is one where the material cost is between about \$50,000 and \$75,000. Depending on how large the purchase, the materials cost can be discounted by up to 30%. IRTA did not include a discount in the analysis but it is important to note it is available.

The installation cost also needs to include the cost of the initial floor finish. When the VCT is first installed, it is raw and contains no finish whatsoever. A floor finish must be applied before the floor is used. VCT manufacturers, as part of the warranty, require the floor to be stripped to remove any residue of a mold release agent used in the VCT manufacturing process, three coats of wax, a high speed burnish of the floor and two additional coats of wax, called a scratch or sacrificial coat.

5.3.2.2.Operating/Maintenance Cost

IRTA used information from Riverside USD and a flooring supplier to estimate the maintenance costs of the VCT. Some of the schools and public buildings have reduced their maintenance activities in recent years to minimize labor costs. Some schools no longer do certain types of the maintenance procedures described below and some may continue to do them, but less often. IRTA has included all of the maintenance activities that are required in the instructions for maintaining VCT flooring in the discussion, but, in some cases, has assumed they are conducted with less frequency than suggested.

The maintenance staff dust mops all the floors daily and it requires about five minutes to dust mop 1,000 square feet of VCT. Every other day, the maintenance staff wet mops the floor and it requires seven minutes per 1,000 square feet. A multipurpose cleaner is used during the wet mop process and about one gallon of liquid is used for 1,000 square feet. The cleaner cost is about $14 per gallon and one ounce is used per 64 ounces of water.

Every six months, the VCT is burnished. This process requires use of a natural hog hair pad run at 2,500 rpm. The high speed heats up the floor finish and the burning of the top coat gives the floor a gloss. One pad is used to burnish 5,000 square feet. The cost of five pads is $50. The burnishing process requires one worker and it takes about 15 minutes to burnish 1,000 square feet. About 12 ounces of burnishing formulation are required for each 1,000 square feet and the cost of the burnishing liquid is $60 for a five gallon pail.

The maintenance staff strips the floor, rinses it and applies wax every seven months. It requires three workers working for four hours each to strip 1,000 square feet of VCT. Two gallons of stripper and four gallons of rinse water are used to strip 1,000 square feet. The cost of the stripper is $105 per five gallon pail. Hi-pro pads are used in the floor machine to strip the wax. One pad is used to strip 1,000 square feet. The cost of five pads is $45.

After stripping, a sealer and three coats of wax are applied to the floor. The first coat, the sealer coat, is used to seal the pores of the VCT. About one-half gallon of this coating is required per 1,000 square feet. The cost of the sealer is $89 per five gallon pail. The maintenance people then apply three coats of wax. For each coat of wax, 32 ounces cover 1,000 square feet so a total of 96 ounces are used to cover 1,000 square feet. The cost of the wax is $85 per five gallon pail. It requires 20 minutes to apply the sealer and 20 minutes to apply each coat of wax. The staff must wait 20 minutes for the sealer and each coat of wax to dry before they apply the next coat. This adds an additional hour to the maintenance time.

The maintenance staff top scrubs the floor twice between stripping events. During a top scrub, the wax is removed with a neutral mild detergent but the sealer is not. The cost of the detergent is $18 per gallon and eight ounces are used per gallon of water. For 1,000 square feet, 40 ounces of the detergent would be required in five gallons of water. The surface preparation pads used for the top scrub are $90 for 10 pads and one half of a pad is used to top scrub 1,000 square feet. As was the case for the full stripping, four gallons of rinse water are required for every 1,000 square feet for rinsing.

Two coats of wax are then applied. The same wax used in the stripping process above is used for the top scrub. The cost of the wax is $85 per five gallon container and 32 ounces per coat are used per 1,000 square feet. The two coats of wax require 64 ounces of the wax per 1,000 square feet. The top scrub process requires three workers for 45 minutes each. The workers must wait an additional 20 minutes for each of the coats of wax to dry so the total labor hours are 85 minutes for each of the three workers.

Riverside USD indicates they have a labor rate of about $29 per hour. This is a burdened labor rate which includes benefits. IRTA assumed this labor rate would be representative of maintenance staff labor rates for other schools and public buildings and used it for the analysis.

5.3.2.3. Case Study Cost Analysis

IRTA analyzed the cost of using VCT for 10 classrooms in a school. A typical classroom has 960 square feet so 10 classrooms would have a surface area of 9,600 square feet. Assuming a cost of $2.70 per square foot which includes materials and installation for new flooring and surface preparation, the total cost of installing VCT in 10 classrooms is $25,920. To replace old VCT, the cost per square foot is higher, at $3.95 per square foot because the old flooring needs to be removed. For this case, the total cost of replacing VCT with new

VCT flooring for 10 classrooms amounts to $39,360. Assuming the school will finance the cost over the five-year life of the flooring and assuming a cost of capital of 4%, the annualized capital cost for putting in new VCT is $5,391. The annualized cost of replacing old VCT with new VCT is $7.887.

The maintenance staff spends five minutes per day dust mopping each 1,000 square feet. Assuming the staff mops 260 days per year and a burdened labor rate of $29 per hour, the labor cost for dust mopping amounts to $6,032 annually.

The staff wet mops the floor every other day and it requires seven minutes per 1,000 square feet. Assuming the staff mops 130 days per year and the same labor rate, the labor cost of wet mopping is $4,222 annually. The cost of the cleaner used for the wet mopping process is about $14 per gallon. The cleaner is diluted one ounce to 64 ounces of water or two ounces per gallon of cleaner. One gallon is used for 1,000 square feet so 9.6 gallons containing 19.2 ounces of cleaner is used every other day. Over a year, again assuming wet mopping is done 130 times during the year, the amount of cleaner used is 19.5 gallons at a cost of $273. About 1,229 gallons of water are used in the process.

The floors are burnished twice a year and the activity requires one worker for 15 minutes for each 1,000 square feet. The annual labor cost is $139. The cost of each burnishing pad is $10 and it is used for 5,000 square feet. On this basis, the annual cost of the pads is about $38. The cost of the burnishing liquid is $12 per gallon and 12 ounces are used per 1,000 square feet. The annual cost of this liquid is about $22.

The floors are stripped every seven months. Twelve labor-hours are required for the stripping job per 1,000 square feet. For 9,600 square feet, about 115 hours are required at a labor cost of $3,341 or an annual cost of $5,727. Two gallons of stripper at a cost of $21 per gallon are used to strip 1,000 square feet. On this basis, the stripper cost for each stripping job is about $403 and the annual cost is $691. The cost of each abrasive stripping pad is $9 and one pad is used for 1,000 square feet. Taking this into account, the annual cost of the stripping pads is $148. The amount of water used for diluting the stripper is 132 gallons per year and the amount used for rinsing is about 66 gallons per year. Total water usage for 9,600 square feet is 198 gallons.

After stripping the floor, the maintenance staff applies one coat of sealer and three coats of wax. It requires 20 minutes per 1,000 square feet for the three workers to apply each coat for a total of four hours. An additional 20 minutes is spent for dry time between each coat which requires three additional hours. The annual labor cost for this activity amounts to $348. For 9,600 square feet, the annual labor cost is $3,341. The cost of one-half gallon of the sealer coat is $8.90 per stripping job per 1,000 square feet or about $146 per year. The annual cost of the three coats of wax for the 9,600 square feet is $210.

There are two top scrub processes between stripping jobs. The labor requirement is three people for 85 minutes each twice per seven-month period per 1,000 square feet. This amounts to an annual labor cost of $4,057. The pads used for top scrubbing are $9 per pad and half a pad is used each time per 1,000 square feet. On this basis, the annual cost of the pads is $148. The cost of the neutral cleaner used in the process is $185 annually. The cost of the wax is $85 per five gallons or $17 per gallon. Thirty-two ounces are used for each coat of wax for 1,000 square feet. The total cost of the wax is about $280 annually. Four gallons of water are used for rinsing per 1,000 square feet for an annual rinse water use of 132 gallons. The dilution water used in the neutral cleaner is 165 gallons per year. The total water use for the top scrub process is 297 gallons annually.

Per the warranty, the installation needs to include the cost of the initial floor finish which is a one-time cost. This initial floor finish involves stripping the mold release from the floor, applying a sealer and three coats of wax, burnishing the floor and then applying two additional coats of wax, which is called a scratch coat. IRTA assumed that the maintenance staff would conduct this operation. As discussed for operating and maintenance costs above, the cost for one stripping job and wax application, taking into account labor and materials, is $5,987. The cost to burnish the floor is $100, taking into account the labor and materials. Finally, two additional coats of wax, the scratch coat, are required. This requires three workers for one hour each per 1,000 square feet for a labor cost of $835 and a materials cost of $82; the total cost is $917. The total cost of the installation operation is $7,004. This cost is part of the capital cost of the installation and it needs to be amortized over the life of the flooring. Assuming a warranty life for VCT of five years and a 4% cost of capital, the contribution to the annualized capital cost is $1,457.

Table 5-2 summarizes the annualized capital and operating cost of using VCT for 9,600 square feet or 10 classrooms. The capital cost for a new installation accounts for 21% of the total annualized cost; the capital cost for a replacement installation accounts for somewhat more, 27% of the total annualized cost. In terms of the annual operating cost, the labor cost dominates and accounts for 92% of the total operating cost.

Table 5-2
Annualized Cost of Using VCT Flooring

Cost Category	New Installation	Replacement Installation
Capital cost	$6,848	$9,344
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4.222
-materials	$273	$273
Burnishing cost-labor	$139	$139
-materials	$60	$60
Stripping cost-labor	$9,068	$9,068
-materials	$1,195	$1,195
Top scrub cost-labor	$4,057	$4,057
, -materials	$613	$613
Total labor cost	$23,518	$23,518
Total materials cost	$2,141	$2,141
Total cost	$32,507	$35,003

5.3.2.4. Case Study Water Usage

There has been increasing concern about water usage, particularly in California in recent years because of the drought. The amount of water used annually in the maintenance processes is 1,724 gallons for 9,600 square feet. Water usage per square foot amounts to 0.18 gallons. Most of the use is a result of the wet mopping process. In an average household, one person uses about 100 gallons of water per day. The water usage for maintaining 9,600 square feet of VCT annually is equivalent to the water used by 17 people per day. Compared with other industrial processes, like plating, which requires 25,000 gallons per day for a typical facility, the water usage for flooring maintenance is small.

5.4.Cost Analysis for Coatings Over VCT

5.4.1. Background

VCT, as discussed above, requires routine waxing and stripping throughout its life. It requires wax to maintain its shine. There are many types of alternative flooring that schools and public buildings can use that do not require any waxing or stripping. Schools and public buildings may not be able to invest in alternative flooring, however, so another option is to apply a coating on top of the VCT and the coatings, like the alternative flooring, do not require waxing and stripping. As discussed earlier, IRTA tested three types of alternative coatings for the VCT with Riverside USD over a school year. These included a vinyl seal, a polyurethane coating and a UV cured urethane acrylic coating. The application and maintenance costs for each of the coatings are discussed below.

Virtually all schools and public buildings have the coating supplier/contractor prepare the VCT and apply the coatings to the floors. It is a fairly complex process and the contractors are skilled at the tasks. The coating suppliers/contractors charge a specific rate for the coating application on a per square foot basis. For more expensive coatings, the per square foot installation cost is higher. IRTA assumed these rates for the installation costs for each of the three coatings discussed below. In the case of one of the coatings, the vinyl seal, a detailed breakdown and reconciliation of the labor and materials costs for each of the steps in the preparation and application process is provided in Appendix C.

5.4.2. Vinyl Seal

5.4.2.1. Preparation and Application Costs

If the VCT is old, the contractor preparation process involves stripping the floor, sometimes up to three times, to remove the wax buildup. The contractor applies three coats of wax and then buffs the floor. If the VCT is newer and in good shape, all that is necessary is to scrub the floor and buff it. The cost charged by the contractor for preparation and coating application when the VCT is old is $1.60 per square foot. The cost charged by the contractor if the stripping step is unnecessary is $0.99 per square foot. A reconciliation of the cost of the preparation and application cost of $1.60 per square foot for the vinyl seal coating is shown in Appendix C. This information demonstrates how the flooring company derives the per square foot cost of applying coatings.

5.4.2.2. Maintenance Costs

The coating supplier indicates that an acceptable maintenance regime is to dry or wet mop every day and to perform a weekly cleaning with a neutral cleaner containing no acids. Once a month, the floor should be auto scrubbed and it should be burnished periodically. For purposes of analysis, IRTA used the costs from the dry and wet mopping procedure used by Riverside USD and also assumed the costs for burnishing the vinyl seal twice a year.

5.4.2.3. Case Study Cost Analysis

The case study for the vinyl seal is the same as for the VCT. It assumes that the coating will be applied over 9,600 square feet of VCT or the equivalent of 10 classrooms. For one case, it was assumed that the vinyl seal warranty life is one year and that the coating must be reapplied each year. Thus, the cost of the installation was treated as an annual operating cost rather than a capital cost. For another case, it was assumed that the vinyl seal warranty life is 18 months and that the coating must be reapplied every 18 months. The application cost, in this case was amortized over 18 months and was treated as a capital cost.

The contractor charges $1.60 per square foot for preparation of old VCT and application of the vinyl seal. On this basis, the total cost of applying the coating to 9,600 square feet amounts to $15,360. The contractor charges slightly less, $0.99 per square foot, if the VCT is new. The total cost for preparation and application for new VCT is $9,504. These are the annual costs assuming a one year warranty life. If an 18-month warranty life is assumed, the annualized cost of applying the coating to old VCT is $10,650 and the annualized cost of applying it to new VCT us $6,589.

IRTA assumed that Riverside USD would perform the regular maintenance on the floors. The labor cost of dust mopping each day is $6,032 annually for 9,600 square feet. The cost of wet mopping every other day is $4,222 for the labor and $273 for the materials annually. The cost of burnishing is $139 for labor and $60 for materials annually. No additional maintenance is required since waxing and stripping are not necessary for this coating.

The total cost of using a vinyl seal on top of the VCT using a warranty life of one year is shown in Table 5-3. Table 5-4 presents similar results, this time assuming a warranty life of 18 months. In each case, the table presents results of applying the coating over old VCT and new VCT.

Table 5-3
Annual Cost of Using Vinyl Seal Coating with One-Year Life

Cost Category	Old VCT (Includes Stripping)	New VCT (Stripping Not Included)
Preparation/application cost	$15,360	$9,504
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
-materials	$273	$273
Burnishing cost-labor	$139	$139
-materials	$60	$60
Total labor cost	$10,393	$10,393
Total material cost	$333	$333
Total cost	$26,086	$20,230

Table 5-4
Annual Cost of Using Vinyl Seal Coating with 18-Month Life

Cost Category	Old VCT (Includes Stripping)	New VCT (Stripping Not Included)
Preparation/application cost	$10,650	$6,589
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
-materials	$273	$273
Burnishing cost-labor	$139	$139
-materials	$60	$60
Total labor cost	$10,393	$10,393
Total material cost	$333	$333
Total cost	$21,376	$17,315

One more case that needs to be included is applying the vinyl seal over a vinyl seal coating already on the VCT. When the old vinyl seal is wearing away, new coats of vinyl seal can be applied over it. In this case, the vinyl seal is cleaned by the contractor using an autoscrubber and neutral cleaner. Then two new coats of vinyl seal are applied. The cost of the cleaning and reapplication of the coating is $0.78 per square foot. For the 9,600 square foot example, the cost of reapplying the vinyl seal is $7,470. If the life of the reapplied coating is 12 months, the annual preparation/application cost is $7,470; if the life is 18 months, the annualized cost is $5,179.

Table 5-5 shows the cost of reapplying the vinyl seal coating over another vinyl seal coating with a 12 month and 18 month life. The cost of this option once the vinyl seal has been applied is lower than the costs shown in Tables 5-2 and 5-3. This follows from the fact that the preparation work, in this case, does not involve stripping the floor.

Table 5-5
Annual Cost of Using Vinyl Seal Coating over Vinyl Seal Coating

Cost Category	12-Month Coating Life	18-Month Coating Life
Preparation/application cost	$7,470	$5,179
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
-materials	$273	$273
Burnishing cost-labor	$139	$139
-materials	$60	$60
Total labor cost	$10,393	$10,393
Total material cost	$333	$333
Total cost	$18,196	$15,9050

5.4.2.4. Comparison of Vinyl Seal Costs and VCT Baseline Cost

Table 5-2 shows that the annualized cost of using newly installed VCT or using replacement VCT is $32,507 or $35,003 respectively. The values of Table 5-3, where the life of the vinyl seal is one year, indicate that the cost of using a vinyl seal over old VCT is 20% less than the cost of continuing to use newly installed VCT and is 38% lower than the cost of continuing to use VCT replacement flooring. The cost of using the vinyl seal over new VCT is 25% and 42% lower than the cost of continuing to use newly installed VCT or replacement VCT respectively.

The values of Table 5-4 where the life of the vinyl seal is 18 months show that the cost of using a vinyl seal over old VCT is 34% lower than the cost of continuing to use newly installed VCT and is 47% lower than the cost of continuing to use VCT replacement flooring. The cost of using the vinyl seal over new VCT is 39% and 51% lower than the cost of continuing to use newly installed VCT or replacement VCT respectively.

Comparing the values of Table 5-2 and 5-5, there is more of a cost advantage of applying the vinyl seal over existing vinyl seal in subsequent years. If the vinyl seal has a life of one year, it is 44% less costly to reapply vinyl seal over new VCT; if the vinyl seal has a life of 18 months, it is 51% less costly to reapply the vinyl seal. For the same two scenarios over replacement VCT, the savings in reapplying the vinyl seal are 48% and 55% respectively.

5.4.3. Polyurethane Coating

5.4.3.1. Preparation and Application Cost

In the case of the polyurethane coating, both new and old VCT must first be stripped with an alkaline stripping formulation. As was the case for the vinyl seal, the floor may need to be stripped up to three times. The floor is then neutralized with an acid, rinsed and tacked. Tacking involves using a tacky cloth towel to sweep the floor; it picks up the lint, dust and hair and leaves a particle free surface. Once the floor is prepared, the supplier/contractor applies one coat of the polyurethane coating. In this case, full gallons of the coating must be used since the coating cannot be reused once it is opened. The cost charged by the supplier for preparing the floor and applying the coating is $2.50 per square foot.

5.4.3.2. Maintenance Costs

The coating supplier indicates that the maintenance in the case of the polyurethane coating includes the dry mopping and the wet mopping procedures. The polyurethane coating, in contrast to the vinyl seal, should not be burnished.

5.4.3.3. Case Study Cost Analysis

The case study for the polyurethane coating is the same as for the VCT and the vinyl seal. It assumes that the coating will be applied over 9,600 square feet of VCT or the equivalent of 10 classrooms. The supplier indicates the coating has a warranty life of two to three years. The cost of the preparation and application is treated as a capital cost and it is amortized over two years or over three years for the two cases IRTA considered.

The contractor charges $2.50 per square foot for preparation of the VCT and application of the polyurethane coating. On this basis, the total cost of applying the coating to 9,600 square feet amounts to $24,000. Amortizing the cost over two years and assuming a cost of capital of 4%, the annualized cost for the preparation and application is $12,480. Amortizing the cost over three years leads to an annualized cost of $8,320.

Again, it was assumed that Riverside USD would perform the regular maintenance on the floors. The labor cost of dust mopping each day is $6,032 annually for 9,600 square feet. The cost of wet mopping every other day is $4,222 for the labor and $273 for the materials annually. In this case, unlike the vinyl seal, the coating does not need to be burnished. No additional maintenance is required since waxing and stripping are not required for this coating.

The total cost of using a polyurethane coating on top of the VCT is shown in Table 5-6. Because the preparation cost is the same for either new or old VCT in this case, there is only one scenario with two different warranty lives presented.

One additional case for the polyurethane coating needs to be considered. Like the vinyl seal, the polyurethane coating can be reapplied over itself when it is wearing down. The supplier indicates the cost for cleaning and reapplying one coat of polyurethane amounts to $1.60 per square foot. Table 5-7 shows the annual cost of recoating for the polyurethane coating assuming a life of two years and a life of three years for the coating.

Table 5-6
Annual Cost of Using Polyurethane Coating

Cost Category	Cost Assuming Two Year Life	Cost Assuming Three Year Life
Preparation/application cost	$12,480	$8,320
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
-materials	$273	$273
Total labor cost	$10,254	$10,254
Total materials cost	$273	$273
Total cost	$23,007	$18,847

Table 5-7
Annual Cost of Using Polyurethane Coating over Polyurethane Coating

Cost Category	Cost Assuming Two Year Life	Cost Assuming Three Year Life
Preparation/application cost	$7,987	$5,325
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
-materials	$273	$273
Total labor cost	$10,254	$10,254
Total materials cost	$273	$273
Total cost	$18,514	$15,852

5.4.3.4. Comparison of Polyurethane Coating Costs and VCT Baseline Cost

The values of Table 5-6 can be compared with those of Table 5-2 for the VCT. The data indicate that the annual cost of using the polyurethane coating is 29% lower than the cost of installing new VCT when the coating has a life of two years. It is 42% lower than the cost of installing new VCT when the coating has a life of three years. The same values for the replacement installation of VCT are 34% and 46% if the coating has a life of two or three years respectively.

The values of Table 5-2 can also be compared with the values of Table 5-7. They show that the cost of using the polyurethane coating over another polyurethane coating is 43% lower than the cost of using VCT in a new installation when the coating has a life of two years. When the coating has a life of three years, it is 51%. The same values compared with a replacement VCT installation are 45% and 55% respectively.

5.4.4. UV Cured Urethane Acrylic Coating

5.4.4.1. Preparation and Application Cost

The preparation of the VCT for applying the UV cured urethane acrylic coating is the same as the preparation of the VCT for applying the polyurethane coating. This indicates that both new and old VCT must first be stripped with an alkaline stripping formulation. The floor is then neutralized with an acid, rinsed and tacked. Once the floor is prepared, the supplier/contractor applies one coat of the UV coating. It requires more time to apply the UV coating than it does to apply the polyurethane coating. Two people are needed to handle the equipment so nothing drags into the wet coating. In this case, the coating must be rolled out thinner than for the polyurethane coating. It must then be back rolled several times. The coating is cured by moving a floor machine with UV lights on the bottom over it. The cost charged by the supplier for preparing the floor and applying the coating is higher than it is for the polyurethane coating, at $3.00 per square foot.

5.4.4.2. Maintenance Costs

The coating supplier indicates that the maintenance for the UV cured urethane acrylic coating is the dry mopping and the wet mopping procedures, the same as for the polyurethane coating.

5.4.4.3. Case Study Cost Analysis

The case study for the UV coating is the same as for the other types of coatings. It assumes that the coating will be applied over 9,600 square feet of VCT or the equivalent of 10 classrooms. The supplier indicates the coating has a warranty life of three to five years in this case. For this case study, the coating would need to be applied and cured over half the floor and then applied and cured over the other half. The cost of the preparation and application is treated as a capital cost and it is amortized over three and five years.

The contractor charges $3.00 per square foot for preparation of the VCT and application of the UV cured coating. On this basis, the total cost of applying the coating to 9,600 square feet amounts to $28,800. Amortizing the cost over three years and assuming a cost of capital of 4%, the annualized cost for the preparation and application is $9,984. Amortizing the cost over five years and making the same assumption for the cost of capital, the annualized cost is $5,990.

Assuming Riverside USD performs the regular maintenance on the floors, the labor cost of dust mopping each day is $6,032 annually for 9,600 square feet. The cost of wet mopping every other day is $4,222 for the labor and $273 for the materials annually. No additional maintenance is required since waxing and stripping are not required for this coating.

The total cost of using a UV cured coating on top of the VCT is shown in Table 5-8 for a three-year and a five-year warranty life. Because the preparation cost is the same for either new or old VCT in this case, there is only one scenario with the two warranty lives.

Table 5-8
Annual Cost of Using UV Cured Coating

Cost Category	Cost Assuming Three-Year Life	Cost Assuming Five-Year Life
Preparation/application cost	$9,984	$5,990
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
materials	$273	$273
Total labor cost	$10,254	$10,254
Total materials cost	$273	$273
Total cost	$20,511	$16,517

An additional case for the UV cured coating needs to be considered. Like the vinyl seal and the polyurethane coatings, the UV cured coating can be reapplied over itself. The supplier indicates the cost for cleaning and reapplying one coat of UV coating amounts to $2.10 per square foot instead of the new application cost of $3.00 per square foot. Table 5-9 shows the annual cost of recoating for the UV coating assuming a life of three years and a life of five years for the coating.

Table 5-9
Annual Cost of Using UV Cured Coating Over UV Cured Coating

Cost Category	Cost Assuming Three Year Life	Cost Assuming Five Year Life
Preparation/application cost	$6,989	$4,193
Dust mop cost-labor	$6,032	$6,032
Wet mop cost-labor	$4,222	$4,222
materials	$273	$273
Total labor cost	$10,254	$10,254
Total materials cost	$273	$273
Total cost	$17,516	$14,720

<u>5.4.4.4. .Comparison of UV Cured Coating Costs and VCT Baseline Cost</u>

The values of Table 5-8 can be compared with those of Table 5-2 for the VCT. The data indicate that the cost of using the UV cured coating is 37% lower than the cost of installing new VCT when the coating has a life of three years. It is 49% lower than the cost of installing new VCT when the coating has a life of five years. The same values for the replacement installation of VCT are 41% and 53% if the coating has a life of three or five years respectively.

The values of Table 5-2 can also be compared with the values of Table 5-9. They show that the cost of using the UV cured coating over another UV cured coating is 46% lower than the cost of using VCT in a new installation when the coating has a life of three years. When the coating has a life of five years, it is 55%. The same values compared with a replacement VCT installation are 50% and 58% respectively.

<u>5.5. Cost Analysis for Alternative Flooring</u>

As part of this project as discussed earlier, IRTA arranged for installation of four different types of flooring in two schools in hallways at Riverside USD. These included:

- Optima IQ
- EcoPure
- Omni Sports
- Centiva Contour

In addition, Riverside USD had installed two other types of flooring. One of these, Powerbond, was installed in several locations throughout the school system and another type, Mondo, was installed in a multipurpose room in a Riverside USD school. One additional type of flooring was analyzed even though it was not installed at Riverside USD; this flooring is called Centiva Mineral Chip. IRTA developed cost information on these seven types of flooring for comparison to the cost of using VCT. The cost information on each of the flooring types is described below.

Floor preparation is always necessary if the flooring is new or if existing flooring is being replaced. The preparation includes sanding the existing flooring, scraping it and adding concrete patches if needed. If any of the alternative flooring types except Powerbond is being installed, the preparation cost is $0.35 per square foot. If Powerbond is being installed, the preparation cost is lower, at $0.19 per square foot. If the alternative flooring is replacing old flooring, there is a demolition/removal process. If the contractor is removing VCT or other types of resilient flooring to replace it with new resilient flooring, the cost for the demolition is $1.25 per square foot. If Powerbond is being removed so it can be replaced with new Powerbond, the cost is lower, at $0.40 per square foot.

The flooring can be installed once the surface preparation is complete. A layer of glue is put on the floor and the installers wait for the adhesive open time until it starts to tack. This will require 10 to 20 minutes. Then, for all the resilient flooring except Mondo, the flooring tiles are laid in small sections. Once the installation is complete, a 100 pound roller is pushed over the floor to ensure that the glue is contacted by the flooring. The floor can be cleaned within 24 to 72 hours, depending on the flooring type. The installation cost for the resilient flooring is estimated at $1.30 per square foot except for Mondo. The installation cost for the Powerbond is lower, at $0.67 per square foot.

The installation for the Mondo flooring takes longer. The tiles are laid out on the floor and dry fitted to the space to allow the natural rubber flooring to relax. After about a 24 hour period, the tiles are pulled up, adhesive is applied and the flooring is applied in rows starting at the back end of the room. The installation cost for the Mondo flooring is estimated at $1.70 per square foot.

Table 5-10 shows the seven different types of flooring, their materials, surface preparation and installation cost per square foot. The materials cost includes the cost of adhesive and freight. The contractor markup is included in these costs so it is the cost paid by the customer. The surface preparation cost is $0.35 per square foot all other flooring and $0.19 per square foot for Powerbond. If demolition and removal are needed, the additional cost for removing VCT or other resilient flooring and latex backed carpeting given above must be added. The total cost for each type of flooring is the sum of the materials, the surface preparation, and the installation cost.

Table 5-10
Materials and Installation Cost Per Square Foot for Alternative Flooring

Flooring Type	Materials Cost	Surface Prep Cost	Demolition Cost	Installation Cost	Total Cost No Demolition	Total Cost Demolition
Optima IQ	$3.52	$0.35	$1.25	$1.30	$5.17	$6.42
EcoPure	$4.85	$0.35	$1.25	$1.30	$6.50	$7.75
Omni Sports	$4.81	$0.35	$1.25	$1.30	$6.46	$7.71
Centiva Contour	$4.75	$0.35	$1.25	$1.30	$6.40	$7.65
Centiva Min Chip	$7.30	$0.35	$1.25	$1.30	$8.95	$10.20
Powerbond	$2.53	$0.19	$0.40	$0.67	$3.39	$3.79
Mondo	$7.25	$0.35	$1.25	$1.70	$9.30	$10.55

Table 5-11 shows the warranty life for each of the flooring types. Optima IQ has the shortest life and Powerbond has the longest life. The Centiva Contour and Centiva Mineral Chip flooring types also have relatively long lives.

Table 5-11
Warranty Life of Flooring Types

Flooring Type	Life (years)
Optima IQ	5
Ecopure (linoleum)	8
Omni Sports	15
Centiva Contour	20
Centiva Mineral Chip	20
Powerbond	30
Mondo	10

5.5.1. Case Study

The case study for the alternative flooring is the same as the case study for the coatings and VCT. It involves using each type of alternative flooring in 9,600 square feet in a school or public building. The preparation and Installation cost of the alternative flooring is a one-time only cost and the maintenance cost is an ongoing cost. These costs for each type of flooring are discussed below.

5.5.1.1. Installation/Preparation Cost

The up-front cost for installation and floor preparation must be amortized over the life of the flooring so it can be annualized. For each type of flooring, IRTA assumed the total cost in Table 5-10 and the warranty life in Table 5-11 in the analysis. IRTA also assumed a cost of capital of 4% which is likely to be high and therefore conservative. IRTA also considered two different cases, one where new flooring is being installed and one where demolition/removal of flooring is required.

As an example, the cost of purchasing the Optima IQ is $5.17 per square foot for the case where the flooring is new and $6.42 for the case of existing flooring where demolition is necessary. For 9,600 square feet, the cost for new flooring amounts to $49,632 and the cost for existing flooring is $61,632. The warranty life of the Optima IQ flooring is five years so the total costs must be amortized over five years. The annualized cost, assuming the 4% cost of capital, is $10,323 for the no demolition case and $12,819 for the case where demolition is required.

Table 5-12 summarizes the annualized installed costs for the two cases for Optima IQ and the other types of alternative flooring. The costs for the other types of alternative flooring were calculated in the same manner as described for the Optima IQ flooring above.

The annualized installation cost for the alternative flooring in Table 5-12 can be compared with the annualized installation cost for VCT in Table 5-2. From Table 5-2, the annualized installation cost of VCT for a new building is $6,484 and for a replacement, it is $8,980. Four of the alternative flooring types, Omni Sports, Centiva Contour, Centiva Mineral Chip and Powerbond, have a lower annualized installed cost than the VCT. This is of particular interest because of the argument that VCT is preferred over other types of flooring because of its lower up-front cost.

Table 5-12
Annualized Installed Costs for Flooring Types

Flooring Type	Annual Installed Cost No Demolition	Annual Installed Cost Demolition
Optima IQ	$10,323	$12,819
EcoPure	$8,112	$9,672
Omni Sports	$4,300	$5,132
Centiva Contour	$3,195	$3,819
Centiva Mineral Chip	$4,468	$5,092
Powerbond	$1,128	$1,261
Mondo	$9,285	$10,533

5.5.1.2. Maintenance Cost

No burnishing or waxing and stripping is required for any of the alternative types of flooring. IRTA assumed that the only maintenance that would be done on the alternative flooring is the dust mopping and wet mopping except for Powerbond. Thus, the labor and materials costs for all the flooring except Powerbond from Table 5-21 for dust and wet mopping are the ongoing maintenance costs. For dust mopping, the annual costs are exclusively a labor cost of $6,032. For wet mopping, the annual labor cost and materials cost are $4,222 and $273 respectively. It's worth noting that the materials cost for the maintenance is only 3% of the combined labor and materials cost for the maintenance which amounts to $10,527.

The Powerbond has a completely different maintenance regime. It involves vacuuming the floor every two to three days and deep cleaning the floor once a year. The deep cleaning involves spraying the floor with a neutral cleaner, agitating the floor and extracting the cleaner with hot water. On average, it requires about seven minutes to vacuum 1,000 square feet of Powerbond and the deep cleaning requires 35 to 40 minutes to treat 1,000 square feet. Assuming the Powerbond is vacuumed three times per week and using the Riverside USD labor rate of $29, the annual cost of vacuuming is $5,067. Assuming the deep cleaning requires 40 minutes, the labor cost is $186 annually. The deep cleaning requires six to eight ounces of cleaner per 1,000 square feet and the cost of the Riverside USD cleaner is $14 per gallon. On this basis, the materials cost of the deep cleaning is negligible. The total cost of maintaining the Powerbond is $5,253 annually and it is exclusively a labor cost.

5.5.1.3. Total Cost

The total annual cost of using each type of flooring is the sum of the annualized installed cost and the maintenance cost. Table 5-13 summarizes the total annual cost for the flooring types.

The values of Table 5-13 show that the lowest cost option, by far, is to use Powerbond. Indeed, many schools, particularly elementary schools and middle schools, use this flooring routinely in their classrooms. The highest cost option is the Optima IQ. Mondo and EcoPure also have relatively high costs and both types of flooring are natural products. The lowest cost resilient flooring is Centiva Contour. Centiva Mineral Chip and Omni Sports are also relatively low cost options.

Table 5-13
Total Annual Cost of Using Alternative Flooring

Flooring Type	Annual Cost No Demolition	Annual Cost Demolition
Optima IQ	$20,850	$23,346
EcoPure	$18,639	$20,199
Omni Sports	$14,827	$15,659
Centiva Contour	$13,722	$14,346
Centiva Mineral Chip	$14,995	$15,619
Powerbond	$6,381	$6,514
Mondo	$19,812	$21,060

5.5.1.4. Comparison of Alternative Flooring Costs to VCT Costs

The costs in Table 5-13 for using the alternative flooring can be compared with the costs of using VCT in Table 5-2. The cost of using the alternative flooring is 28% to 61%, lower than the cost of using VCT, depending on the scenario for all flooring types except Powerbond. The values demonstrate that the costs of using the alternative flooring types in all cases are lower than the cost of using the VCT. The major difference is the high cost of maintaining the VCT, specifically the requirement for waxing and stripping.

5.6. Cost Comparison of Case Study VCT Baseline and Alternatives

Table 5-14 shows the annual cost of using the VCT baseline flooring, the coatings applied to VCT flooring and the alternative flooring types. In the case of the VCT which serves as the baseline, there are two scenarios. The first is installing VCT in a new building and the second is replacing old VCT with new VCT. For the coatings, there are also two different scenarios. The first is where the coating is applied to VCT and the second is where the coating is reapplied over the existing coating. For the vinyl seal, two cases, one where it is applied over old VCT where floor stripping is necessary and the other over new VCT where stripping is not necessary, are shown. The polyurethane coating may have a life of two years or a life of three years. The UV cured urethane acrylic coating may have a life of three years or a life of five years. For each of the alternative flooring types, the different options are shown in the table.

The values of Table 5-14 show that the highest cost option is to use VCT, whether it is new or replacement flooring. The values also show that the lowest cost option is to use Powerbond. The Powerbond, however, does not serve as an across-the-board alternative for VCT, the coatings or the other types of flooring. Rather, it is often used in certain situations, like in classrooms in elementary schools, where the students sit on the floor. In cases where Powerbond is a good option, it could be used but there are many cases where it is not appropriate.

The lowest cost resilient flooring options are Centiva Contour, Omnisports and Centiva Mineral Chip which are all vinyl flooring. The UV cured coating when it is reapplied and has a five-year life is comparable in cost to using the three types of flooring. The cost of using the vinyl seal is a relatively high cost option but the cost of using the polyurethane and UV cured coating with the longer lifetimes are lower in cost than using some of the higher cost flooring options. The most costly flooring option is the Optima IQ followed by the Mondo. Ecopure is also a fairly high cost option. Mondo and Ecopure are both made of natural materials

Table 5-14
Annual Cost Comparison of VCT, Coatings and Alternative Flooring for Case Study

Flooring/Coating Type	Annual Cost of Using Alternative Option
VCT	
New	$32,507
Replacement	$35,003
Coatings	
Vinyl seal over VCT (12-month life)	$26,086 (over old VCT); $20,230 (over new VCT)
Vinyl seal over VCT (18-month life)	$21,376 (over old VCT); $17,315 (over new VCT)
Vinyl seal reapplication	$18,196 (12 month life); $15,905 (18 month life)
Polyurethane coating over VCT	$23,007 (two-year life); $18,847 (three-year life)
Polyurethane coating reapplication	$18,514 (two-year life); $15,852 (three-year life)
UV cured coating over VCT	$20,511 (three-year life); $16,517 (five-year life)
UV cured coating reapplication	$17,516 (three-year life); $14,720 (five-year life)
Alternative Flooring Types	
Optima IQ	$20,851 (no demolition); $23,346 (demolition)
EcoPure	$18,639 (no demolition); $20,199 (demolition)
Omni Sports	$14,827 (no demolition); $15,659 (demolition)
Centiva Contour	$13,722 (no demolition); $14,346 (demolition)
Centiva Mineral Chip	$14,995 (no demolition); $15,619 (demolition)
Powerbond	$6,381 (no demolition); $6,514 (demolition)
Mondo	$19,812 (no demolition); $21,060 (demolition)

and some school and public building decision makers may opt for these types of flooring in spite of the cost if they prefer natural materials.

5.7. Cost Comparison of VCT Baseline and Alternatives on a Per Square Foot Basis

The cost comparison presented in Table 5-14 is the comparison for the case study of 10 classrooms with 9,600 square feet. Table 5-15 presents the cost information on a per square foot basis. Using the figures in this table, a school or public building administrator can calculate the cost of using each of the options simply by multiplying by the square footage of the space in question. Again, the important point to note is that all of the alternative options are less costly to use over the life of the coating or flooring than continuing to use VCT with waxing and stripping.

Table 5-15
Annual Cost Comparison of VCT, Coatings and Alternative Flooring Per Square Foot

Flooring/Coating Type	Annual Cost of Using Alternative Option
VCT	
New	$3.39
Replacement	$3.65
Coatings	
Vinyl seal over VCT (12 month life)	$2.72 (over old VCT); $2.11 (over new VCT)
Vinyl seal over VCT (18 month life)	$2.23 (over old VCT); $1.80 (over new VCT)
Vinyl seal reapplication	$1.90 (12 month life); $1.66 (18 month life)
Polyurethane coating over VCT	$2.40 (two year life); $1.96 (three year life)
Polyurethane coating reapplication	$1.93 (two year life); $1.65 (three year life)
UV cured coating over VCT	$2.14 (three year life); $1.72 (five year life)
UV cured coating reapplication	$1.82 (three year life); $1.53 (five year life)
Alternative Flooring Types	
Optima IQ	$2.17 (no demolition); $2.43 (demolition)
Ecopure	$1.94 (no demolition); $2.10 (demolition)
Omni Sports	$1.54 (no demolition); $1.63 (demolition)
Centiva Contour	$1.43 (no demolition); $1.49 (demolition)
Centiva Mineral Chip	$1.56 (no demolition); $1.63 (demolition)
Powerbond	$0.66 (no demolition); $0.68 (demolition)
Mondo	$2.06 (no demolition); $2.19 (demolition)

VI. Health and Environmental Effects

The major motivating factor for this project was to identify, test, demonstrate and analyze safer alternatives to the floor wax strippers used today. IRTA used three approaches to accomplish this end. For the first approach, IRTA assumed that the school or public building would continue to use VCT flooring and would need to perform regular waxing and stripping maintenance on the floors. IRTA worked with two formulators to develop alternative floor wax strippers that would be safer for workers than the strippers used today. For the second approach, IRTA assumed that the school or public building would apply coatings to the VCT which could be maintained without waxing or stripping. In this case, IRTA worked with coating suppliers to apply three different types of coatings that were monitored for a school year. For the third approach, IRTA assumed the school or public building would replace the VCT with alternative flooring that does not require waxing or stripping. IRTA worked with flooring suppliers to install and/or monitor six different types of flooring during the school year. Another type of flooring that was not installed was also included in the analysis. Seven types of alternative flooring were evaluated in all.

As mentioned earlier, IRTA did not conduct a comprehensive life cycle assessment to compare the implications of continuing the current practices on the one hand with adopting the alternative strategies on the other hand. The major focus was on the potential health and environmental implications of the currently used materials and the alternative strategies at the point of use. IRTA did identify certain issues that may arise, however, and research on these issues could be pursued in more detail in future research. A few of the major issues are discussed below for each of the alternatives. There are other issues as well and those identified here are not meant to be comprehensive. Although specific brands of coatings and flooring were tested during the project, the discussion centers around the issues that affect the general type of coating or flooring and not the specific brands.

6.1. Floor Wax Strippers

There are two types of wax strippers on the market today. The first type, conventional strippers, which have been used for many years and are still widely used today, are generally highly alkaline strippers with a pH in the 12 to 14 range. They often contain amines, most commonly monoethanolamine (MEA). Very recently, some suppliers are starting to substitute other amines for MEA. Often a glycol ether, 2-butoxy ethanol, is the solvent used in these conventional strippers. The second type, so-called" green" strippers, generally also contain MEA or may contain another amine, AMP. The reason some suppliers are beginning to substitute AMP is that it has been deemed exempt from VOC regulations by U.S. EPA. The pH of the green strippers is lower, generally below 11.5. The green strippers may contain benzyl alcohol and/or glycol ethers which are now considered safer than 2-butoxy ethanol.

A major aim of the project was to formulate and test a few strippers that do not contain amines which are sensitizers and asthmagens. IRTA also discussed AMP with a toxicologist IRTA works with regularly. She had evaluated the toxicity of AMP and found that it could be a developmental toxin and that it, or its contaminants could form nitrosamines which are carcinogens. Even though the chemical is not a VOC, it could therefore pose a risk to workers. IRTA wanted to avoid the use of amines altogether in the alternative strippers because of the problems they pose.

Many of the strippers on the market today—both conventional and "green" strippers—contain VOCs which are generally solvents. As discussed earlier, CARB has established VOC content limits for strippers of 12% and 3% for high and medium buildup of wax respectively. IRTA's aim was to develop floor wax strippers that had zero VOC content in the CARB Consumer Product Regulation definition. SCAQMD had established a certification program that had a much more stringent definition of VOC content and IRTA also tried to develop alternatives that would meet this lower VOC limit.

The two strippers IRTA and the formulators developed and tested during the project have a pH below 11.5 and they contain no amines. Both of the strippers have zero VOC content according to the CARB regulation standards. One of the strippers has zero VOC content according to the SCAQMD certification program standard.

One of the alternative strippers does contain solvents, benzyl alcohol and a glycol ether. Many other green strippers contain benzyl alcohol. The chemical has been tested for carcinogenicity and has been found to be negative. The surfactant used in this stripper is listed on the U.S. EPA Safer Choice approved list.

The other alternative stripper does not contain any solvents. It does, however, contain a phosphate. Phosphates can contribute to eutrophication which can be deleterious to lakes. None of the publicly owned treatment works in California has a limit for phosphates, apparently because the low levels found in water-based industrial products have not caused a problem. The level of phosphate in the alternative stripper is low and it is diluted in use so the concentration that enters the sewer is very small. In addition, schools and public buildings are not required to have a discharge permit and, in this case, even if they were, there would be no limit for the phosphate. If a phosphate limit were adopted at POTWs in California, it is likely that the concentration of phosphate in the effluent from the maintenance operations using the stripper would not exceed it.

6.2. Coatings

As the second strategy for reducing the use of toxic floor wax strippers, IRTA tested coatings that make waxing and stripping unnecessary altogether. Two of the coating types IRTA tested, however, are coming under increasing scrutiny because of their ingredients.

The California Department of Toxic Substances Control (DTSC) recently adopted a green chemistry regulation. One of the product/chemical combinations DTSC is regulating is wet or uncured spray polyurethane foam materials containing unreacted methylene diphenyl diisocyanates (MDI) used for home and building insulation, weatherizing and sealing and roofing. Exposure to MDI has been shown to cause occupational asthma. Asthma is common among workers in the polyurethane industry. Do-it-yourselfers are also at risk when using the products without personal protections. MDI is a sensitizer; after just one or two exposures to the unreacted material, users may become more sensitive to MDI.

Polyurethane coatings are two part coatings, part A and part B. The part A component of the coating applied at Riverside USD contains an isocyanate, hexamethylene diisocyanate. This is not the same chemical as MDI but, because of structural similarities, other members of the diisocyanate group may also lead to asthma or cause sensitization. If this is the case, then some workers applying polyurethane coatings could be affected.

The UV cured coating applied at Riverside USD contains a number of different types of acrylates which function as reactive species to enhance polymerization. Acrylates are asthmagens and sensitizers. They can pose a danger to the workers who apply them. There is some evidence that even polymerized acrylates can cause problems so the issues may remain even after the coating is applied.

As mentioned in Section III, some floor coatings may contain tert-butyl acetate (TBAC) which acts as a carrier solvent for the coating resins. TBAC forms a metabolite, tert-butyl alcohol, which is a carcinogen. The SCAQMD rule for architectural coatings allows an exemption from VOC regulations for TBAC used in Industrial Maintenance coatings which, in some cases, includes floor coatings. Many of the floor coatings in the market for covering VCT do not contain this solvent and users selecting coatings should avoid using coatings that do include TBAC.

6.3. Vinyl Flooring

The VCT and several of the alternative flooring types, including Optima IQ, Omni Sports, Centiva Contour and Centiva Mineral Chip, are made from polyvinyl chloride (PVC). Many other brands of flooring are similarly made of PVC. Vinyl chloride, the monomer used in the polymerization process for making PVC, is a carcinogen. Small quantities of unreacted monomer may remain in the PVC matrix and they could potentially migrate out. There is no evidence that this unreacted monomer has caused cancer from use of or exposure to any PVC products. If the PVC ends up in landfills, some vinyl chloride has been found, presumably from degradation or pressure placed on the PVC matrix. If the PVC is destroyed in a municipal waste incinerator, dioxins can be formed from the chlorine in the PVC under certain conditions.

Plasticizers are used to make the vinyl feedstock for producing vinyl flooring products. They soften the product and make it more flexible. Some phthalate plasticizers which are commonly used to make PVC have been shown to be reproductive toxins and, in some cases, they are carcinogens. Even after the PVC has polymerized, there may be trace quantities of phthalates in the flooring which can migrate out over time. A few manufacturers, including Tarkett who makes the vinyl flooring tested during this project, have phased out the use of traditional phthalates. Other manufacturers, however, continue to use them. In addition, some of the vinyl flooring has a significant recycled content and, since older flooring relies on the traditional plasticizers, it could be many years before these plasticizers are eliminated entirely from the product stream.

6.4. Natural Flooring

The Mondo flooring which was tested during this project is made from natural rubber which contains latex; other products of this type also may contain a significant portion of natural rubber Some people have allergies to latex but there is no evidence that there have been allergic reactions to latex based flooring.

6.5. Nylon Flooring

The Powerbond material tested during the project is similar to other products of this type are based on nylon. These products are treated with a bleach and stain resistant material during the production process and it contains a fluoropolymer. Many fluoropolymers are made from fully halogenated perfluorocarbons (PFC) which have very long atmospheric lifetimes and contribute to global warming. PFCs can also form perfluorooctanoic acid (PFOA) which is very toxic. Some companies are trying to find alternatives that do not pose health and environmental problems.

VII. Results and Conclusions

During this project, IRTA identified, developed, tested and demonstrated safer alternatives to the toxic and high VOC floor wax strippers used widely today in schools and public buildings. IRTA demonstrated and evaluated three options for reducing or eliminating the use of currently used strippers. These included:

- developing alternative low-VOC, low toxicity strippers for use with VCT
- using coatings over the VCT that makes waxing and stripping unnecessary
- using alternative flooring in place of VCT that makes waxing and stripping unnecessary

The results of the project for each of these options is summarized below.

7.1 Alternative Strippers for Use with VCT

IRTA worked with two formulators during the project to develop alternative wax strippers that would not contain amines which cause asthma and are sensitizers; that would have zero VOC content under the CARB regulatory definition; that would meet the more restrictive VOC limit in the SCAQMD certification program; and that would have relatively low pH. IRTA and the formulators tested various stripper formulations with the Riverside USD maintenance staff to optimize the stripper performance given the health and environmental restrictions. Two formulations that performed well compared with existing green and non-green strippers on the market were tested with several schools and public buildings.

Both of the alternative strippers that performed well contain no amines, they have zero VOC content under the CARB regulations and they have relatively low pH. One of the alternative strippers, III-A, contains solvent and the other, III-C, contains no solvent. The stripper that contains no solvent also meets the more stringent VOC definition in the SCAQMD certification program. Both strippers have no objectionable odor like many other strippers because they do not contain amines. Some of the maintenance workers testing the strippers mentioned this. A few of them also cited another advantage. The alternative stripper that contains solvent produces a non-slip surface after it is applied. This is in contrast to other strippers that provide a slippery surface that can sometimes lead to accidents for the maintenance staff.

IRTA performed a cost analysis to determine whether the alternative strippers' prices would be in a reasonable range in the market if they were commercialized. The two alternative strippers are considered green strippers and green strippers are generally priced higher than non-green strippers. The cost information is summarized and compared with other strippers in Table 7-1. The table shows that the price of the alternative solvent-free stripper (III-C) even with a very high markup is substantially lower in price than the currently used green and non-green strippers. The price of the alternative stripper containing solvent (III-A) with a very high markup is in the price range of non-green strippers and is lower in price than the range for green strippers.

The results of the tests of the alternative strippers show they can perform well when compared with both green and non-green strippers used today. The values of Table 7-1 show that the price of the alternative strippers is below or in the range of strippers marketed and used today. This indicates that strippers without amines that cause asthma and sensitization and with zero VOC content can perform well and be cost effective in the market.

Table 7-1
Price Comparison for Alternative Strippers and Currently Used Strippers

Stripper	Materials/Blending Price Per Gallon	1.3 Markup Price Per Gallon	2.0 Markup Price Per Gallon	Market Price Per Gallon
Alternative III-C (solvent-free)	$5.54	$7.20	$11.08	$7.20 to $11.08
Alternative III-A (with solvent)	$8.41	$10.93	$16.82	$10.93 to $16.82
Bombers Industrial Strength Stripper	NA	NA	NA	$21.00
Clair 316 Stripper	NA	NA	NA	$25.00
Typical non-green strippers	NA	NA	NA	$14 to $20
Typical green strippers	NA	NA	NA	$18 to $25

NA is not applicable

7.2. Using Coatings Over VCT

During the project, IRTA worked with a coating supplier and coating application company to test three different types of coatings. These coatings, when applied over VCT, do not require waxing and therefore do not require the use of strippers at all. The three types of coatings that were tested included:

- Vinyl seal
- Polyurethane coating
- UV urethane acrylic coating

All three of the coating types were applied over VCT in a well-used hallway system at one of the Riverside USD schools. The performance of the three coatings was monitored over a school year by a group including IRTA, Riverside USD maintenance staff, a coating company representative and several flooring alternative representatives. The vinyl seal turned quite yellow early on, possibly because of a cleaner used on its surface. The coating company reapplied the coating and it performed well throughout the remainder of the testing period and did not appear yellow. Near the end of the school year, the polyurethane coating had certain recessed areas where the coating seemed to be wearing but, overall, still had a reasonable look. The UV coating performed very well and remained shiny throughout the period.

7.3. Replacing VCT With Alternative Flooring

IRTA worked with different flooring suppliers during the project to install four different types of alternative resilient flooring in two schools in the Riverside USD. The advantage of the alternative flooring is that it does not require waxing or stripping. The four types of flooring that were installed and monitored over the school year were:

- Optima IQ
- EcoPure
- Omni Sports
- Centiva Contour

In addition to these four types of flooring, two other types of flooring were also monitored during the project. These were Powerbond which was present in many different locations in the Riverside school system and Mondo which had been installed in a multipurpose room in one Riverside school. Yet another type of flooring, Centiva Mineral Chip, was included in the cost analysis but was not installed or monitored. In all, six different types of flooring were monitored and seven different types of flooring were included in the cost analysis.

Four of the flooring types are made of vinyl. These include, Optima IQ, Omni Sports, Centiva Contour and Centiva Mineral chip. One of the flooring types, Powerbond, is a carpet-like material made of nylon. Two of the flooring types are natural flooring; these are EcoPure which is linoleum and Mondo which is rubber.

The flooring types were monitored over the school year on a monthly basis by the same group that monitored the coatings. The purpose was to see if there were any performance problems with the flooring. Part way through the year the EcoPure flooring had to be reattached with adhesive on one side where it had been lifted by foot traffic. In general, all of the flooring alternatives performed well.

7.3. Cost Comparison Results

IRTA performed a cost analysis and comparison for continued use of VCT with waxing and stripping, use of coatings over VCT with no waxing and stripping, and substitution of alternative flooring with no waxing and stripping. The cost analysis included the materials and installation cost and the on-going maintenance cost. The materials and installation cost was amortized over the warranty life of the coatings and the flooring. The results of the cost comparison on a per square foot basis are presented in Table 7-2.

Table 7-2
Annual Cost Comparison of VCT, Coatings and Alternative Flooring Per Square Foot

Flooring/Coating Type	Annual Cost of Using Alternative Option
VCT	
New	\$3.39
Replacement	\$3.65
Coatings	
Vinyl seal over VCT (12 month life)	\$2.72 (over old VCT); \$2.11 (over new VCT)
Vinyl seal over VCT (18 month life)	\$2.23 (over old VCT); \$1.80 (over new VCT)
Vinyl seal reapplication	\$1.90 (12 month life); \$1.66 (18 month life)
Polyurethane coating over VCT	\$2.40 (two year life); \$1.96 (three year life)
Polyurethane coating reapplication	\$1.93 (two year life); \$1.65 (three year life)
UV cured coating over VCT	\$2.14 (three year life); \$1.72 (five year life)
UV cured coating reapplication	\$1.82 (three year life); \$1.53 (five year life)
Alternative Flooring Types	
Optima IQ	\$2.17 (no demolition); \$2.43 (demolition)
EcoPure	\$1.94 (no demolition); \$2.10 (demolition)
Omni Sports	\$1.54 (no demolition); \$1.63 (demolition)
Centiva Contour	\$1.43 (no demolition); \$1.49 (demolition)
Centiva Mineral Chip	\$1.56 (no demolition); \$1.63 (demolition)
Powerbond	\$0.66 (no demolition); \$0.68 (demolition)
Mondo	\$2.06 (no demolition); \$2.19 (demolition)

Table 7-2 shows the annual cost of using the option under various circumstances for new or replacement VCT for each of the three coating types for original and reapplication and for the seven different types of flooring with or without demolition. Schools and public buildings considering flooring in a new or existing building can use the information in the table to determine a cost of any of the options given the square footage of the area of consideration. The table shows that the annual cost of continuing to use VCT with waxing and stripping is unequivocally higher than the cost of using any of the other options without waxing or stripping. Indeed, waxing and stripping is the highest cost item in the VCT flooring maintenance. Applying the coatings to the VCT and, particularly, reapplying them over themselves, is a lower cost option than using VCT. The highest cost flooring to use is the Optima IQ, primarily because of its short warranty life. The two natural types of flooring, EcoPure and Mondo, are also relatively costly to use. Applying coatings over VCT, particularly with reapplication, is a lower cost option than using some of the alternative flooring types. The lowest cost option of all is to use Powerbond. This material is not universally applicable, however, and it is not a substitute for other types of flooring in many cases.

An issue that arises for new buildings is that architects specify the type of flooring that should be used. Often during construction, there are cost overruns and the cost of the original materials needs to be reduced. Frequently, architects decide to cut the cost by putting in VCT. On a per square foot basis, the materials cost for VCT is the lowest of the flooring types. The installed cost, however, is not low and the installed cost of other types of flooring is lower. Table 7-3 summarizes the annualized installed cost of the different flooring types. The annualized cost of the installation was determined by amortizing the installed cost over the warranty life of the particular type of flooring.

Table 7-3
Annualized Installed Costs for Flooring Types for a New Building

Flooring Type	Annual Installed Cost (per square foot)
VCT	$0.71
Optima IQ	$1.08
EcoPure	$0.85
Omni Sports	$0.45
Centiva Contour	$0.33
Centiva Mineral Chip	$0.47
Powerbond	$0.12
Mondo	$0.97

The values show four of the alternative types of flooring have a lower annualized installed cost than VCT. These include Omni Sports, Centiva Contour, Centiva Mineral Chip and Powerbond. This information should assist architects in understanding that the annualized installed cost of many types of alternative flooring are actually lower than the cost for VCT. Better decisions can be made when they are selecting flooring for new buildings.

The cost analysis presented here is sensitive to many of the assumptions. The approach IRTA used was to amortize the installed or applied cost over the life of the flooring or the coating to get an annualized installed cost. This cost was then added to the annual maintenance cost to give a total annual cost of using the flooring or coating. Perhaps the most sensitive variable in the cost analysis is the warranty life of the flooring or coating. IRTA assumed the warranty life assigned by the manufacturer. Manufacturers are conservative and do not want to pay for covered failures so they set the warranty life lower than it probably ever is in practice. Obviously, the lower the warranty life, the higher the annual cost of using the coating. VCT has a warranty life of five years and this was used in the analysis. In fact, however, most schools and public buildings actually use VCT much longer before they replace it. If they do use it much longer, then the relative cost of the alternatives would be higher. It is important to note, however, that the coatings and alternative flooring may also have much longer lives in practice than the warranties would suggest. Thus, the relative costs of comparing the options assuming higher warranty lives across the board would not change.

Another factor that heavily influences the results is the assumptions about the maintenance costs. The values of Table 5-2 show that the waxing and stripping cost and the top scrub cost for VCT account for the majority of the maintenance. Neither of these two activities is necessary for any of the coatings or the alternative flooring. Some schools and public buildings have become aware of the high cost and have reduced the frequency of stripping and top scrubbing. Even so, including those activities even on a less frequent basis will act to raise the cost of using VCT above that of using the coatings or the other types of flooring.

7.4. Conclusions

The results of this project indicate that using VCT flooring in new buildings is not a good option. Building owners and architects should select alternative flooring because the alternatives are less costly to use over the life of the flooring in all cases. The results also indicate that for existing buildings, when old flooring is being removed and replaced, using new VCT is also not a good option. Again, using any of the alternatives is a better option. In buildings where VCT still has a useful life, the best option is to use a coating over the VCT. For all types of coatings, this is a less costly option over the life of the coating than continuing to use the VCT with waxing and stripping. For building staff still using VCT flooring, safer low-VOC, low toxicity alternative strippers should be used in schools and public buildings to reduce the health and environmental risk to maintenance staff, teachers, students and the public.