Safer Alternative Nail Polish Removers for Salons and Consumers

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DISCLAIMER

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EXECUTIVE SUMMARY

There may be as many as 8,500 salons in California with 400,000 full and part time licensed nail technicians and cosmetologists. It is estimated that as many as 80%of the nail salon workers in California are Vietnamese immigrant women and more than half of them are of reproductive age. Nail salon workers are exposed to hundreds of chemicals each day that are ingredients in polishes, removers, glues, solvents and other cosmetic products. Beauty supply stores sell hundreds of nail products to consumers annually and consumers are also exposed to the ingredients when they apply and remove products.

This document summarizes the results of a project sponsored by the Paul H. Johanson Fund and the Bay Area Air Quality Management District. The aim of the project was to identify, develop, test and demonstrate safer alternative nail polish removers. The project was conducted by Institute for Research and Technical Assistance (IRTA), a small technical environmental nonprofit organization. IRTA has expertise in finding safer alternatives in industrial and consumer product applications with a primary focus on solvents.

IRTA partnered with the Healthy Nail Salon Collaborative (Collaborative) to find and work with three salons in California to assist in testing the promising alternative removers. IRTA recruited one additional salon and several consumers who also participated in the testing.

The most widely used nail polish remover in California is acetone. The chemical is lower in toxicity than most other organic solvents. The disadvantage of acetone for this application is that it evaporates very quickly and has a strong odor. Many salons are small and poorly ventilated and the workers find the smell objectionable and are exposed to high concentrations of acetone. The chemical, like other solvents, causes central nervous system effects like headaches and dizziness. Consumers also may experience these effects. Another strong disadvantage of acetone is that it dries out the nails and leaves them brittle.

IRTA conducted preliminary investigation and/or testing on several alternative removal methods including abrasion, freezing, water-based ultrasonic techniques and use of low vapor pressure solvents. The tests were performed on three different types of polish including regular polish, UV cured gel polish and hybrid polish, a combination of regular and natural light cured polishes. IRTA identified two low vapor pressure solvents, one a carbonate and the other an ester, which held promise for removing polishes on their own. IRTA combined these solvents with acetone and developed two alternative blends. These two blends seemed effective for removing regular and hybrid polish; for UV cured gel polish, the alternatives softened the polish matrix and the polish had to be removed with a tool or a longer time frame was needed for removal.

In preliminary testing with salons and consumers, IRTA found that alternative #1, the blend of acetone and the carbonate, performed somewhat faster than alternative #2. In scaled-up testing with consumers, IRTA found that consumers liked both alternatives and were willing to use them on regular, hybrid and UV cured gel polish. The salons indicated they liked alternative #1 better because of its slightly quicker action but that they would only likely use it for regular and hybrid polish. They indicated their customers would not like them to use the tool for the UV cured gel polish removal and they have time constraints..

IRTA investigated compatibility to determine what types of containers should be used with the alternatives. IRTA found they should be used in high density polyethylene (HDPE) containers which are also used for acetone removers today. IRTA also conducted evaporation tests to determine the best types of containers for the alternatives in the consumer market. The results demonstrated that HDPE containers with a flip spout top allowed less evaporation than HDPE pump bottles with a twist lock top. IRTA also conducted adhesion tests designed to identify the best method of treating the nails after use of the alternatives and prior to reapplication of polish. The results indicated that the nails could be wiped with a dry cloth before nail polish is reapplied.

IRTA attended a Collaborative meeting with their member salons and provided 18 eight ounce samples of alternative #1 to the workers and owners who attended for testing. Feedback from the salon workers was that they liked the smell of the alternative. Workers and owners thought the alternative worked effectively and liked the shiny more lubricated condition of the nails after use. One salon owner said he would use the alternative on gel polish even though it took longer. One salon owner indicated she could not use it without having customers wash their hands which was in conflict with IRTA's adhesion test results.

IRTA performed a cost analysis and comparison for acetone remover and the two alternative removers. IRTA evaluated two scenarios. The first assumes the same amount of the alternative would be used; the second assumes that 20% less of the alternative would be used because of the lower evaporation rate. The results of the analysis for gallon containers which are purchased by salons are shown in Table E-1. The cost of purchasing both alternatives is higher than the cost of purchasing acetone remover because of the higher raw materials cost of the alternatives. If salons perceived advantages of lower exposure and better nail condition, they could be willing to pay a higher price for the alternatives.

Table E-1
Cost Comparison for Salons for Gallon Containers

Remover	Total Cost	Total Cost Assuming Reduction of 20% in Alternative Remover Use
Acetone	$5.88	$5.88
Alternative #1	$10.62	$8.50
Alternative #2	$11.96	$9.57

Note: Profits not included in cost.

Table E-2 shows a similar cost comparison for acetone and the two alternatives for consumers. IRTA assumed the removers would be sold in eight ounce bottles for the analysis. In this case, the costs of the alternatives are higher under the assumption that the same amount is used but are comparable in cost for the case where20% less of the alternative is used. IRTA also gathered information on prices of consumer removers. For an equivalent eight ounce container, prices of the alternatives ranged from $1.29 to $18.40. Because of the substantial markups for profit in the consumer market, the alternatives could easily be priced competitively in this sector.

Table E-2
Cost Comparison for Consumers for Eight Ounce Container

Remover	Total Cost	Total Cost Assuming Reduction of 20% in Alternative Remover Use
Acetone	$1.11	$1.11
Alternative #1	$1.35	$1.08
Alternative #2	$1.44	$1.15

Note: Profits not included in cost.

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I. Introduction and Background

There are thousands of nail salons in the U.S. and they work with millions of customers each year to apply and remove different types of nail polish. Beauty supply stores and drug stores also sell a range of different types of polish and removers to millions of consumers who apply and remove polishes routinely. Online sales of polish and removers have also increased substantially in recent years.

In the U.S., nail salons generate approximately $6 to $8 billion in annual sales. The nail salon industry is one of the nation's fastest growing professions. There are as many as 48,000 salons in California and there may be as many as 400,000 full and part time licensed nail technicians and cosmetologists in the state. It is estimated that as many as 80%of the nail salon workers in California are Vietnamese immigrant women and more than half of them are of reproductive age. Nail salon workers handle and are exposed to hundreds of chemicals each day that are ingredients in polishes, removers, glues, solvents and other cosmetic products. Beauty supply stores sell hundreds of nail products to consumers annually and consumers are also exposed to the ingredients in these products when they apply and remove polishes, acrylic nails and practice nail art. Tweens have become involved in nail products in recent years as increasingly younger consumers are attracted to the market.

In 2005, the California Healthy Nail Salon Collaborative (Collaborative) was formed to advance a preventative environmental health agenda for the cosmetology and nail salon sector in California. Over the last several years, the Collaborative pioneered a program to bring attention to the so-called toxic trio, dibutyl phthalate (DBP), formaldehyde and toluene, chemicals that were used routinely in nail products. Many suppliers modified their formulations to eliminate the use of these chemicals. More recently, the Collaborative has established a salon recognition program to recognize salon owners that use products without the Toxic Trio.

The California Air Resources Board (CARB) is responsible for regulating air emissions from consumer products in California. Because of a significant smog problem in the state, there is a strong need to regulate Volatile Organic Compound (VOC) emissions which contribute to smog. Some VOCs, in addition to causing smog, are often also toxic. CARB currently requires that nail polish removers have a VOC content of 1% or less and the limit has been in effect since December 31, 2007.

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 grant from the Paul H. Johanson Fund to identify, develop, test and demonstrate alternative nail polish removers for use in salons and by consumers. The Bay Area Air Quality Management District (BAAQMD) also provided support to IRTA for the project. As part of the project, IRTA worked with the Collaborative in Northern and Southern California to recruit nail salons that could assist IRTA in testing alternatives. IRTA also coordinated the work with the City of Santa Monica and the San Francisco Department of the Environment who are involved in the Collaborative salon recognition program. In addition, IRTA tested alternatives, as part of the project, with several consumers.

The Collaborative assisted IRTA in recruiting three salons that were participating in their recognition program. IRTA separately recruited one salon that is not part of the Collaborative's recognition program. The salon participants in the project included:

- Cute Nails in Santa Monica, CA
- Hana Nails in Marina Del Rey, CA
- Leann's Nails in Alameda, CA
- Diva Nails in Oakland, CA

In addition to working with these salons, IRTA attended a meeting held by the Collaborative in Northern California that was also attended by several salons. IRTA provided 18 samples for testing to the salons that attended. IRTA also attended a second salon meeting to share the results of the project with the salons.

The most widely used chemical in nail polish removers in California is acetone. The chemical is exempt from VOC regulations so it meets the CARB VOC limit. Acetone is often combined with other ingredients like oils, emollients and fragrances that help in conditioning the nails. There are two issues that arise in using acetone removers. First, acetone has a very high vapor pressure and strong odor. Salons often have poor ventilation so exposure to the chemical is high. Acetone is low in toxicity but, like many other solvents, it causes central nervous system effects. These include dizziness or headaches when the concentration is high. Second, acetone dries out the nails and makes them brittle so, although it does remove polish, it leaves the nails in poor condition. There are many non-acetone alternatives on the market to take advantage of this limitation but, in general, they do not work very effectively.

As part of the project, IRTA worked with a formulator, WA & Associates , to develop and test the safer alternative nail polish removers. The aim was to examine both chemical and physical methods of removal that might be effective. IRTA and the formulators tested a variety of alternative methods and ended up developing two products that seem to work well.

1.1 Project Approach

In general, the first step in the project was to investigate the different types of polishes and the different types of removers and removal processes that are used today. As discussed in more detail in the document later, there has been a movement in recent years to so-called gel polishes that are cured with ultraviolet (UV) lights. Regular polishes are also still used and there are a range of different variations, like glitter, that are also used. IRTA needed to investigate these different types of polishes to scope out the removal challenges and to determine what removers are in the market today.

The second step was to establish a working relationship with other organizations. IRTA wanted to work with the Collaborative because of their heavy involvement with and knowledge of the industry and to help in recruiting nail salons. IRTA also wanted to work with a product formulator/distributor to test alternative methods of removal. One company, WA & Associates, was interested in working with IRTA on the project.

The third step in the project was to conduct preliminary testing. This involved applying many different types of nail polish and trying to identify alternative chemicals that might be effective in removing them. As part of this step, IRTA worked with the formulator to formulate certain water-based removers that could possibly hold promise. IRTA also worked with the formulator to try to design removal methods based on abrasion or mechanical action.

The fourth step was to recruit consumers and, with the assistance of the Collaborative, salons. Once IRTA had alternative formulations that seemed effective and knew the characteristics of their most effective uses, IRTA needed input from salons and consumers on their efficacy. In addition, when a consumer or salon liked an alternative, IRTA provided larger quantities for testing over a longer period.

The fifth step in the project was to conduct testing on the most promising alternatives that would have an effect on performance and cost. This work involved conducting adhesion tests and evaporation and compatibility testing on containers and container caps for the remover. Because salons in particular are businesses, they need to service many customers in a short period of time. If they use a remover to take off the polish, it is important that they be able to reapply new polish quickly. The technicians need to know that the new polish will adhere to the nails for durability and that the remover will not interfere with that aim. It was important to test for compatibility to decide what containers and caps would be appropriate for the cost analysis. It was also important to conduct evaporation tests in the containers so IRTA could be assured the performance would not deteriorate over time.

Once the most effective formulations were identified, the sixth step was to perform a cost analysis. This step built on the results of the fifth step to determine the kind of label and packaging a nail polish remover would need for sales to both salons and beauty supply stores for consumers. IRTA also contacted a cosmetics product manufacturing facility to obtain information on the cost they would charge for filling the containers with the removers. This cost could then be compared with the prices of other nail polish removers. .

The seventh 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 removers with the salons and consumers was evaluated on a case-by-case basis. In all cases, the salon personnel or consumers using the removers judged the alternative's performance by comparing it to the remover they use currently which was commonly acetone.

1.3 Cost Analysis

IRTA performed cost analysis for the safer alternative removers and compared it to the cost of using the acetone and non-acetone removers on the market today.

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 nail polish types used today and some of the removers that are marketed currently.

1.5 Report Organization

Section II of this report gives background on the procedures for applying and removing different types of nail polishes. It also discusses the different types of polishes and the toxicity of their ingredients. Section III provides detailed information on the approach IRTA used in evaluating safer alternative nail polish removers and the results of the testing. Section IV presents and discusses the results of the adhesion testing and the compatibility and emission testing of the packaging. The results of the cost analysis are also presented in Section IV. Section V describes the health and environmental effects of the polishes and removers evaluated during the project. Finally, section VI summarizes the results of the project and the findings and Sections VII and VIII list the references and organization contact information respectively. Appendix A includes Safety Data Sheets (SDSs) for the most promising alternative removers that were tested during the project.

II. Nail Polish and Nail Polish Removers

2.1. Description of Nail Polish

There are two different generic types of nail polish that dominate the market today and there is a third type that has emerged recently. The two major types of polish are air dry nail polish and ultraviolet (UV) light cured polish. The new polish type is natural light cured polish. Each of these polish types is described in more detail below.

2.1.1. Air Dry Nail Polish

This polish type is referred to as regular nail polish and it has been widely used in the market for decades. It is sold in liquid form in small bottles. It is applied to the nails with a small brush and, within a few minutes of application, it forms a shiny coating on the nail and hardens. It is water and chip resistant and may last a few days to a week before removal and reapplication is required. Figure 2-1 shows a picture of a bottle of regular nail polish.

Figure 2-1. Bottle of Regular Nail Polish

The base material of regular polish is nitrocellulose lacquer and it is often called lacquer. Historically, many of the coatings used for furniture were based on the same material. Nitrocellulose acts as the film-forming medium. The nitrocellulose is dissolved in an organic solvent, like butyl acetate or ethyl acetate or both, that is volatile and evaporates quickly. This is a basic formulation for nail polish but many other ingredients are added to give the polish various properties. There are literally thousands of different formulas for nail polish with a variety of different ingredients for nourishing the nails, enhancing drying and film forming and assisting with hardening.

Other ingredients in polishes are resins and plasticizers that soften the film and keep it from being brittle and make it resistant to soap and water. Plasticizers that are commonly used are dibutyl phthalate and camphor. To provide color, the polishes today generally rely on pigments which are suspended in the solvents. Various other ingredients are added depending on the look that is desired. These include components that give a pearlized or shimmery look to the polish.

The resins, plasticizers and other ingredients in the polish are dissolved in solvents. The polish hardens and dries when the solvent evaporates from the blend. This mechanism is a simple air dry; once the solvents have evaporated, the polish is dry and cured.

In general, the procedure for applying nail polish involves first applying a base coat, then applying two color coats of the regular polish and finally, applying a top coat. The base coat is commonly a clear coat which strengthens and restores moisture to the nails, fills in ridges to make a smooth surface for the polish and helps with the adhesion of the polish. The top coat is also commonly a clear coat that forms a hardened barrier and gives the nails a finished look. It speeds up the color coat drying process.

2.1.2. Ultraviolet Light Cured Polish

This type of polish, commonly referred to as gel polish, has penetrated the market over the last several years and, in many cases, is now preferred over regular polish. The strong advantage of this polish is its durability. Rather than a few days to a week, this polish lasts at least two weeks and often longer. It also gives a more glossy appearance than regular polish.

These polishes are made of urethane acrylics. When they are first applied, they are in a monomer state and they look and feel like a gel. The formulations contain a photoinitiator which starts the chemical reaction when light from a UV source is applied. This photoinitiator and UV light essentially trigger the reaction where the monomers rapidly combine with one another forming a polymer, a much longer molecule which contains many monomers linked together. The material that activates the polymerization is acrylates which react very quickly. This type of polish is sold in opaque bottles so it will not cure until it is applied and irradiated with light. A picture of a bottle of a gel polish color coat is shown in Figure 2-2.

Applying the gel polish system is more complex than applying lacquer polish. The nails are first buffed to create a rough surface which will result in better adhesion. Alcohol is then applied to the nail to remove the particles created during buffing. The first coat to be applied is the base coat which creates a smooth surface for the color coats. A picture of a bottle of base coat is shown in Figure 2-3. The base coat is cured by being irradiated with a light. A picture of a typical light used for this purpose is shown in Figure 2-4. Two color coats of the polish are then applied and the light is used to cure each of the coats in turn. Finally, a more durable top coat is applied and cured with the light. A picture of a bottle of a gel polish top coat is shown in Figure 2-5. This top coat leaves a tacky surface and alcohol is then applied to the surface coat to smooth it out.

Figure 2-2. Opaque Bottle of Ultraviolet Light Cured Gel Polish Color Coat

Figure 2-3. Opaque Bottle of Ultraviolet Light Cured Gel Polish Base Coat

Figure 2-4. Typical UV Light Used to Cure Gel Polish in a Salon

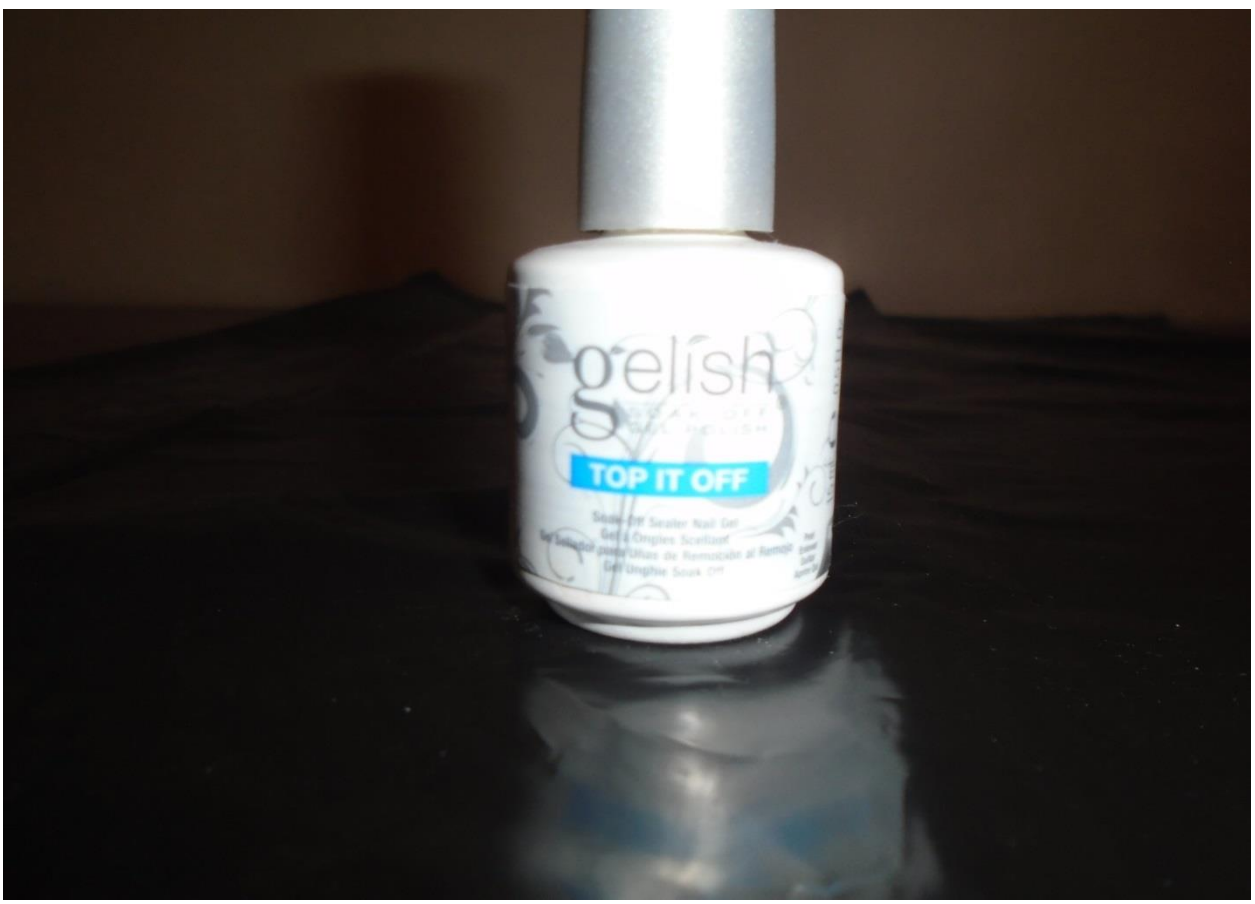

Figure 2-5. Opaque Bottle of Ultraviolet Light Cured Gel Polish Top Coat

The gel polish does not contain solvents since it does not rely on solvent evaporation for curing. Rather, as discussed above, the activators, photoinitiators and light all contribute to the curing process.

2.1.3. Hybrid Polish

This type of polish is a combination of regular polish and light cured polish. The base coat and color coat are made of materials identical to regular polish. The top coat contains acrylic copolymers and is cured with natural light rather than a UV or LED light. The top coat cures quickly in roughly the same time as regular nail polish when it is exposed to natural light. Some brands consist of a color coat and a top coat and others require use of a base coat, a color coat and a top coat. This type of polish is much easier and quicker to apply than gel UV light cured polish. In many cases, the hybrid polishes have the word gel in the name, presumably because the topcoat is cured with light, albeit natural light. A picture of the bottles for two brands of hybrid systems is shown in Figure 2-6. The base/color coat is transparent since it is nitrocellulose lacquer like regular polish (in this case pink or red). The topcoat bottle on the right is opaque so the formulation will not cure until it is applied and encounters natural light.

Figure 2-6. Two Brands of Hybrid Nail Polish

2.2. Description of Nail Polish Remover

Many different solvents have been and are used for removing nail polish. Historically, removers contained toluene. Because of the chemical's toxicity, it has largely been replaced with other solvents. Some of the other solvents that are used in nail polish removers include:

- Ethyl acetate
- Butyl acetate
- Ethyl lactate
- Methyl acetate
- Acetone

Nail polish removers often contain one or more of these solvents and also various additives that have certain functions. These include Vitamin E for enriching the nails, Aloe Vera which conditions the nails and glycerin which keeps the nails and skin from drying out. Other proprietary ingredients are also used in the wide range of nail polish removers that are on the market.

By far, the most commonly used nail polish remover ingredient in California today is acetone. Removers based on acetone are sold in drug stores, beauty supply stores and online and they are purchased by and used in salons. The industry seems to believe that acetone is toxic and also markets many non-acetone formulations. Acetone is actually low in toxicity compared with other organic solvents but, because of its high evaporation rate, it can lead to high exposure, particularly in salons without sufficient ventilation. Acetone, like most other solvents, can cause central nervous system effects like headaches or dizziness with high exposure. The chemical does dry out the nails and skin and leaves the nails brittle which is the reason removers are often formulated with ingredients that condition and enrich the nails.

Nail polish remover is sold in gallon quantities or in four-gallon case quantities to salons. Salons generally use pure acetone without any additives. Acetone is a very fast and aggressive polish remover; the formulations with other ingredients added do not perform as well. Because salons are interested in performance and have time constraints, they virtually always use the pure chemical.

A whole range of acetone and non-acetone removers are sold in drugstores, beauty supply stores and online. The most common container sizes are 2 ounces, 4 ounces and 8 ounces. Some of these formulations are pure acetone but most of the acetone formulations have other ingredients to condition the nails. Many non-acetone formulations are also sold in these venues and they contain a range of different ingredients. Consumers generally purchase the products sold in drugstores and beauty supply stores and they are most often not pure acetone.

In recent years, nail polish remover pads have entered the market. These consist of pads that are premoistened with a whole range of different types of nail polish remover ingredients. They are a convenience, particularly for people who must remove and reapply polish while travelling.

2.3. Nail Polish Removal Processes

The process for removing regular and gel polish differs substantially. Most people are familiar with the process for removing regular nail polish. In general, a cotton ball is moistened with the remover. The remover on the cotton ball is placed on the nail containing polish and is moved over all parts of the nail to entirely remove all vestiges of the polish. The process takes only a few seconds. Some removers take longer to act and repeated application may be necessary in certain cases where many coats of polish have been applied. Figure 2-7 shows a picture of a typical removal process for regular polish in a salon during IRTA's testing.

Figure 2-7. Removal Process for Regular Polish in a Salon during Testing

As mentioned above, suppliers have also developed nail polish remover pads which are saturated with typical nail polish removers. These are a convenient alternative to bottles of remover and the pads can more easily be used by consumers when they are travelling. A picture of two brands of remover pads is shown in Figure 2-8. The pad on the left is acetone based and the pad on the right is based on methyl acetate.

For removing gel UV light cured polish, the process is much more complicated because the coats of polish are so much more durable. The first step is to use a file to abrade the top coat of the gel polish. It is designed to be a more durable cover for the color coats below. Its surface must be broken by the filing so the remover can penetrate the top coat and get to the coats below. The next step is to soak cotton balls (or pieces of cotton balls) in remover. These moistened cotton balls are placed on top of each nail containing the polish. Pieces of aluminum foil are wrapped around the cotton balls and each finger to secure the moistened cotton balls in place. The cotton ball/aluminum foil is left on for 10 to 15 minutes so the remover can act on the polish for a sustained period of time. A picture of the wrapped nails is shown in Figure 2-9. When the foil and cotton balls are removed, chips of polish may still be attached to the nails in certain places so these are pushed from the nail gently with a tool.

Figure 2-8. Two Types of Polish Remover Pads

Figure 2-9. Foil Wrapped Nail for Removal of Gel Polish During Testing

Some suppliers have developed pads that can be saturated and put on each of the nails. They are wrapped around the nail and secured with Velcro. A picture of nails wrapped with these pads is shown later in Figure 3-3. This is an alternative to using the cotton ball with foil.

An alternative method of removing gel polish is to immerse the polished nails in a small dish or container of remover. Generally, it will also take 10 to 15 minutes of immersion to remove the polish. Although this method is used, it is less common than the aluminum foil wrap process.

The removal process for hybrid polish is the same as the removal process for regular nail polish. The polish can be removed very quickly with a moistened cotton ball or pad. Nail polish remover pads can also be used to remove hybrid polish.

Many other remover processes are being investigated and/or marketed but they are not used widely. One method, called Steam Off, uses an enclosed device with a heater to remove UV/LED light cured gel polish. The removal formulation, which contains acetone in part or whole, is placed in the container and heated to form an acetone steam. The nails are individually inserted in the device and it requires 10 to 15 minutes to loosen the gel polish. Any residual particles are pushed off with an orange stick. This device may be risky to use because of acetone's low flash point. If the concentration of the vapor exceeded the lower explosion limit for the chemical, the device could explode. It is not clear whether explosion proof materials have been used to make the device.

Another method that can be used with any type of polish is to use swatch strips. These are clear strips that are applied to the nail with a pressure sensitive adhesive prior to applying nail polish. The nail polish system, including a base coat, a color coat and top coat are applied over the strip. When the polish begins to degrade, the strips can be pulled from the nails. With this process, there is no need to use a formulation at all and it may be a good option. This type of approach should be further investigated.

2.4. Regulations on Nail Polish and Nail Polish Remover

In California, the California Air Resources Board (CARB) regulates air emissions from consumer products. Nail polish remover is defined in CARB's General Consumer Product Regulation as "a product designed to remove nail polish and coatings from fingernails or toenails." On December 31, 2007, a VOC limit of 1% for this category became effective. This means that high VOC content solvents cannot be used in nail polish removers in the state. There are currently no CARB regulations on nail polish.

III. Testing Alternative Nail Polish Remover Ingredients

3.1 Background and Approach

IRTA investigated and tested many different candidates as potential nail polish remover ingredients in the course of the project. For this effort, IRTA assumed that the existing polishes that are used by consumers and in salons were the polishes that required removal. At the beginning of the project, IRTA focused on finding alternative nail polish removers for regular polish and for UV/LED cured gel polish which were the polish types available at the time. In the middle of the project, one hybrid polish came on the market followed by others somewhat later. At that stage, IRTA also included the hybrid polish cured with natural light in the testing.

Nail polish and nail polish removers are obviously intimately connected as is apparent from the descriptions in Section II. Regular and hybrid polish can be removed quickly whereas the UV/LED light cured gel polish requires a much more elaborate and lengthy removal process. The characteristics of the polish greatly affect the removal process. During the testing, IRTA became aware of this early on and focused effort on analyzing polishes to some extent. This section describes the tests IRTA conducted to find effective alternative nail polish removers and also discusses some of the advantages and limitations of the polishes being removed.

3.2. Alternative Remover Tests

In years past, as discussed earlier, toluene was used in many nail polish removers. It is generally no longer used because of toxicity concerns, particularly in California. In addition, it is a VOC and would not meet the VOC limits of the CARB regulation if it were used in more than about a 1% concentration. Acetone is now the most commonly used ingredient in nail polish removers. It is exempt from VOC regulations so acetone has a zero VOC content and it meets the 1% VOC limit established by CARB. There is a perception that acetone is very dangerous. Although the chemical does have a low flash point, it is used in only small quantities in nail polish remover so the flammability is not a significant issue. As mentioned in Section II, acetone is lower in toxicity than almost all other organic solvents. It is an irritant and it does cause central nervous system (CNS) effects like headaches and dizziness in high concentrations but it is not a chronic toxicant. One main disadvantage in using acetone is that it leaves the nails dried out and brittle. Another disadvantage is that in unventilated spaces like many salons, the exposure can be very high and cause irritation and CNS effects.

Because of the perception that acetone is dangerous and because of its effects on nails, many alternative removers are been marketed. Other volatile solvents like butyl acetate, ethyl acetate and ethyl lactate are potential alternatives. These solvents are all VOCs and their VOC content far exceeds the limit set by CARB. In California, therefore, these alternative solvents could not be used legally in a remover.

There are a variety of other solvents that could be tested and would likely be effective, perhaps more effective than acetone, in removing nail polish. These solvents, however, are toxic in certain ways that make them unacceptable in this application. Methylene chloride would likely be a very effective solvent for removing UV/LED light cured gel polish in particular. The chemical is a carcinogen and should never be used in this or any other application for that reason. It would likely also dissolve the nails and be extremely painful on the skin.

Benzyl alcohol is another solvent which might be effective for removing polish. The chemical has been tested for carcinogenicity and was found to be negative. IRTA has tested this solvent extensively as an alternative to methylene chloride in paint stripping and graffiti removal. Although it is effective and reasonable to use in those applications, it would not be acceptable as an ingredient in a nail polish remover. Benzyl alcohol is a skin sensitizer and would not be appropriate for use directly on nails or skin.

N-methyl pyrrolidone (NMP) is another solvent that might be technically suited for nail polish removal. Although it does not work well for removing cross linked paint and would not likely be suitable for UV/LED gel polish removal, it would probably work for removing regular and hybrid polish. The chemical is a reproductive and developmental toxin, however, and should not be used in this or any other application for that reason.

IRTA rejected methylene chloride, benzyl alcohol and NMP when considering alternatives in this application for the reasons given above. IRTA did examine other classes of solvents and individual solvents as potential candidates and these are discussed below. The criteria were that the alternatives must be low in toxicity and have a toxicity profile that would not preclude their use on peoples' skin and nails and that they meet the VOC content limit for nail polish removers in the CARB regulation. In addition, the removers had to be capable of removing polishes, taking into account the characteristics of requirements in salons and by consumers.

One solvent that could serve as an alternative to acetone is methyl acetate. This chemical is actually used in some non-acetone nail polish removers that are on the market. IRTA tested this ingredient and it is not quite as effective as acetone in removing regular polish. The chemical is exempt from VOC regulations so it has a zero VOC content. It would therefore be acceptable as an alternative since it would meet the VOC limit of the CARB regulation. Methyl acetate, however, has similar physical characteristics to acetone. It evaporates roughly as quickly as acetone which means its concentration in salons would be high. It has CNS effects and is more acutely toxic than acetone. Because of its high evaporation rate, it is likely it would dry out the nails and make them brittle just as acetone does. It is also more expensive than acetone. For these reasons, IRTA rejected the chemical since it would replace a chemical that is less toxic and have the same disadvantages.

A class of solvent that could potentially be used as alternatives is low vapor pressure solvents. These are solvents that don't evaporate readily so they would not dry out the nails or make them brittle like acetone or other fast evaporating volatile solvents. In screening tests, IRTA tested numerous low vapor pressure solvents to determine if they were capable of removing nail polish in a reasonable period of time. The tests of these solvents are discussed below.

IRTA also investigated water-based materials to determine if a process where they could be used for nail polish removal could be devised. IRTA had substantial experience in testing water-based materials for cleaning applications of all kinds. Water-based materials are more effective at higher temperature and with agitation. IRTA investigated and tested some water-based processes to see if they could effectively remove polish and these are also discussed below.

Finally, IRTA had worked with graffiti removal methods extensively and abrasive methods were very effective for removing certain types of graffiti. IRTA also investigated whether abrasive or mechanical methods could be used for polish remover. This effort is discussed below as well.

3.2.1. Water-Based Removal Processes

Somewhat before IRTA's project was initiated, IRTA became aware of a new surfactant that was being marketed. It appeared to be very powerful and was advertised as being appropriate for graffiti and adhesive removal. IRTA tested this surfactant, which is called Stepasol MET-10U, extensively in a variety of different ways to determine if it offered promise. Surfactants are like soaps and they are diluted in water at various concentrations. In general, the higher the surfactant concentration, the more powerful the cleaning process is. Another method of enhancing cleaning capability is to heat the water-based cleaner. Yet another method is to use mechanical agitation of the water cleaning solution.

IRTA conducted a variety of tests to investigate the efficacy of using the new surfactant in a water-based process for nail polish removal. IRTA first tested the surfactant at full concentration on regular nail polish and hybrid polish. Although it did work, it took longer than acetone and it would have required a rinsing operation to remove the thick oily residue that remained. There did not seem to be any advantage in using the surfactant for regular polish removal so IRTA rejected it for these types of polish.

IRTA conducted tests with the surfactant in a range of different concentrations in water in an ultrasonic cleaning system for removing gel polish. Since gel polish removal takes much longer and is more complex, IRTA thought perhaps a water-based process might be effective there. IRTA conducted testing with a company called eChem who offers ultrasonic cleaning systems. These systems are one of the most aggressive cleaning methods for water cleaners; they rely on sound energy to remove contaminants and are highly effective for parts with crevices or blind holes. A picture of the small benchtop ultrasonic cleaning system similar to those used for the testing is shown in Figure 3-1.

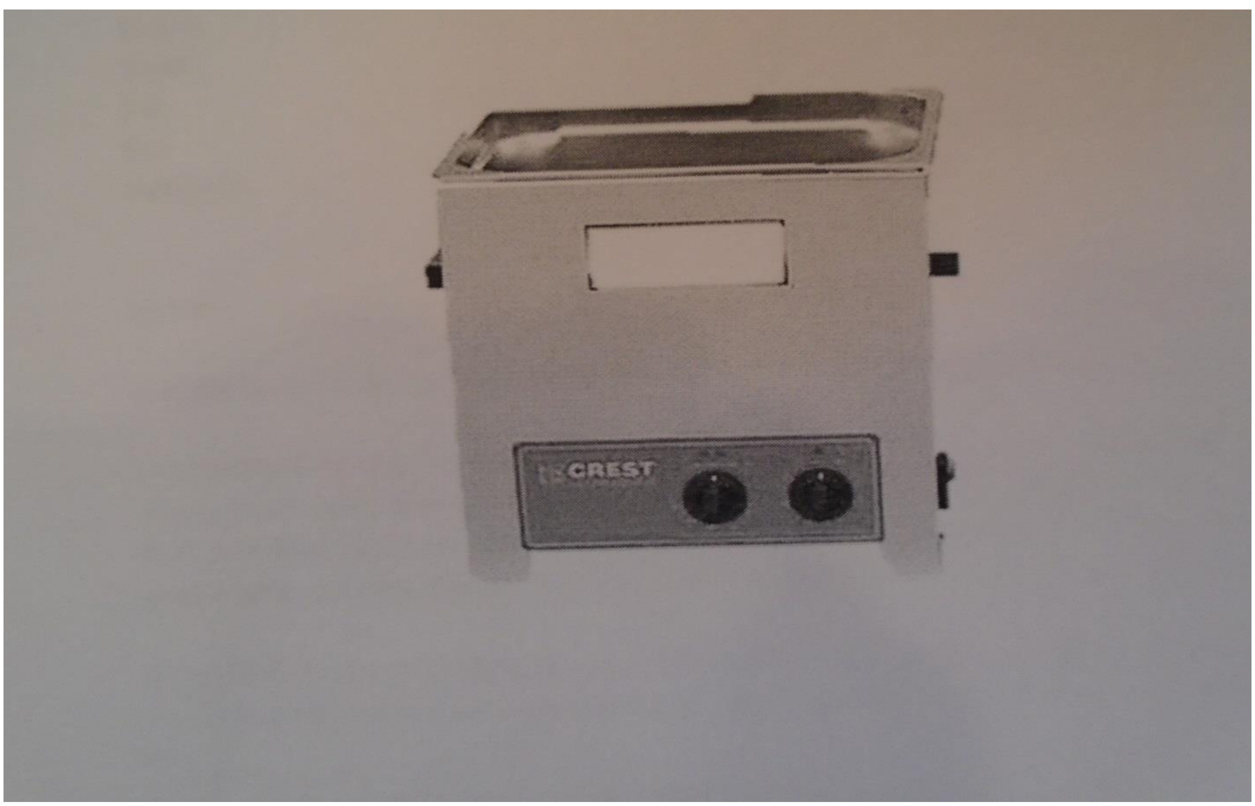

Figure 3-1. Ultrasonic System Used for Testing Water-Based Removers

The ultrasonic system includes a heater and IRTA also conducted removal tests at elevated temperature. In this case, since the hands would have to be placed in the heated formulation, the temperature could be no higher than about 110 degrees F, which is about the highest temperature a person can tolerate. IRTA later conducted a variety of tests in a small ultrasonic jewelry cleaner with a heated formulation. A picture of the jewelry cleaner is shown in Figure 3-2.

Figure 3-2. Ultrasonic Jewelry Cleaner Used for Testing Water-Based Removers

The surfactant, the heat from the process and the ultrasonic action seemed to help in softening the gel polish although it never did remove the polish altogether, no matter how long the immersion continued. IRTA did devise a process for removal, however. After about 10 minutes in the heated formulation with ultrasonics, the nails were dried with a hair dryer. A cuticle tool could then be used to lift up and push off the gel polish in one to about three sections. IRTA concluded that the action softened the polish and apparently loosened the bond with the nail.

At that stage, IRTA obtained information from a toxicologist that indicated there could be a toxicity problem with the MET-10U. Since this process required immersing the fingers in a highly concentrated formulation of the surfactant, IRTA eliminated this chemical from further consideration. IRTA had tested a few other surfactants as well and none was especially effective for removing gel polish.

3.2.2. Abrasive Removal Methods

IRTA conducted a preliminary evaluation of abrasive methods to determine whether they held any possible promise for removing polish. The simplest and first abrasive removal method IRTA considered would be to use something like a nail file to abrade the polish from the surface of the nail. IRTA had conducted some tests with acetone to try to remove regular polish containing glitter and acetone removal was not especially effective. In fact, heavily glittered regular polish actually has to be removed physically by filing it off. False nails, which are also used widely, also often require filing for complete removal. In discussions with salons and consumers, it became obvious that people would not be willing to use abrasive methods exclusively to remove polish because of potential damage to the nails. IRTA rejected this approach for this reason.

The second abrasive removal method IRTA considered was to use an abrasive media with a small tool designed for the purpose of removing the polish. In paint stripping and graffiti removal, media of various types are used for blasting the paint or graffiti from the surface. Media that are used for this purpose include sand, plastic media, glass and sodium bicarbonate. IRTA rejected this approach for the same reason as filing. Even if a tool could be designed, the method could lead to nail damage.

The third method IRTA considered is actually a combination of abrasive and freeze removal. In paint stripping, cryogenic removal of the paint is used for hooks used to carry parts through a conveyorized paint line. The hooks become laden with many coats of paint after passing through the line several times. They are put into a chamber with liquid nitrogen. The freezing action causes the paint to contract more than the metal hooks and the paint matrix loosens. Media blasting is then used to completely remove the coatings. IRTA rejected the use of liquid nitrogen because the low temperatures would cause damage and be very painful.

Another method that relies on both low temperatures and abrasion is use of carbon dioxide snow. Small tools have been designed for delicate operations like removing conformal coatings from printed circuit board assemblies and semiconductors. Carbon dioxide, is propelled toward the coating and it creates a low temperature which shrinks the coating and it is propelled off by the abrasive action. The suppliers of this device were not interested in conducting any testing because of potential liability. The low temperatures created were not likely to be tolerable in any case.

3.2.3. Low Vapor Pressure Solvents

Low vapor pressure solvents offered the most promise as potential alternative nail polish remover ingredients. These are solvents that do not evaporate readily like acetone. IRTA thought that some of these materials might function well in unventilated spaces because the solvent concentration would not build up in the air as it does for acetone. Furthermore, many of these materials leave the nail with a more oily feel since they evaporate very slowly and this might keep the nails from drying out and becoming brittle.

The first solvent of this type IRTA tested was a soy based formulation. This material, called Soy Gold 2500 was developed for industrial cleaning and it is effective in removing asphalt and ink in the printing industry. Although it does not evaporate readily, it can be rinsed with water since it contains a high level of surfactant. IRTA also tested another soy material, in this case one that did not contain surfactants. The basis for both of these cleaners is methyl esters. They have extremely low VOC content and would meet the CARB VOC limit for removers of 1%. They are also low in toxicity.

IRTA conducted testing of the soy based products on regular and UV/LED light cured gel polish. The tests were unsuccessful. These products do not themselves remove polish of any kind. If they are combined with acetone, they will remove regular polish. In the case of the gel polish, the combination remover does not completely remove the polish but rather softens it, as was the case with the water-based surfactant. The polish must them be removed with a tool. After the testing, IRTA concluded that soy based materials are not effective removers on their own and would not help in the removal process. IRTA then moved on to test other low vapor pressure solvents.

IRTA tested a variety of other ester based products that are similar to soy. IRTA also tested several other types of low vapor pressure solvents, including carbonates. These materials, in contrast to the soy methyl esters, were capable of removing regular and hybrid polish on their own. They were slower in the removal than acetone, however. In the case of the gel light cured polish, these materials again softened the polish but it still had to be removed with a tool.

3.2.4. Low Vapor Pressure Solvent/Acetone Blends

When IRTA combined some of the low vapor pressure solvents with acetone, the removal process for regular and hybrid polish went more quickly, almost as quickly as with plain acetone. The removal process for gel light cured polish was also enhanced but the tool still needed to be used for full removal within the same removal time frame. IRTA settled on two of the blends and conducted testing with a variety of different consumers and four salons. The results of the testing are described in the next section.

3.3. Alternatives Testing

IRTA's screening tests of alternatives were all performed on an IRTA staff member on regular, hybrid and light cured gel polish. The two best performing formulations were then tested on two different sets of consumers and four salons to obtain further input on their performance. Samples of one of the formulations, the one that worked slightly faster, were also provided to 18 additional salons and a few of these salons provided feedback. This testing is described below.

3.3.1. First Consumer Group

One of the consumers in the first group preferred one of the low vapor pressure solvents without the acetone added. Even though it was much slower in removing the polish, she liked the way it left her nails lubricated. IRTA provided larger quantities of the remover and she tested it a number of different times on gel and hybrid polish. Even though she had to use a tool for complete removal of the gel polish, she liked the remover better than plain acetone.

IRTA tested the two different blends of low vapor pressure solvents with acetone with this consumer and another consumer for regular polish removal. Blend #1 was a blend of a carbonate and acetone and blend #2 was a blend of an ester and acetone. Safety Data Sheets (SDSs) for these two removers, called "Reduced Acetone Nail Polish Remover Formula 1" and "Reduced Acetone Nail Polish Remover Formula 2" respectively, are shown in Appendix A. This same consumer described above preferred blend #2 which contained the same ingredient she liked without the acetone. The other consumer liked blend #1 better because it removed regular polish slightly faster than the other blend. IRTA monitored the testing and observed that blend #1 did work slightly faster on regular polish. This confirmed the findings with the IRTA staff member's testing. Both consumers commented on the fact that the alternative polishes did not dry out the nails like their traditional remover did. They cited this as a strong advantage.

3.3.2. Second Consumer Group

IRTA conducted testing with two women who constituted the second consumer group on both gel light cured polish and regular polish. Both had the two types of polish on their hands and feet. Pictures of the tests that were conducted are shown in Figure 3-3 through 3-6. For the regular polish, the two consumers indicated that both blends worked extremely well. They used the tool for removal of the gel light cured polish after it had been softened by the two blends. Both of them indicated that they would use the tool for the removal and did not view it as a disadvantage. Both of them also mentioned they liked the way it made the nails feel in contrast to the feel of the nails with traditional remover. A distinct advantage seemed to be that the nails were not as dried out and brittle as with traditional acetone remover.

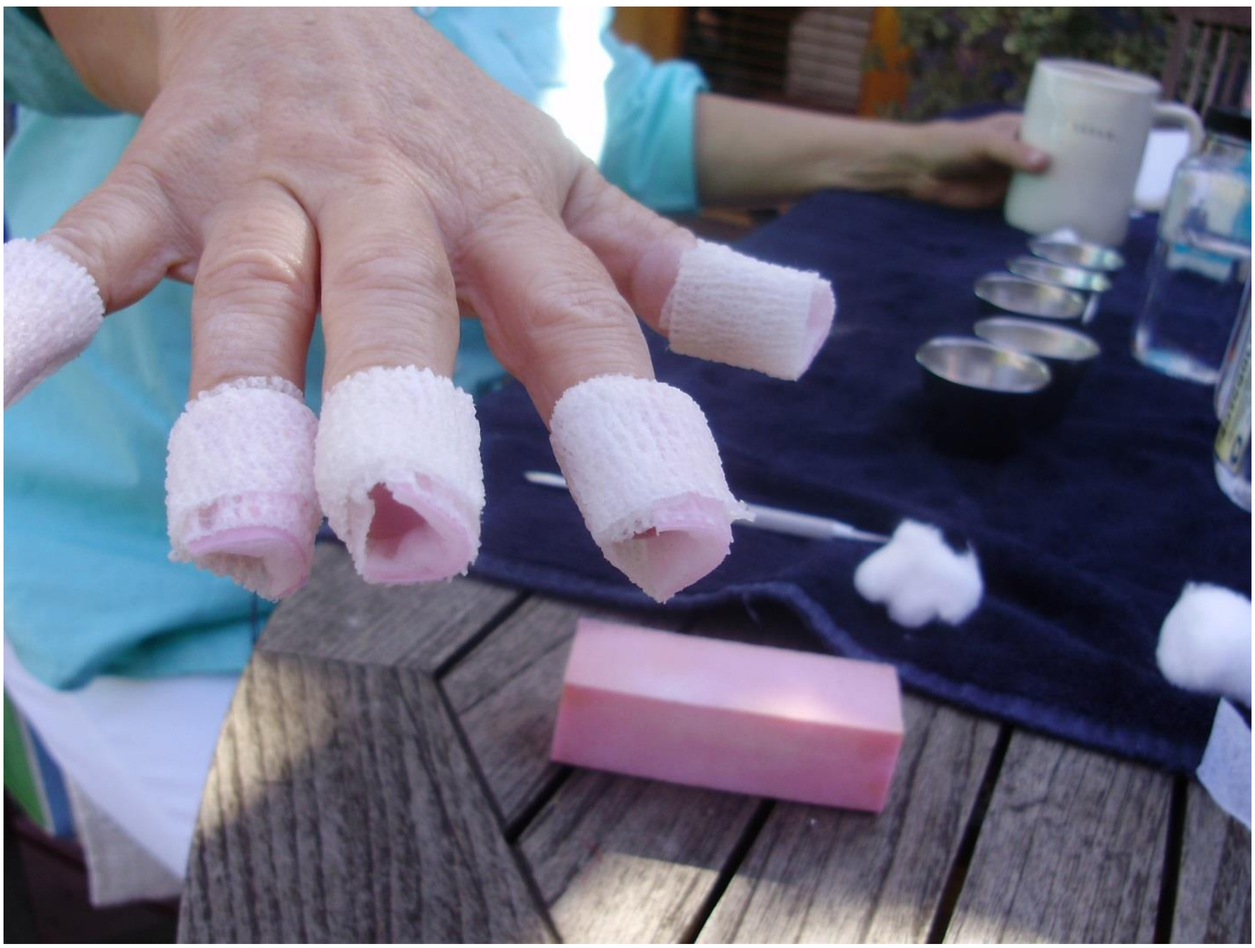

Figure 3-3. Tests of Alternatives for Gel Polish Removal with Consumers

Figure 3-4. Tests of Alternatives for Regular Polish Removal with Consumers

Figure 3-5. Additional Tests of Alternatives for Regular Polish Removal with Consumers


Figure 3-6. Alternative Formulations and Equipment for Tests with Consumers

3.3.3. Salon Testing

IRTA conducted testing with four salons, two in Southern California and two in Northern California. The salons included:

- Cute Nails in Santa Monica
- Hana Nails in Marina del Rey
- Diva Nails in Alameda
- Leann's Nails in Alameda

At Cute Nails, Diva Nails and Leann's Nails, IRTA had applied the polishes to an IRTA staff member the day before and asked the salon owners to participate in the removal process with the alternatives. In these three cases, IRTA tested the alternatives on both regular and gel light cured polish. The three salon owners indicated that the two alternatives seemed to work well on regular polish but they also indicated they would not be willing to use the tool for removal with the gel light cured polish. In further tests with one of the salons, the salon owner tested the two blends on an IRTA staff member and a staff member from the Collaborative. During these tests, the results indicated that one of the blends, blend #1, worked slightly faster than the other blend for removing regular polish. All of the salons indicated that the blends left the nails in better condition than traditional remover. IRTA provided larger quantities of both blends to one of the salons and the salon preferred one of the blends, again blend #1, that seemed to work slightly faster. Both blends were tested on regular and hybrid polish. Pictures of some of the testing in the three salons are shown in Figures 3-7 through 3-10.

Figure 3-7. Testing Alternatives with Owner at Leann's Nails

Figure 3-8. Alternative Formulation Testing at Salon

Figure 3-9. Testing Alternatives for Regular Polish Removal at Salon

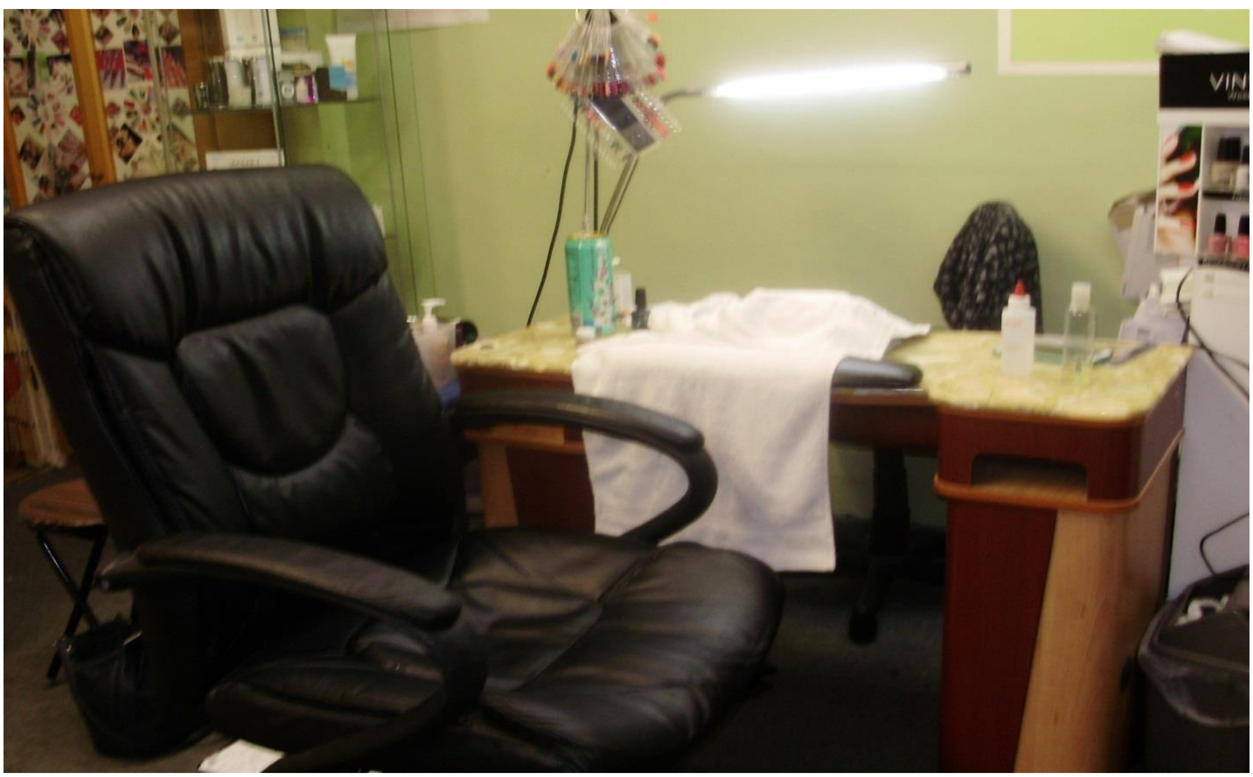

Figure 3-10. Testing Alternatives at Cute Nails

For the fourth salon, Hana Nails, IRTA provided larger quantities of both blends to the business successively for tests on regular polish. This salon also mentioned they liked the way the blends left the nails. They preferred one of the blends, again because it worked a little more quickly. This was blend #1, the same blend the consumers thought worked more quickly.

The tests with the salons brought IRTA to the conclusions that both blends were likely to be viable products for removing regular and hybrid polish. While these blends might be used by consumers for removing gel light cured polish, they would probably not be used in salons for that purpose. IRTA also concluded that both blends left the nails in better condition than traditional remover. Finally, IRTA also concluded that one of the blends worked slightly faster than the other blend in removing regular and hybrid polish.

3.3.4 Additional Salon Testing

IRTA provided eight ounce samples of the faster acting remover, blend #1, to 18 salons for testing on regular and hybrid polish; these salons attended a meeting held in Northern California and they are members of the Healthy Nail Salon Collaborative. IRTA demonstrated the removal capability for regular polish on an IRTA staff member at a Collaborative meeting and handed out the samples to the salons that attended the meeting. Collaborative members followed up with a few of the salons and they provided comments on the remover.

Two of the salons that attended the meeting, Diva Nails and Leann's Nails, had assisted IRTA in conducting the preliminary tests of the removers. They tested the eight ounce samples and indicated that the formulation performed well and that they liked it. Three workers at other salons also tested the formulation and they commented that the smell was much better than their conventional remover and that they left the nail with a shine. One additional salon owner also liked the formulation. He indicated that he used it for removing UV light cured gel polish and that it worked but took longer than plain acetone. He said he would use it for removing both regular and UV cured polish if he could purchase it. One additional salon owner had a negative comment. She said the formulation left a residue and that the customers would have to wash their hands before she could apply polish. As discussed in the next section, IRTA conducted adhesion tests to identify the best process for handling any residue and the findings indicated that polish could be applied again if the remover was wiped from the nail with a dry cloth. It is not clear why this salon had a different finding.

IV. Additional Tests and Cost Analysis

This section describes some additional testing IRTA conducted on the two candidate alternative nail polish removers to ensure they could be used as viable products for salons and consumers. This involved performing adhesion tests and evaporation tests on different containers and tops that might be used for the removers. These tests and the results are summarized below. Also in this section, IRTA discusses the two removers and describes their contents. IRTA also conducted a cost analysis and comparison to determine if the cost of the alternatives would be competitive if they were commercialized; the results of the cost analysis are presented and discussed in this section.

4.1. Adhesion Tests

IRTA believed it was very important to conduct adhesion tests on the candidate alternatives because of IRTA's experience in working with coatings. When coating a surface, the surface generally has to be free of contaminants—and particularly oil-based contaminants—so the coating will stick to the substrate that is being coated. Oily materials, if they are not removed can interfere with the adhesion. In this case, since the alternative ingredients evaporate less readily than acetone, they could leave a residue that would prevent good adhesion on the surface of the nail. IRTA wanted to devise the proper process for treating the nails after using the nail polish removers so the base coat of the new polish would stick to the nail when it was applied.

IRTA decided to use one of the same approaches that are used to test coating adhesion. This involves the use of a particular kind of tape called Permacel Tape. The procedure involves coating the surface, allowing the coating to dry or cure, pressing the tape with force to the surface and pulling it off. If there is coating residue on the tape when it is pulled off, then the adhesion to the substrate was not adequate. If there is only a very small residue of coating on the tape or no residue, then the adhesion was adequate.

IRTA first prepared four nails by applying one of the alternative polish removers with a cotton ball. IRTA then treated each of the nails in a different manner after applying the remover. The first nail was left as is and, in this case, whatever residue was on the nail was left intact. The second nail was wiped with a dry cloth. The third nail was wiped with a cloth containing plain water. The fourth nail was washed with dish soap and water, rinsed and dried.

The coat that is first applied to the nail after removal of the previously applied polish is the base coat. Since this is the first coat applied to the nail, it is the one that needs to adhere well. IRTA assumed that the subsequent color coats and top coats were designed to adhere to the coat below. IRTA then had to select a polish for testing and decided on using the base coat of a set of regular lacquer polish. The reasoning was that this base coat, which is an air dry base coat, would adhere less strongly to the nail than the base coat of a light cured gel polish. UV cured coatings are generally much more difficult to remove so this seemed to make sense. IRTA applied the regular polish base coat to the four nails that received the treatment described above and allowed it to cure overnight to ensure it would be fully cured.

IRTA then applied the tape to each of the nails. A picture of the Permacel tape used in the testing is shown in Figure 4-1. At this stage, IRTA realized that the test procedure was flawed. It was extremely difficult to determine whether there was a residue of the base coat on any of the pieces of tape because base coats are clear. One of the hybrid polish types, Sally Hansen Miracle Gel, does not have a base coat as such. The first color coat serves as the base coat. It is a lacquer regular polish color/base coat. IRTA decided to use this colored base coat which would show up on the tape if a residue was left on the surface. IRTA prepared the four nails in the same manner again and applied the base/color coat and let it cure overnight.

Figure 4-1. Permacel Tape Used in Adhesion Testing

IRTA conducted the testing with the tape the next day. IRTA conducted this test three different times with both of the candidate alternative removers. The results showed a pattern. The two treated nails where there were few, if any, color spots on the tape were the second and third nails. These are the nails where a dry cloth and a cloth wet with plain water were used to wipe the nail after applying the remover. In fact, for all four treated nails, there were very few color spots even for the first and fourth treated nails. Pictures of the tape with the residue from some of the treated nails are shown in Figures 4-2 through 4-4. This indicated that a good procedure would be to simply wipe the nail after applying the remover with a dry cloth. That should be sufficient to prepare the nail for application of new polish.

<u>4.2. Container Compatibility and Evaporation Tests</u>

The types of containers the candidate alternative removers should use needed to be investigated. IRTA determined that acetone removers are always sold in containers that are made of high density polyethylene (HDPE). IRTA examined compatibility information for the two low vapor pressure solvents used in the blends and found that both solvents were also compatible with HDPE. This verified that the containers to be evaluated in the cost analysis for the alternatives would have to be made of HDPE.

Figure 4-2. Base/Color Coat Applied for Adhesion Testing

Figure 4-3. Permacel Tape Applied to Base/Color Coat for Adhesion Testing

Figure 4-4. Residue Left on Permacel Tape from Adhesion Testing

Because the candidate alternatives are blends of acetone, a fast evaporating solvent, and a low vapor pressure slow evaporating solvent, IRTA was concerned that selective evaporation would occur. This means that the acetone could evaporate from the mixture selectively and the remaining formulation would lose some of its effectiveness over time. What this indicates is that it is important to use the removers in a container that allows only minimal evaporation.

Salons generally purchase their removers in gallon quantities. A picture of a gallon container with an acetone remover for a salon is shown in Figure 4-5; IRTA used this acetone for testing and the other testing equipment is shown in the picture as well. Salons either purchase the remover one gallon at a time or they purchase it in a four gallon case. The gallon containers are made of HDPE. In order to use the removers at technician tables when working on nails, salons pour the contents from the gallon containers into smaller containers that are generally eight ounces in volume. One of the most common smaller bottles used for applying remover in salons is a bottle with a flip spout dispensing cap. A picture of two of these bottles is shown in Figure 4-6. The bottle on the left has the flip spout open and the bottle on the right has it down or closed. To use the remover, salon workers raise the spout and apply the liquid to a cotton ball and use it to remove polish.

Figure 4-5. Gallon Container of Acetone Purchased by Salons

Figure 4-6. Bottles Used by Salons with Flip Spout Top Up and Down

Consumers generally purchase nail polish remover from beauty supply stores or drugstores. They also may purchase them online. The smaller containers in beauty supply stores, drugstores and online generally range from two ounces to eight ounces in size. Because many of them contain acetone, they are also made of HDPE. The smaller bottles generally have a common twist-open top. Although the bottle shape of the larger bottles often varies, the bottles most commonly have a twist lock dispensing cap. This cap can be opened or closed. When the cap is opened, the top of the bottle is turned and a cotton ball is placed on a surface which can be depressed and moved up and down. The bottle contains a pump and liquid is dispensed onto the cotton ball when the surface is pushed down. A picture of this type of bottle with the dispensing cap open is shown in Figure 4-7. Another picture of this type of bottle with the dispensing cap closed is shown in Figure 4-8.

IRTA purchased a few of these bottles with different removers in them. The caps broke easily and couldn't be opened after a few uses for some of the bottles. They also seemed to be wet with liquid often which indicated they were leaking readily. IRTA was wary of using bottles with this type of cap for the alternative removers because of concern about selective evaporation. IRTA believed that the bottles with the flip spout tops used by salons were better for containing the removers.

Figure 4-7. Twist Lock Bottle with Top Open

Figure 4-8. . Twist Lock Bottle with Top Closed

IRTA and the formulator IRTA worked with decided to conduct evaporation tests on bottles with the two different types of tops to determine if they varied. The tests were conducted on eight-ounce HDPE bottles with flip spout tops and four ounce HDPE bottles with twist lock tops. These sizes of bottle were selected because they were readily available.

Acetone served as a control in the testing and it was put into both the twist lock top bottles and the flip spout bottles. Each of the two alternative removers was put into the two different types of bottles. When the bottles were filled, about one inch of headspace was left at the top of each of the bottles. The bottles were tightly capped and stored in a warehouse area to simulate storage conditions. They were then weighed. The bottles were opened for one hour each day for the 32 day duration of the testing. This was meant to simulate use of the remover in a salon for removing nail polish on a daily basis. After the bottles were opened each day, they were again tightly closed and weighed. The bottles were weighed before and after the test period to determine how much of the formulation would evaporate. Two additional bottles containing each of the alternative formulations were tested in a bottle with a flip spout top that remained closed for the duration of the test.

After 10 days of testing, the twist cap on the acetone control twist lock bottle broke. The twist lock bottle containing one of the formulations began leaking after 19 days. This verified IRTA's belief that the twist lock bottles were not the best container for the alternative removers or for any other removers for that matter.

The results of the testing are presented in Table 4-1. The table shows the product and type of bottle, the weight of the bottle and liquid in grams at the start of the testing, the weight of the bottle and liquid in grams at the end of the testing, the weight loss in grams and the percentage loss. TL represents twist lock and FS represents flip spout.

Table 4-1
Results of the Evaporation Tests for Bottles with Twist Lock and Flip Spout Caps

Product	Type of Top	Initial Weight (grams)	Final Weight (grams)	Weight Loss (grams)	Percentage Weight Loss (%)
Acetone Control	TL	110.3	102.7	7.6	6.9
Acetone Control	FS	195.5	192.8	2.7	1.4
Blend #1	TL	133.7	120.0	13.7	10.2
Blend #2	TL	128.7	124.9	3.8	3.4
Blend #1	FS	254.1	253.4	0.7	0.3
Blend #2	FS	245.6	244.8	0.8	0.3
Blend #1 Unopened	FS	205.8	205.4	0.4	0.2
Blend #2 Unopened	FS	214.3	213.9	0.4	0.2

Note: TL is twist lock and FS is flip spout

The bottles with the twist lock top have a lower weight before and after than the bottles with the flip spout top. This is expected since the twist lock bottle types are four ounce bottles and the flip spout bottle types are eight ounce bottles. The twist lock bottles, in all cases, show a higher percentage loss than the flip spout bottles. This means that the bottles with the twist lock top allow significantly more emissions than the bottles with the flip spout top. The twist lock cap on the acetone control bottle broke after 10 days of testing. The twist lock bottle containing Blend #1 began leaking after 19 days. The results clearly indicate that the best choice of bottle type is one with a flip spout top.

After the testing was completed, IRTA wanted to test all of the alternative formulations to determine if they still worked effectively. This would indicate that, even if the alternative blends were used in a bottle with a more emitting twist lock top, they would still function well. These tests indicated that the blends still performed well in spite of the evaporation. This suggests that even if salons use were to pour their blends into bottles with twist lock tops, the blends would continue to be effective even if there was evaporation. This was encouraging since some salons do use twist lock bottles for dispensing remover.

4.3. Discussion of Alternative Formulations

The SDSs in Appendix A show the ingredients in each of the two alternative removers. Blend #1 is a combination of acetone and a carbonate. Blend #2 is a combination of acetone and an ester. Blend #1 performs slightly faster than Blend #2. One consumer, however, preferred Blend #2 in spite of its slower acting time. It is possible that some salons and consumers would like this blend better.

IRTA consulted with a toxicologist as part of the project to ensure that the ingredients in the removers were safe for the intended use. The toxicologist, who has evaluated the toxicity of acetone for IRTA in the past, reiterated that acetone is low in toxicity. She reviewed the available toxicity data on the ester and the carbonate and indicated there is no reason to believe that these ingredients would be a problem in this use based on the existing toxicity information. Both ingredients are already used in other cosmetics products.

In using the blends there would be two significant advantages. First, because the second ingredients are low vapor pressure solvents and more oily, they do not dry out or make the nails brittle like plain acetone. Second, the low vapor pressure solvents prevent the high evaporation of the solvent in an unventilated workplace so the CNS effects of the removers should be less than the CNS effects of plain acetone removers.

Since the alternative formulations contain a low vapor pressure solvent in addition to acetone, they are likely to evaporate more slowly than plain acetone removers. This could translate into a lower usage rate than pure acetone for salons and consumers. To take this into account, IRTA examined the effects on the cost analysis of assuming the same usage rate as pure acetone and one slightly lower usage rate than for pure acetone.

4.4. Cost Analysis and Comparison

IRTA wanted to determine whether the two alternative removers would be viable products from a cost standpoint if they were commercialized. This involves evaluating the raw materials and packaging cost under the assumption that a cosmetics packaging company would package the materials. This cost generally includes the cost of the label, the container and the cap. It also includes a cost for filling and packaging the containers. This cost needs to be compared with the same cost elements for a plain acetone remover. This comparative analysis would give an indication of whether the alternatives would be more or less costly than plain acetone removers.

The cost of the containers can vary widely, depending on the size, material and configuration. IRTA evaluated the cost for large one-gallon and four one-gallon cases that would be purchased by salons and eight ounce containers with a flip spout top that would be purchased by a consumer at a drugstore, beauty supply store or online. All of the containers were assumed to be made of HDPE. The analysis for salons and consumers are each discussed below.

4.4.1. Salon Remover Cost Analysis

As mentioned above, salons purchase their remover in large one gallon or four gallon case quantities. They then pour them into smaller bottles for use in removing polish. Generally, salons purchase pure acetone because it is the most effective solvent for removing regular, hybrid and UV light cured gel polish. IRTA compared the cost of purchasing the alternatives to the cost of purchasing acetone.

4.4.1.1. Raw Materials Cost

IRTA obtained prices of the raw materials from suppliers of the chemicals. It was assumed that the blender would purchase the chemicals in drum quantities. On that basis, the price of acetone is 62 cents per pound for a 364 pound drum. Assuming a density for acetone of 6.62 pounds per gallon, the cost of one gallon of acetone would be $4.10.

Alternative formulation #1 is a blend of acetone and a carbonate. Assuming the formulation makeup and taking into account the densities of the components, the raw materials cost for one gallon of formulation #1 is $8.84. Using the same procedure for alternative formulation #2, a blend of acetone and an ester, the cost of one gallon would be $10.18. Both of these costs are significantly higher than the raw materials cost of one gallon of plain acetone as expected.

4.4.1.2. Container and Labeling Cost

Other costs that must be included in the analysis are the cost of the gallon containers, the packaging for the four one-gallon cases and the label cost. IRTA obtained the cost of one-gallon containers in a natural color from a container company. The price of the gallon containers is 66 cents each for a minimum 5,000 container purchase. The price of the caps is 5.5 cents each for the same minimum number. The total cost of the container and cap is about 72 cents. The cost of the cardboard container for holding the four one-gallon bottles is $0.993 for the four gallon case and the cost of the cardboard partition that separates the gallon containers is $0.392. Both of these costs are for a minimum order of 5,000. This is the cost for the cardboard packaging for the four bottle case. The cost amounts to about $0.35 per one gallon container.

The label for the gallon containers is sealed paper label applied to the gallon containers. The container company estimates this cost at $206.25 per thousand for an order of 5,000. This translates into a cost of about $0.21 per gallon.

4.4.1.3. Total Materials and Labeling cost

The materials and labeling cost represent the cost of the ingredients and packaging before taking into account the filling cost charged by the cosmetics company. The acetone raw materials cost is $4.10 per gallon. The container cost is $0.72, the cost of the case is $0.35 and the labeling cost is about $0.21 per bottle. This leads to a cost of $5.38 for the plain acetone formulation.

The materials cost for formulation #1 is $8.84 and the materials cost for formulation #2 is higher, at $10.18 per gallon. In both cases, the gallon containers would cost $0.72, the cardboard contain would cost $0.35 and the label would cost $0.21. On this basis, the total materials and labeling cost for formulation #1 is $10.12 and for formulation #2, it is $11.46.

4.4.1.4. Filling Cost

IRTA obtained information on the filling costs for gallon containers from a cosmetic products packager. This is the cost the filler charges based on obtaining all of the materials from the supplier, including the packaging and the chemicals. For gallon containers, this cost would amount to $0.50 per gallon based on filling 5,000 units.

4.4.1.5. Total Cost Comparison for Salons

Table 4-2 summarizes the costs for purchasing remover in one gallon containers for acetone and the two alternative formulations. The values indicate that the price of the alternatives is higher than the price of acetone. This follows from the fact that the raw materials price of the acetone is higher than the raw materials price of the alternatives. As described earlier, the salons preferred alternative #1 over plain acetone because it lubricated the nails more than plain acetone and did not dry the nails out and make them brittle. Salons would purchase the alternative removers if this preference was sufficient to outweigh the higher cost.

The values show that the total cost of alternative #1 is 81 percent higher than the total cost of acetone. The cost of alternative #2 is more than twice the cost of acetone. These values exclude any profit the supplier takes in selling the product and the actual prices paid by the salons would be higher for this reason. A

Table 4-2
Cost Comparison for Salons for Gallon Containers

Remover	Raw Materials Cost	Container, Cardboard and Labeling Cost	Filling Cost	Total Cost
Acetone	$4.10	$1.28	$0.50	$5.88
Alternative #1	$8.84	$1.28	$0.50	$10.62
Alternative #2	$10.18	$1.28	$0.50	$11.96

reasonable profit might range between 20 and 30 percent so the prices paid for the three different types of products might be higher by this amount.

The cost analysis presented here is based on purchasing drum quantities of raw materials and minimums of 5,000 for the bottles, labeling and filling. In most cases, the cost of an established product would be based on much higher raw materials purchase volumes, like multiple drums or tank quantities. Costs would also be based on purchases of many thousands of containers, labels and filling units. The actual cost or all three products, acetone and the two alternatives, would be much lower for the much higher quantity purchases. On a comparative basis, however, roughly the same percentage difference in cost would likely still apply. This means that the alternative products would be higher cost than the acetone under any comparative scenario simply because of the relatively higher raw materials cost.

<u>4.4.1.6. Comparison with Prices Paid by Salons</u>

IRTA obtained information on the purchase habits of three different salons. Salon #1 purchases one case containing four one-gallon bottles every two months from a large beauty supply chain called Skylark Nail & Beauty Supplies located in Garden Grove, California. The cost of the remover is $8 per gallon and the total annual cost of purchasing 24 gallons of remover for the salon amounts to $192 per year.

Salon #2 purchases one four-gallon case every month for a total of 12 cases or 48 gallons per year. This salon purchases remover from the same source as Salon #1. The cost for this salon is $6 or $7 per gallon. Assuming a cost of $6.50 per gallon, the annual cost of purchasing the remover is $312.

Salon #3 purchases ten gallons of remover once a year in individual gallon quantities. This salon purchases the remover online and pays a price of $5 per gallon. On this basis, the annual cost of purchasing the remover for this salon is $50.

The prices paid by these salons range from $5 to $8 per gallon. These prices can be compared with the price for the acetone remover in Table 4-2. There are three reasons that suppliers may be able to reduce the price of acetone in gallon containers lower. First, they may purchase the acetone in totes or multiple drums prior to any blending. The price of chemicals is much lower when they are purchased in very high quantities. In this case, the raw materials price for acetone could be much lower than the 62 cents per pound used in the analysis presented in Table 4-2. For instance, if the carbonate were purchased in one drum quantities, the cost would be $1.28 per pound; if it were purchased in four drum or more quantities, the price would be lower, at $1.18 per pound. Second, the costs for the packaging, labels and filling could be significantly lower if many thousands of units are processed. Third, the suppliers of remover may actually discount the gallons of acetone below their costs if they also offer several other types of nail products. In many industries, this is a common marketing strategy. Certain products are discounted to below cost because the vast majority of the company's profits come from selling other products that have a much higher profit margin.

If the company marketing the alternative removers developed here were to purchase the ingredients in much larger quantities or if the company also supplied a range of other nail products, the alternatives could be discounted like the acetone removers mentioned here. Table 4-2 nevertheless is a reasonable cost comparison because the same assumptions are used for developing the costs of the plain acetone remover and the alternative removers. The bottom line is that the alternatives are more expensive in gallon quantities. Some salons may purchase the alternative removers, however, because the owners believe the technical and safety advantages make them worth it.

4.4.1.7. Salon Cost Analysis Assuming Lower Use

The two alternative blends developed during this project are based on acetone and a much lower vapor pressure solvent in both cases. The other solvents have a much lower evaporation rate than acetone and they will act to inhibit the evaporation of acetone to some extent. This is verified by the input from salon workers and consumers that the alternative does not smell whereas acetone remover does. The lower evaporation rate means that salons could end up using less nail polish remover if they converted to the alternatives.

The three salons described above purchase 10, 24 and 48 gallons of remover each year. The total cost of purchasing the acetone remover ranges from $50 to $312 annually. If these salons converted to alternative #1, the best performing alternative, they might be able to purchase less remover based on the lower evaporation rate of the material. The results of the evaporation tests for the twist lock and flip spout bottles were provided in Table 4-1. One of the twist lock bottles broke during the testing and another began leaking. Assuming the data on the losses for the twist lock bottle are more reliable, the percentage weight loss for the acetone control was 1.4%. The percentage weight loss for both Blend #1 and Blend #2 was much less, at 0.3%. The percentage loss for the alternative blends was almost five times less.

The cost analysis indicates that the base cost of alternative #1 is 81% higher than the base cost of acetone remover evaluated using the same assumptions. This means that the cost of purchasing remover could still increase, depending on how much lower the actual use losses were but it would increase less than expected because of the lower evaporation rate.

As an example, consider the salon that purchases 24 gallons per year of acetone remover at a total cost of $192 per year. Under the assumptions used in the cost comparison, the alternative remover would be priced 81% higher for a total cost of remover of $347.52 per year. The actual loss during the evaporation tests for Blend #1 in the flip spout bottle was five times less than the loss from the acetone control. To be conservative, it might be assumed that the loss of the alternative would be 20% less than the loss of acetone. Making this assumption, the cost of purchasing the alternative remover would be lower, at about $278.02 per year. The cost increase for purchasing the alternative remover instead of the acetone remover in this case is 45%. If use of the alternative were even lower, say a 50% reduction, then the cost of purchasing the alternative blend would be lower, at $173.76 per year, than the cost of purchasing the acetone.

It is difficult to know at this point how much use would decline if salons adopted the alternative. It is not unreasonable, however, to assume there would be a reduction in use of remover with conversion to the alternative. It is unlikely use would decline enough to offset the price increase but, at least, the price increase could be less than assumed in the relative cost comparison in Table 4-2.

4.4.2. Consumer Remover Cost Analysis

As discussed earlier, consumers generally purchase their nail polish remover from drug stores, beauty supply stores or online. They purchase remover in much smaller quantities than salons and the size of the containers ranges from two ounces to eight ounces and sometimes as much as 32 ounces. In this case, IRTA determined the cost to consumers of purchasing the alternative removers in eight ounce containers and compared it to the cost of purchasing acetone or higher end removers in the same size container.

4.4.2.1. Raw Materials Cost

The cost of the raw materials, in this case, is the same as the cost of the raw materials for the salon case. This indicates that the price of acetone is 62 cents per pound for a 364 pound drum. The cost of eight ounces of acetone or half a pound amounts to 31 cents. It's worth noting that for the consumer sector, many suppliers blend in a variety of other ingredients with acetone in remover. These ingredients often include things like Vitamin E, glycerin, gelatin, oils like flaxseed or apricot kernel and fragrances. When these ingredients are included, the raw materials cost of the remover is higher since even small quantities of these materials are much more expensive than acetone which is a commodity chemical. For this comparison, IRTA is assuming no other ingredients are added which is the lowest possible cost for the acetone remover.

Alternative formulation #1 is a blend of acetone and a carbonate. Assuming the formulation makeup, the raw materials cost for eight ounces of formulation #1 is about 55 cents. Using the same procedure for alternative formulation #2, a blend of acetone and an ester, the cost of eight ounces is about 64 cents. Again the raw materials cost of the alternatives are significantly higher than the cost of raw materials for plain acetone.

4.4.2.2. Container and Labeling Cost

Other costs that must be included in the analysis are the cost of the eight ounce container, the cost of the flip spout caps and the label printing cost. IRTA obtained the cost of an eight ounce bottle called a Boston Round from a container company. A picture of a Boston Round bottle is shown in Figure 4-9. The price of the eight ounce bottles is $202.25 per thousand for a minimum 5,000 container purchase. The price of the flip spout caps is $149 per thousand. The printing process used for the eight ounce containers is screen printing the label directly on the bottle. The container company estimates this cost at $83 per thousand. The total cost is $434.25 per thousand or 43.425 cents per bottle.

4.4.2.3. Total Materials and Labeling cost

The materials and labeling cost represents the cost of the ingredients and packaging before the containers are filled. The acetone raw materials cost is 31 cents per eight ounce container. The container and labeling cost is about 43 cents per container. This leads to a cost of roughly 74 cents for the plain acetone formulation.

The materials cost for formulation #1 is 55 cents and the materials cost for formulation #2 is higher, at 64 cents per eight ounces. In both cases, the container and label cost would be the same as it is for acetone. On this basis, the total materials and labeling cost for formulation #1 is about $0.98 and for formulation #2, it is $1.07 per container.

Figure 4-9. Boston Round Bottle with Flip Spout Top

4.4.2.4. Filling Cost

IRTA obtained an estimate of the filling cost from a packager, again under the assumption that the raw materials, the packages with labels and tops would be provided to the filler. The filling is estimated at $0.37 per eight ounce container. For the acetone, the total cost amounts to $1.11; for alternative #1 and alternative #2, the total cost is $1.35 and $1.44 respectively

4.4.2.5. Total Cost Comparison for Consumers

Table 4-3 summarizes the costs of purchasing remover in eight ounce Boston Round bottles for acetone and the two alternative formulations. The values again indicate that the total cost of the alternatives is higher than the price of acetone. The total cost of alternative #1, the alternative that works slightly more effectively than alternative #2 is about 24% higher than the total cost of acetone. The total cost of alternative #2 is 30% higher than the total cost of the acetone product. Again, this results from the fact that the raw materials price of the other ingredients is higher than the raw materials price of the acetone. The costs given in the table reflect the potential cost of the alternatives based on the assumption that there is no profit markup. As discussed below, the profit markup for removers sold to consumers can be very high.

Table 4-3
Cost Comparison for Consumers for Eight Ounce Container

Remover	Raw Materials Cost	Container, Top and Labeling Cost	Filling Cost	Total Cost
Acetone	$0.31	$0.43	$0.37	$1.11
Alternative #1	$0.55	$0.43	$0.37	$1.35
Alternative #2	$0.64	$0.43	$0.37	$1.44

4.4.2.6. Comparison with Remover Prices Paid by Consumers

IRTA investigated the prices of nail polish removers available in drug stores, beauty supply stores and online in a range of different size containers. These are summarized in Table 4-4. The table also shows the prices for each remover normalized to an eight ounce container. The prices in the table for an equivalent eight ounce container range from $1.29 to $18.40. Only the Target acetone based remover has a lower price than the total costs for the alternatives tested in this project given in Table 4-3. This indicates that the profit markup by the supplier for currently available products is very high. It also suggests that both alternatives developed during this project could be priced competitively for consumers in the market.

Table 4-4
Market Prices of Various Nail Polish Removers

Remover Description	Container Size	Price	Price for Equivalent Eight Ounce Container
Target Up and Up Strengthening Nail Polish Remover (acetone base)	6 Ounces	$0.97	$1.29
Cutex Advanced Revival Nail Polish Remover (acetone base)	10 Ounces	$3.49	$2.79
Sally Hansen Nail Polish Remover Strengthening (unknown base)	5 Ounces	$3.81	$6.10
Sally Hansen Nail Polish Remover Acetone Free	5 Ounces	$3.81	$6.10
Manicure Nail Polish Remover (non-acetone base)	2 Ounces	$3.99	$15.96
Cutex Nail Polish Remover Strengthening (unknown base)	3.4 Ounces	$3.83	$9.01
Cutex Nail Polish Remover Nourishing	3.4 Ounces	$3.83	$9.01
Manicure Nail Polish Remover Super Fast Enriched with Tea Tree (unknown base)	4.24 Ounces	$5.99	$11.30
Zoya Remove Plus Nail Polish Remover	2 Ounces	$4.60	$18.40

(unknown base)			
Zoya Remove Plus Big Flipper Polish Remover (unknown base)	8 Ounces	$9.99	$9.99
Zoya Remove Plus Nail Polish Remover (unknown base)	32 Ounces	$25	$6.25

V. Health and Environmental Effects of Nail Polish and Nail Polish Remover

As discussed and demonstrated in earlier sections, nail polish and nail polish remover are intimately related. The type of removal process that is used depends on the type of polish that is being removed. This section focuses first on the toxicity issues that may arise with the type of nail polish used. The section then addresses the toxicity issues of nail polish removers.

5.1. Nail Polish Toxicity Issues

There has been a lot of attention given to the exposure of salon workers to hazardous substances in the products they use in the normal course of their tasks. A New York Times article, in particular, focused the general public on the challenges salon workers face in being exposed to toxic chemicals on an ongoing daily basis (New York Times, 2015). The Healthy Nail Salon Collaborative has also put the spotlight on the issue by developing their “three free” program that singles out a so-called Toxic Trio. This program called on salons to voluntarily stop using three especially toxic chemicals. These included toluene, a solvent used in nail polishes and removers; formaldehyde, used in polishes; and dibutyl phthalate, a plasticizer used in polish (www.cahealthynailsalons.org). Many salons did discontinue the use of these chemicals but a study by the California Department of Toxic Substances Control (DTSC), which analyzed several different nail products, found that some of the supposedly “three free” products still contain one or more of the three identified chemicals (DTSC, 2012). Salons may not have been aware they were still purchasing the products. Although programs like the “three free” effort are commendable, there are still numerous toxic components salon workers come in contact with regularly. As discussed later in this section, two California regulatory agencies in particular may have the authority to ban certain types of ingredients although none has done so to date.

5.1.1. Comparison of Lacquer and Gel Light Cured Polish

Many salon owners are aware they are exposed to toxic substances on a daily basis and many are greatly concerned about offering a better workplace environment for themselves and their workers. In recent years, gel light cured polish came on the market and was adopted widely by salon customers because of its durability. Salon workers also liked the new type of polish because they believed it was less toxic than regular lacquer polish. They thought the lacquer polish was dangerous because it contains solvents that evaporate quickly leaving a high concentration and odor of solvents in the workplace. Gel light cured polish does not contain solvents and most salon workers believe it is less dangerous for that reason.

The solvents in regular lacquer polish are generally ethyl acetate and butyl acetate which are not high in toxicity and they are not chronic toxicants. They do have a fairly strong odor, however, which is apparently the reason workers believe they are dangerous. Gel light cured polish does not rely on solvent evaporation for curing. Rather it contains monomers (or individual units) that combine with a photoinitiator (a light sensitive material) in the presence of a UV light. This starts a chemical reaction. The monomers in the coating, called acrylates, are very reactive and, when the photoinitiator and light start the reaction, the acrylates keep the reaction going until the monomers combine with one another repeatedly to form polymers or multiple units. The polymer is a hard sheet of cured polish.

The acrylates in the gel light cured polish are called methyl methacrylates (MMA) when they are in monomer form and polymethylmethyacrylates (PMMA) when they are polymerized. Many people have the impression that the MMA is a dangerous component and that once it polymerizes to PMMA, it no longer poses a danger. Recent research indicates that both MMA and PMMA can cause asthma and skin sensitization and allergic contact dermatitis. The health effects of PMMA are caused by residual MMA in the polymer which migrates out, and/or depolymerization of the polymer and release of MMA. (Quint, 2013).

More recently, another issue concerning regular lacquer polish has emerged. The state of New York Department of Consumer Affairs analyzed 56 polishes to see if they contained a material called triphenyl phosphate (TPHP). Several brands of polish that were analyzed, including Sally Hansen, Essie, OPI, Revlon, Maybelline and a number of others, contained the chemical. TPHP is used in nail polish to improve its flexibility; it is also used in plastics manufacture. Researchers at the Environmental Working Group (EWG) and Duke University found that 10 to 14 hours after applying polish, the levels of a metabolite of TPHP in all 26 participants had increased by an average of nearly sevenfold. TPHP is suspected of being an endocrine disruptor and it could also contribute to weight gain and obesity. The EWG has a campaign to encourage several nail polish manufacturers to eliminate the use of the chemical (Mendelsohn et.al.,2016).

The removal processes for the two polish types also have to be considered in a comparison of the toxicity of the two polish types. As discussed earlier, lacquer polish is generally removed with acetone in a few seconds. In contrast, gel light cured polish requires wrapping with acetone contact or immersion for 10 to 15 minutes. There is no question that the removal process for gel light cured polish offers a greater toxicity risk.

Another risk posed to users of gel light cured polish is the potential for skin cancer through UV light exposure. Some organizations are beginning to recommend the use of sun screen for consumers and salon customers during gel light cured polish application.

Because of the acrylate toxicity, because of the onerous removal process and because of the potential skin cancer risk, use of gel light cured polish poses a high overall toxic risk to workers and consumers. Lacquer polishes that do not contain TPHP probably pose less of a risk to consumers and salon workers. Some would argue that because lacquer polish needs to be applied more often than gel light cured polish because it is less durable, it is actually more dangerous. Even taking into account the more frequent use and removal, however, the use of gel light cured polish poses a higher potential risk than lacquer polishes without TPHP. Companies offering lacquer polishes that do contain TPHP should remove the chemical from their products.

5.1.2. Comparison With Hybrid Polish

Taking these factors into account and also with the understanding that durability of gel light cured polish offers an advantage, IRTA investigated other types of nail polishes. IRTA noticed a new polish that was starting to be marketed to consumers in drugstores. It turned out to be a hybrid polish described earlier. It is called Sally Hansen Miracle Gel. It is composed of two coats, a color coat that also functions as a base coat and a topcoat. In general, a consumer would apply two of the color coats and the topcoat. IRTA investigated the polish further and found that the color coat is a regular lacquer polish material and the topcoat, which is cured with natural rather than UV light, contains acrylate copolymers. A few months later, other polishes of this type came onto the market. These include a product from OPI called Infinite Shine and a L’Oreal product called Gel-Lacque Nail 1-2-3. These two latter products are composed of a base coat, a color coat and a topcoat. Again, the topcoat is cured with natural light. Another two coat polish, made by Revlon, is also now available. It is likely that virtually all suppliers will eventually offer this type of polish.

The advantage offered by the hybrid polish is that it lasts much longer than regular lacquer polish before it needs to be removed and reapplied. It does not last as long as gel light cured polish, however. Gel light cured polish may last two weeks, the hybrid polish may last 1.5 weeks and regular polish generally lasts less than a week. The hybrid polish, therefore, has intermediate durability. Another advantage of the hybrid polish is that it can be removed in a few seconds just like lacquer polish. It is also less time consuming to apply since lights do not have to be used to cure each coat in turn. No lights are used at all and the polish "dries" quickly like lacquer polish. IRTA told several of the consumers IRTA worked with on the project to try this polish and four of them have converted to it. The salons IRTA is working with have also tried the hybrid polish and think it works well. IRTA consulted with a few beauty supply stores and sales of the hybrid polish have been brisk. Customers comment that it is easier to apply than UV cured gel polish.

When the information on TPHP became available, IRTA investigated the ingredient lists of the Sally Hansen Miracle Gel and the OPI Infinite Shine. Both types of hybrid polish contain TPHP. Although it is not clear what the function of TPHP is in the formulations, companies may have substituted it for dibutyl phthalate. This is a typical example of a regrettable substitution where one ingredient that is known to be hazardous is removed and replaced with another ingredient with less certain information on hazards. Recently, however, it has become apparent that there is also a toxicity problem with TPHP. In order to offer a toxicity advantage when compared with gel light cured polish, companies offering regular and hybrid polish should make sure their polishes do not contain either dibutyl phthalate or TPHP. Although there may be regular and hybrid polishes that do not contain the two ingredients, IRTA's project involved focusing on nail polish remover so IRTA could only do limited investigation of nail polishes. IRTA did investigate nail polishes to some extent but did not have the resources to do a more extensive analysis. As discussed later, some of the regulatory agencies in California may have the authority to regulate the use of nail polish ingredients and they could take on this task.

5.1.3. Comparison of Three Polish Types

On balance, then, the regular lacquer polish without TPHP probably poses less of a toxic risk than the other two types of polish. A hybrid polish that does not contain TPHP is a good compromise, however, for people who are looking for a more durable polish that can be removed easily and quickly. Although the topcoat does contain acrylate copolymers, it is only one of the three or four coats. The hybrid color and base coat do contain solvents but the top coat does not. If the hybrid polish does contain TPHP, it is hard to say which type of polish offers an advantage in terms of toxicity.

The information on the different types of polish is summarized in Table 5-1 below. The table indicates that the hybrid polish may be a good compromise from both health and durability standpoints, particularly in cases where the polish does not contain TPHP.

5.2. Nail Polish Remover Toxicity Issues

The nail polish remover toxicity issues were discussed earlier in this report but bear repeating here. Plain acetone is the remover of choice for salons. Acetone, compared with other organic solvents, is relatively low in toxicity. The major issue that arises in salons with the use of acetone is that most salons have poor ventilation. As a result, when large quantities of acetone removers are used, the acetone concentration builds up and exposure of customers and particularly the salon workers who are there all day is high. High concentrations of acetone can cause CNS effects like headaches and dizziness and acetone has a strong and unpleasant odor. For the customers, another serious issue is that acetone contacts the skin for extended periods of time both with the wrap method and the dip method for the UV cured gel polish removal. Some acetone is also likely to contact the skin when it is used to remove regular and hybrid polish. For consumers who use acetone or primarily acetone based removers, the short term effects are less of an issue. Regardless of the type of polish being removed, for both customers in salons and consumers, acetone will be

Table 5-1
Comparison of Nail Polish Types

Polish Type	Typical Number of Coats	Toxicity Issue	Durability	Removal Process
Lacquer	Four (base coat, 2 color coats, top coat)	Possible high solvent concentration with CNS effects, may contain TPHP	Poor	Quick
Hybrid	Three or four (base coat, 2 color coats, top coat or base/color coat, top coat)	acrylate copolymers in top coat, may contain TPHP	Intermediate	Quick
Gel—UV Light Cured	Four (base coat, 2 color coats, top coat); must cure each coat separately with UV light	acrylate monomers, acrylate polymers, UV light exposure	Good	Very slow, more toxicity risk

absorbed and will defat the skin and possibly cause irritation. This outcome is related to the fact that a strong disadvantage of acetone cited by both salon workers and consumers is that it dries out the skin and nails and that it makes the nails brittle and causes them to break easily.

Other nail polish removers on the market may be composed of other solvents, like methyl acetate, for instance. This chemical has similar properties to acetone but it is more acutely toxic. Acetone would be a preferred remover from a health and environmental standpoint.

The nail polish removers developed during this project mitigate some of the problems presented by plain acetone removers or acetone removers with small quantities of additives. The alternatives are blends of acetone and either a carbonate or an ester. As discussed earlier in this document, IRTA worked with a toxicologist who evaluated the toxicity of the other ingredients present in the formulations. Based on the available toxicity data, she concluded that the ingredients appear to be low in toxicity. The combination removers inhibit the evaporation of acetone so overall inhalation exposure is lower in salons and for consumers. This should minimize CNS effects. The smell of acetone is also not apparent when the alternatives are used. A major advantage of the alternatives is that they do not affect the skin and nails in the same way as acetone. They leave the nails and skin lubricated so they are not dried out or brittle.

5.3. California Regulatory Agency Authority

In California, some of the regulatory agencies may have authority to regulate the ingredients used in nail products. As discussed earlier, CARB has authority over air emissions from consumer products and has established a VOC limit for nail polish removers of 1%. The agency has not established a VOC limit for nail polishes, however. The solvents used in nail polish are VOCs and there has not been any research done on whether low or non-VOC alternatives might be suitable in this application. CARB has not restricted or banned any of the ingredients from nail polish or nail polish removers because of their toxicity. Generally, the agency only bans carcinogens that are on the California Toxic Air Contaminant (TAC) list from consumer products they regulate. If the toxic ingredients in question are not carcinogens or are not on the TAC list, then CARB likely would not regulate them. This is the case for most of the ingredients discussed here.

Another agency that recently developed a program for regulating consumer product categories is DTSC. As discussed earlier, DTSC did analyze some of the products that advertised they did not contain any of the so-called Toxic Trio products; the results indicated that some of these products still contained some of the Toxic Trio ingredients. At the time the products were analyzed, DTSC did not have a program for regulating consumer products. Somewhat later, DTSC launched their Safer Consumer Products Program which establishes the structure for restricting or banning certain targeted chemical-product combinations. DTSC has already selected the first round of product-chemical combinations but could focus on nail products in the next or later phase.

Another approach might be for the legislature in California to pass a bill giving one of the Cal/EPA agencies t specific authority for restricting or banning nail products in particular. If this approach were used, it is likely that either CARB or DTSC would be the agency selected for developing and implementing the regulations.

VI. Results and Conclusions

During this project, IRTA identified, developed, tested and demonstrated two alternatives to the nail polish removers used widely today in salons and by consumers. The project results are briefly summarized below.

6.1 Alternative Nail Polish Removers

The most widely used nail polish remover in California today is acetone. Salons, in particular, rely on pure acetone to remove polishes of all types. In the consumer sector, there are a number of acetone removers with other ingredients and there are also many non-acetone removers.

Acetone is lower in toxicity than most other organic solvents but it has a very high vapor pressure which means it evaporates quickly. In salons, which often have a small footprint with limited ventilation, the acetone concentration in the air can be very high and the odor can be very strong. Salon workers object to the odor and may experience CNS effects like headaches and dizziness. Acetone is very aggressive and it can damage the nails, dry them out and make them brittle when it is used in removers.

During this project, IRTA conducted research to find safer alternative nail polish removers that could minimize the negative effects of acetone. IRTA investigated a number of different approaches to removing polish. These included using abrasive methods, freezing methods and water-based removers. These methods did not appear promising and IRTA then began examining low vapor pressure solvents as potential alternatives and these offered the most promise. IRTA developed two alternative removers, one a blend of acetone and a carbonate and the other a blend of acetone and an ester, which performed well in preliminary tests.

The preliminary work involved testing the removers on IRTA staff for removing a variety of different types of polish. The polishes that were analyzed and tested included regular lacquer based nail polish, UV light cured gel polish and hybrid polish, a combination lacquer and natural light cured polish. The two alternatives worked effectively on regular and hybrid polish. They also worked for removing the UV cured gel polish if they were allowed to soften the matrix for a period and a tool was used to lift the residue of the polish from the nail or if they were allowed to act for a longer period than is used currently.

6.2. Adhesion and Evaporation Testing

The two removers developed in the first phase of the project had to be tested in certain ways to determine what types of containers they could be used in, whether their use would allow a new application of polish to stick and whether they would evaporate selectively.

IRTA investigated the container compatibility and found that the containers the removers should be used in were made of HDPE. This is the same material used for containers of acetone remover.

IRTA also conducted adhesion tests to determine the proper procedure for preparing the nails after removal for a new application of polish. This was of some concern because the second ingredients in the alternatives were somewhat oily and oily surfaces are known to provide poor adhesion for subsequently applied coatings. The testing indicated that the nail should be wiped with a dry cloth after remover was used to remove any residue that might remain. Wiping with a dry cloth should be adequate to ensure that a new coat of polish would adhere to the nail.

IRTA conducted evaporation tests to determine which types of containers and tops would be most suitable for holding the remover. The findings indicated that the best types of containers for the removers are HDPE bottles with a flip spout top. The findings also indicated that HDPE containers with a pump and a twist lock dispensing cap seem to malfunction frequently and emissions of remover using these containers are higher.

6.3. Field Testing of Alternative Removers

IRTA partnered with the Healthy Nail Salon Collaborative to identify salons that were interested in participating in initial testing of the alternative removers. The Collaborative helped IRTA identify and test with two salons in Northern California and one salon in Southern California. IRTA recruited one additional salon in Southern California where testing was conducted. IRTA also conducted initial testing of the two alternatives with consumers.

The results of the initial testing indicated that one of the alternatives, alternative #1, the blend of acetone and a carbonate, performed slightly faster than alternative #2. The salons preferred alternative #1. The consumers, however, saw very little difference in the two alternatives and thought they both performed well. One consumer, in particular, preferred alternative #2 because she liked the way it left her nails lubricated.

The results also indicated that consumers seemed to be willing to use the alternatives on regular polish, hybrid polish and UV cured gel polish. They did not seem to object to using the tool for final removal of the gel polish matrix. The salons, in contrast, indicated their customers would not allow the use of the tool for removing the gel polish; they would likely only use the alternatives for removing regular or gel polish.

IRTA attended a Collaborative meeting in Northern California to discuss the alternatives with the salon Collaborative members there. Several workers and owners attended the meeting. IRTA provided samples of larger eight ounce quantities of alternative #1 to 18 salons which included the two salons that had participated in the initial testing. The feedback obtained from three of the workers and three salon owners was that they preferred the smell of the alternative and that it worked well for removing regular polish. One owner tested the remover for removing UV cured gel polish and indicated that, although it took a longer time, it did remove the polish. He also said he would be willing to use it for that purpose. One other salon owner said that she would have to tell customers to wash their hands before she could apply a new coat of polish so she would not be able to use it. This is in conflict with what IRTA found in the adhesion testing.

6.4. Cost Comparison of Alternative Removers

IRTA conducted a cost analysis and comparison of acetone and the two alternatives for salons and for consumers. For salons, IRTA assumed that the remover would be packaged in four one gallon cases with a cardboard container and that salons would purchase either cases with four gallons or in individual one gallon containers. For consumers, IRTA assumed the remover would be purchased in an eight ounce container with a flip spout top.

The results of the analysis for salons indicated that the total cost without accounting for profit of the plain acetone remover was lower than the total cost of both of the alternatives. Since the cost of the containers, labels and filling is the same for all three removers, the reason the alternatives have a higher total cost is that the raw materials cost is higher. Table 6-1 summarizes the cost comparison for salons. The values demonstrate that the cost of alternative #1 is higher than the cost of plain acetone by 81%. Because the alternatives do not evaporate as quickly as plain acetone, salons purchasing the alternatives might use less remover overall. The table also shows the cost comparison under the conservative assumption that 20% less of each alternative would be used. In this event, the total cost for using the alternatives would be lower by 20%. Although this brings down the total cost of using the alternatives, they are still more costly to use than plain acetone remover. Salons that perceive an advantage in the safety of the alternatives or in the fact that they leave the nails in better condition would be willing to pay the higher price.

Table 6-1
Cost Comparison for Gallon Containers Used by Salons

Remover	Total Cost	Total Cost Assuming Reduction of 20% in Alternative Remover Use
Acetone	$5.88	$5.88
Alternative #1	$10.62	$8.50
Alternative #2	$11.96	$9.57

Note: Profits not included in cost.

The results of the analysis for consumers presents a very different picture than the results for the salons. Although the raw materials cost of the alternatives is still higher, the variation in actual price of removers on the market today is extremely wide. Suppliers of removers in smaller containers mark up the price of the removers substantially to account for a profit.

Table 6-2 summarizes the total costs of the acetone remover and the two alternative removers for an eight ounce bottle. Again, as for the gallon containers, IRTA also examined the total cost under the assumption that a consumer would use 20% less of the alternative removers because of their lower evaporation rates. This assumption brings the total cost of alternative #1 below the total cost of the acetone remover and the total cost of alternative #2 is only slightly higher than the total cost of the acetone remover. Actual prices of eight ounce equivalent removers on the market today range from $1.29 to $18.40. The values of Table 6-2 indicate that both alternatives could be priced competitively for the consumer market even with a reasonable profit.

Table 6-2
Cost Comparison for Eight Ounce Container Used by Consumers

Remover	Total Cost	Total Cost Assuming Reduction of 20% in Alternative Remover Use
Acetone	$1.11	$1.11
Alternative #1	$1.35	$1.08
Alternative #2	$1.44	$1.15

Note: Profits not included in cost.

<u>6.5,Health and Environmental Effects</u>

As part of the project, IRTA did a limited analysis of the health and environmental effects of three different types of polish. These include:

- Regular lacquer polish
- UV cured gel polish
- Hybrid polish

Some people consider regular polish to be toxic primarily because they smell the solvents that are emitted from them during the curing process. The solvents in polishes, however, are generally reasonably low in toxicity and they are not chronic toxicants. The polishes can be removed easily in a few seconds. Regular polish is not very durable and lasts a few days to a week. Some of these polishes contain TPHP, an endocrine disruptor, and users should seek polishes that do not include this ingredient.

UV cured gel polish contains acrylates which are sensitizers and cause asthma. All coats of the polish must be cured with a UV light which can pose a skin cancer threat. The application process is complicated and takes a significant amount of time. The removal process requires application of or immersion in a remover for 10 to 15 minutes. This polish is very durable and can last at least two weeks.

Hybrid polish is a combination of color coats that have the characteristics of regular polish and a topcoat that is cured with natural light. The topcoat contains acrylate copolymers which could be toxic. Like regular polish, hybrid polish can be removed quickly in a few seconds. This polish has an intermediate durability and will last one to two weeks. Some hybrid polishes may contain TPHP and, again, users should look for polishes that do not include the ingredient.

Table 6-3 summarizes the characteristics of the alternative polishes. The table demonstrates that the best option for salons and consumers may be the hybrid polish without the ingredient TPHP.

Table 6-3
Advantages and Disadvantages of Nail Polish Types

Polish Type	Application Process	Toxicity Issue	Durability	Removal Process
Lacquer	Easy	Possible high solvent concentration with CNS effects, may contain TPHP	Poor	Quick
Hybrid	Easy	acrylate copolymers in top coat, may contain TPHP	Intermediate	Quick
Gel—UV Light Cured	Complex	acrylate monomers, acrylate polymers, UV light exposure	Good	Very slow, more toxicity risk

6.6. Conclusions

The alternative nail polish removers contain non-acetone ingredients that are low in toxicity. Although acetone is also very low in toxicity, plain acetone or acetone dominant removers evaporate quickly and have a high exposure for workers in salons and consumers when it is used in unventilated spaces. Use of the alternatives developed during this project minimizes the evaporation rate and may result in lower exposure.

The cost of the alternatives to salons is likely to be higher than the cost of acetone removers. Some salons may be willing to pay a higher price because of the lower evaporation rate and the fact that the alternative removers leave the nails in better condition. The alternative removers can be priced competitively for consumers.

The alternative removers are effective for removing regular and hybrid polish. Some salons and consumers may be willing to spend more time and effort using these removers for removing UV cured gel polish because of their advantages.

VII. References

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VIII. Organization/Program Contact Information

Bay Area Air Quality Management District, www.**baaqmd**.gov.

California Air Resources Board Consumer Product Program, www.arb.ca.gov/consprod/regs/regs.htm.

California Department of Toxic Substances Control Safer Consumer Products Program, www.dtsc.ca.gov/scp/index.cfm.

California Healthy Nail Salon Collaborative, www.cahealthynailsalons.org.

South Coast Air Quality Management District, www.aqmd.gov.