Amalgam Waste Management - Issues and Answers

Abstract

In reviewing U.S. dental amalgam waste management activities, one finds a wide variety of approaches, processes, and results, within which the authors have observed an inconsistency of definitions, measurements, standards, and even of clearly applied goals. As a result, outcomes have varied greatly from community to community. This manuscript attempts to deliver logical options which might prevail even within an atmosphere of differing perspectives.

The authors share the belief that successful outcomes are achievable within a collaborative environment of shared learning and cooperative planning. By example, the authors attempt to demonstrate how the joint acceptance of certain definitions and goals has served as a pathway to success in one community's dental waste management project. The goal of this* paper is to share tools that may contain some measure of applicability to other similar collaborations.

Case Study No 11 Continued

Purpose:	Replace acetone Reduce fire hazard Reduce storage of waste Reduce consumption of solvents
Motivation:	Eliminate emissions and fire hazard
Equipment Supplier:	***Water-based resin emulsifier*** Insco I95 Cleaner (800) 849-1133 ***Solvent replacement*** Superior S-280 Indianapolis, IN (317) 781-4448
Payback Period:	N A
Comments:	Carolina Classic reduced their acetone usage by switching to a high boiling point solvent and a water-based resin emulsifier in 1990. As a result, acetone emissions decreased 50%, and hazardous waste generation dropped more than 70% during the first year. The reduction in acetone usage still continues. In 1991 the plant used .0148 pounds of acetone per square foot of product laminated. In 1994 this rate decreased to .0071 pounds per square foot of product produced.
Source:	Plant visit on November 2, 1994

In-Plant Solvent Recovery

Small Batch Solvent Distillation Equipment -- Some fiberglass fabricators in North Carolina are finding in-plant batch type distillation systems to be a cost efficient approach for dealing with contaminated solvents. Batch type units have proven to be successful in meeting the needs of firms producing small to moderate quantities of contaminated solvents such as acetone. Unit sizes commonly available range from 5 to 55 gallon units.

A basic batch type system consists of four major components: a contaminated solvent collection tank, a heated boiling chamber, a condenser, and a clean

Amalgam Waste Management - Issues and Answers

James F. Westman, DDS and Timothy Tuominen

During more than a century and a half of use and intense scrutiny, dental amalgam has been repeatedly questioned, analyzed, and repeatedly deemed safe for human use. However, emerging issues within the waste management and environmental communities focus on the mercury component of waste amalgam, its ultimate disposition, and its resultant effects, both potential and actual, upon the environment. Publicly owned treatment works (POTWs) are grappling with increasingly stringent water quality standards and discharge limits. Efforts to identify all potential sources of environmental mercury have recently focused on the dental office, and waste amalgam discharge, as a potential source of environmental mercury.

The authors begin with a brief statement on health and biocompatability findings relating to dental amalgam in an effort to clearly define issues. Discussion regarding speciation of mercury will be followed by a review of environmental amalgam and mercury issues. The relative contribution from dentistry to the overall potential waste-stream mercury burden will be addressed, along with a tracking of the amalgam waste pathway and discussion of factors affecting treatment works.

Since 1992, the authors have participated in the development of a Dentistry/POTW collaborative, a result of which has been a successful, voluntary recycling program based on simple, inexpensive dental waste management practices. We will share details of program successes, outlining the process by which positive results continue to be achieved. Also to be addressed are additional steps being taken to study advanced wastewater treatment options, and the presentation of a relative cost scale associated with various site-based treatment options.

Dental Amalgam and Public Health

As a restorative material, dental amalgam has been controversial from its inception. An abundance of concerns regarding health and biocompatability issues have been addressed by research. Within the past decade, much detailed study has been performed, and several well-documented literature reviews published. Flanders1, in 1992, found "no sound evidence that dental amalgam restorations pose any health risk" and the occurrence of mercury allergy to be "extremely rare." A 1993 report of the U.S. Public Health Service2 concluded very similarly. The ADA Council on Scientific Affairs3, in 1998, found an "overwhelming body of scientific data supporting the safety and efficacy of dental amalgam," mentioned the "absence of any similar database attesting to the safety and efficacy of an alternative material," and chose to also mention the well-documented benefits of dental amalgam as a durable and cost-effective restorative material. Even as the array and clinical acceptance of amalgam alternatives increase, for countless dental practitioners and their patients, dental amalgam remains as a valued option. Thus, environmental concerns relating to waste amalgam should be addressed.

solvent collection container. A typical low cost system is diagrammed in Figure 5-1. The operating systems for these units are typically contained within a single compact cabinet. Space required to house a unit is generally less than the space required for storage of virgin solvents and contaminated waste.

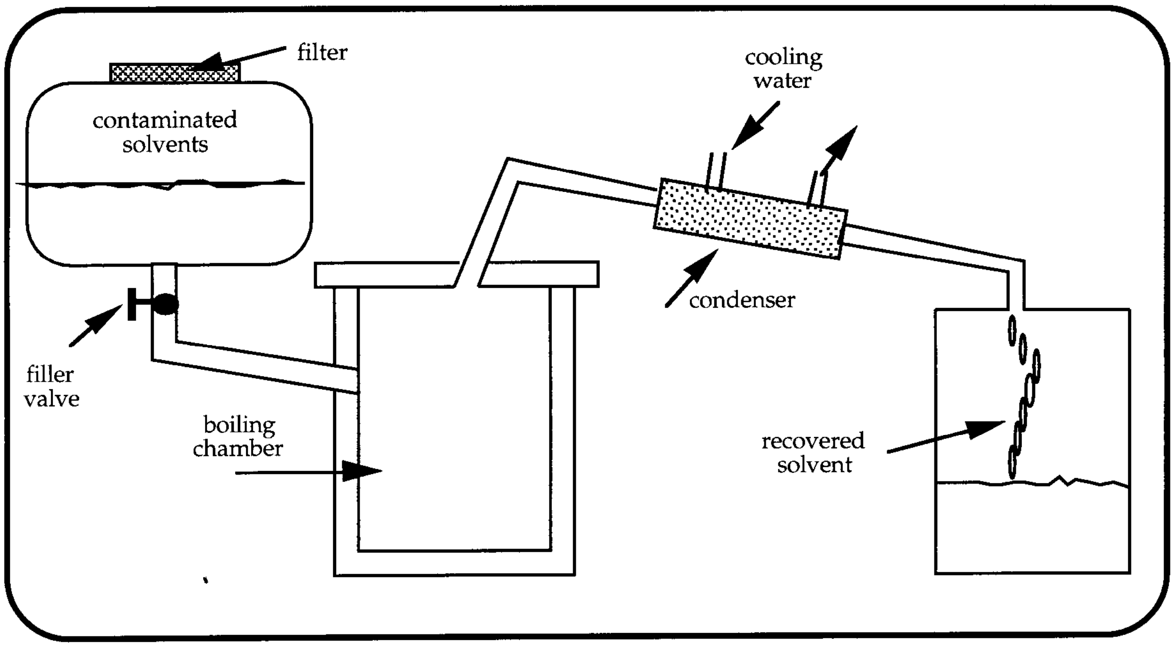


FIGURE 5-1. Basic batch solvent distillation system.

Small quantities of contaminated solvents are poured into the solvent collection tank during normal employee clean-up operations. The contaminated solvent collection tank should have an inlet that can be properly sealed to prevent evaporation. A filtering screen should also be placed in the inlet collection system to prevent solids and sludge from clogging pumps and/or feed pipes which deliver contaminated resins to the heat chamber. If the collection tank is situated higher than the top of the heat chamber, piping and valves can be permanently installed so that solvent can be gravity fed into the heat chamber. If the collection tank is not located above the heat chamber, a pumping system may be required to transfer solvents for processing.

The heat chamber is designed so that a vapor tight seal can be maintained during heating and cooling cycles. In the chamber contaminated solvents are heated to a predetermined vaporization temperature, and these vapors are channeled out of the container to an external condenser. Heat can be supplied by means of electric elements or by steam coils. Steam units offer some advantages in terms of speed and safety. If the plant does not have steam available, a boiler can be supplied by the manufacturer of the still. The heat chamber will also be equipped with a means to collect the unusable residue which has been separated from the reclaimed solvent. This residue is referred to as “distilled bottoms” or “still bottoms”.

Speciation of Mercury - Different Forms Bear Distinctly Differing Properties

Environmental problems associated with the release of mercury to the air and water have been repeatedly documented. It is commonly accepted that elemental mercury released to the air or water ends up in the sediments of lakes. Within the sediment mass, it is known that certain conditions eventuate methylation of elemental mercury. Accumulation of the more toxically bioavailable methylmercury in the tissues of fish has resulted in the issuance of the fish consumption advisories in many states. Not only humans are thus placed at risk. Certain animal species (i.e. loon and mink), that subsist mainly on fish, face an even greater potential danger.

To some minds, anything containing mercury is a poison, a hazard to health and to the environment. Thus, accurate differentiation of dental amalgam from its mercury component is a function deserving active pursuit. From the combining of materials that occurs with dental amalgamation, there evolves a substance bearing properties unique to the resultant product. Compounded dental amalgam is hard, notably stable, and serves as a benchmark to which the wear resistance of other dental materials is regularly compared. It is not uncommon for dental amalgam restorations to provide decades of service.

Amalgam is not mercury. Yet, within certain communities of interest, dental amalgam is often characterized as if it were. It is not uncommon for waste management writings to characterize amalgam waste as an equivalent of mercury waste. This characterization can be considered accurate only if the waste will be subject to conditions which would ultimately, and in a timely manner, cause the release of mercury from the waste amalgam. During tests performed by Fan, Chang, and Siew[4], amalgam scrap subjected to two different Environmental Protection Agency extraction procedures indicated that concentrations of mercury released were minimal, not reaching levels that would qualify it as a hazardous waste. In water, amalgam is highly insoluble, unless subjected to conditions unlikely to occur in a sewerage system. When amalgam, which may be settled in sewage sludge, is treated by high heat incineration, mercury in amalgam will be released. Thus, it is not the existence of amalgam scrap that causes environmental concern, but rather the ultimate treatment of the material that is the problem. This statement is made not as an excuse for substandard dental waste handling practices. It is made to clearly differentiate between pure sources of mercury and mercury bound, as it is, within dental amalgam waste.

Environmental Problems Relating to Mercury and Amalgam

In a presentation entitled “The Ongoing Mercury Controversy”[5] Dr. Ronald Geistfeld spoke of the breathing of ambient air as the lowest potential source of mercury exposure by humans, with bioconcentrated organic sources of mercury, via fish consumption, as vehicles of the largest source for human exposure. Most mercury reaches the aquatic environment via air transport. Natural sources contribute from 1/4 to 1/3 of the total environmental mercury. Energy production accounts for about 1/2 of the human derived air emissions, with coal fired energy production plants as the foremost source.
Waste management incinerators contribute most of the balance, through wastewater treatment sludge incineration, as well as by medical waste and municipal solid waste combustion. Off-gassing from landfills is suspected to be another significant contribution to the atmosphere. By perspective, a single power plant may send 1/2 pound of highly

Depending on design requirements, condenser units may be water cooled or air cooled. Water cooled units are generally more compact and more efficient but require connection of external water inlets and drains. In the condenser, vapors are cooled rapidly in order to promote condensation. This condensate is clean solvent and is drained off and collected in appropriate containers. These collection containers may be either a permanently piped in bulk storage unit or simply conventional barrels. The solvents collected in this manner are generally ready for use without further treatment or additives. The distillation recovery option seems particularly appealing since Federal EPA regulations (Regulation 40 Part 261.6) do not require a permit for this type of solvent treatment. However, the North Carolina Solid and Hazardous Waste Management Branch must be notified when a solvent distillation unit is installed.

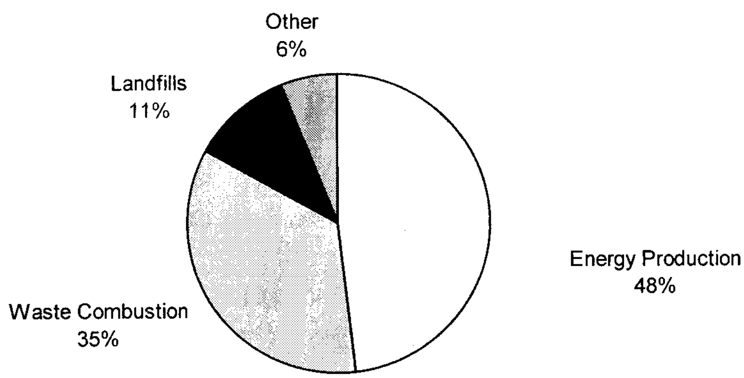
There are a number of cost factors affected by the use of batch distillation units. In comparison to conventional disposal techniques, the quantities of solvents which must be disposed of by hazardous waste handlers may be reduced by as much as 90%. Since usable solvents are produced, the outside purchase of virgin solvents can be dramatically reduced. Long-term liabilities for waste disposal are also significantly reduced. The units do require a considerable initial investment. Prices may vary from approximately $5,000 for a basic 5 gallon per batch unit to more than $40,000 for a relatively sophisticated 55 gallon unit with labor saving automatic control systems and pumps. Stills also require energy for heat, some labor for operation, and water for the condenser. These operating costs will generally be less than 50¢ per gallon, with some manufacturers claiming costs under 20¢ per gallon. Other expenses include disposal of still bottoms, bags, and maintenance.

Batch type distillation systems do not require full-time operators or extensive operator training. With the most basic design an attendant is normally assigned the duty of filling the heat chamber with contaminated solvents, sealing the unit, activating appropriate controls, deactivating the controls after the cycle is completed, and removing the residue distilled bottoms from the heat chamber. The complete cycle time normally ranges from six to eight hours, but the operator need only be present during start-up, shutdown, and clean-up. Supplies consumed in the processing of solvents are usually limited to disposal bags.

The addition of automatic controls and pumping systems to load waste solvents can greatly reduce labor demands and prove greater assurance that the unit will be shut down if an operational problem occurs. A diagram of a larger unit with automated controls is shown in Figure 5-2. Fountain Powerboats in Washington, North Carolina, has used a Recyclene model RX-35, supplied by Southern Recovery Company, for several years. The unit features a number of automatic control systems for materials handling, cycle control, and safety. Liner bags are used to collect still bottoms and keep the boiling chamber clean. Total operator time required for each cycle is only 12 minutes.

Selection and installation of a batch type distillation system requires careful study and planning. Suppliers listed in Appendix C will normally provide expert dilute mercury into the air on a daily basis. The largest wastewater treatment plant on Lake Superior in Duluth, Minnesota discharges 2 grams of mercury in 40 million gallons of water per day. Yet, the Western Lake Superior Sanitary District (WLSSD) also emits 10 grams per day from incinerating sludge and refuse derived fuel. Amalgam waste bears high concentrations of bound mercury and, though reasonably stable while in the general waste stream, when burned as part of sludge and solid waste incineration, amalgam then contributes elemental mercury to the incinerator stack emissions.

Minnesota Mercury Emission Sources



Source, Tuominen T. Western Lake Superior Sanitary District, Duluth, MN

Where Does Amalgam End Up?

The WLSSD, as well as other wastewater treatment facilities, has surveyed the dental profession on waste management activities. Extrapolating the number of fillings placed or removed in order to estimate potential environmental mercury discharge is an interesting activity, but not a technically sound basis for regulation. Inherently lacking in validity, such extrapolation becomes highly suspect due to the obvious risk of cumulative errors. Use of voluntary survey data as a sole basis for regulating discharges may, quite logically, raise the animosity of those being regulated. Issues relating to the density of the compound, and tests on precipitation and dissolution, also raise distinct questions as to how much of the dental amalgam waste ultimately reaches waste facilities. Thus, regulation not based on sound science is inappropriate.

From the time an amalgam restoration is removed from a tooth until the point at which waste amalgam may reach a wastewater treatment facility, many factors enter into the equation of where it actually goes. In a study undertaken by Cailas, et al[6] a primary conclusion was that the mercury content of dental waste-water can vary substantially between samples. However, their analysis discovered that 90% of the particles generated were of a size greater than 10 microns, and thus capable of being captured in by common filter traps. Additional work by Cailas[7] et al estimated that 75% of amalgam waste is captured in a chair-side trap, and showed further that, of the other 25%, all but 1% will settle over 24 hours, an indication that additional scrap settles within, and may be advice about the systems they carry. Demonstrations of equipment should be carried out using representative samples of contaminated solvents from your facility. Insurance requirements, safety, and fire codes should be taken into consideration before a system is selected and installed. Vapors produced during distillation can be highly flammable, so units and surrounding equipment should be of an explosion proof design. Results may be disappointing on solvents which have been heavily contaminated with water or other elements with high vaporization temperatures.

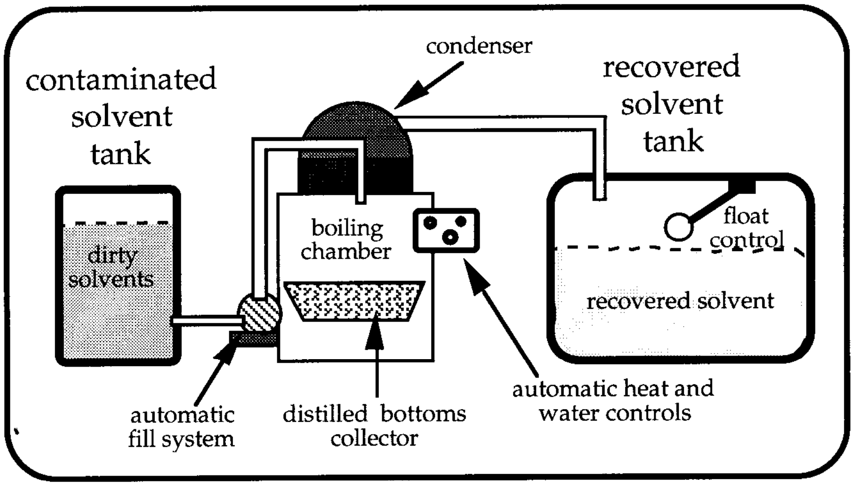


FIGURE 5-2. High efficiency batch distillation system.

Case Study No. 12	
Type:	In-plant batch distillation unit
Company:	Fountain Powerboats
Location:	P.0. Drawer 457 Washington, NC 27889
Contact:	
Phone:	(919) 975-2000
Purpose:	Reduction of waste disposal costs Reduction of solvent costs
Motivation:	Reduced hazardous waste storage and disposal Reduction of expenses

recovered from, the vacuum pump trap. Generally accepted figures estimate the total removed by chair-side and central suction traps to be in the range of 75 to 80%.

Due to the effects of gravity on this dense material, a substantial portion of the amalgam waste settles in sumps and pipes, becoming a portion of other sediment mixes in the wastewater treatment collection system. Studies performed at Goodfellow Air Force Base, Texas,[8] showed that the density of amalgam causes further settling to occur in the sewage transmission system. In Duluth, WLSSD noted high concentrations of mercury/amalgam, which were re-suspended when a sewage line below a major dental-medical building was cleaned. However, not all of the re-suspended mercury/amalgam was ultimately seen at the treatment plant, also demonstrating the re-sedimentation phenomenon. Such documented occurrences beg the question "How much mercury in amalgam ever reaches the treatment plant?" As a practical application, thus demonstrated properties of the material support the theoretical use of sedimentation in the capture of amalgam particles, as a means of removal from the waste treatment/environmental release system.

Yet, a certain amount of dissolved mercury, a portion of which could pass through a wastewater treatment facility, does leave the dental office. The previously mentioned work of Drummond and Cailas[6] showed that less than 0.3% of amalgam waste is soluble. Further, according to Kunkel,[9] amalgam is not further solublized in any of the stages of standard wastewater treatment. From this, one should conclude that there is a greater waste management issue than just mercury discharged from a wastewater treatment plant.

Given the above mentioned properties of the material, it is no surprise that, once it passes the vacuum pump, the remaining amalgam waste enters a twilight zone of disagreement among virtually all who have studied it. Percentages of potential mercury attributed to dentistry compared to the total mercury received at the treatment facilities have been calculated at many cities. San Francisco[10], Seattle[11], and Palo Alto[12] developed estimates ranging from 9 to 14 percent. Dental offices within a community may show wide variations in the range of two orders of magnitude. WLSSD found that the discharge from a single office varies two orders of magnitude on days with reportedly identical workloads.

Variable data impedes the ability to accurately assess amalgam discharge. For example, European data extrapolated to estimate mercury loading from dental practices in Minneapolis and St. Paul, Minnesota[13], resulted in figures pointing to dental amalgam as a contributor of 76 to 80% of the total mercury received at Metropolitan Council Environmental Services treatment facilities. However, total mercury loading from dental offices and any environmental effect, if present, is site specific. Dependence on extrapolated figures not subjected to validity testing, risks wildly erroneous resultant estimates of dental clinic mercury contributions.

Municipal waste managers need numbers with which to judge the total and individual component contributors to their problem. With large industrial operations whose day to day operations deal with nearly identical continuing volumes, patterns are clear and permit levels derived seem fairly logical. However, in dentistry, this logic is less clear for several reasons. A material that contains mercury is amalgamated into a stable, solid substance. Amalgam is produced in variable amounts in widely differing "factories."

Case Study No. 12 Continued	
Equipment Supplier:	Southern Recovery Co. P. 0. Box 3279 Fort Mill, SC 29715 (803) 548-5740
Payback Period:	Less than one year
Comments:	Unit is cycled at least once per work day. Approximately 90% of the contaminated acetone is recovered. Operator time required is less than 15 minutes per cycle. Hazardous waste shipments and solvent purchases have been reduced by at least 75%.
Source:	Plant visit (May, 1987)

Continuous Feed Distillation Equipment

While batch type solvent recovery units may prove to be successful in meeting the needs of many North Carolina firms, large volume producers of contaminated solvents may find continuous feed distillation equipment better suited to their requirements. Recovery output for continuous feed systems which are commonly available can range from 250 gallons per shift to as much as 200 gallons per hour.

A continuous feed distillation system requires all of the major components included in a batch type distillation unit plus more elaborate controls and materials handling equipment. An automatic pumping system is required to transfer contaminated solvents from the collection tanks or drums to the boiling chamber. Condensers may be either water or air cooled. The clean solvent collection system must be equipped with a monitoring system to avoid dangerous spills created by overflows.

With continuous feed systems contaminated solvents should be collected in a centralized solvent collection tank as a part of normal operational activities. Contaminated solvent collection systems should be equipped with a device to prefilter solids and heavy gels. The collection system should be properly sealed to prevent evaporation and made of conductive materials to insure proper grounding.

The heat chamber of a continuous feed system will normally be loaded by an automatic pump system. Some designs allow for overriding of automatic loading systems so that batch processing can be carried out. Heat is normally

Stir in the question of how much of the material actually reaches the treatment facility, and what we have is the source of great consternation, controversy and disagreement as to how, ultimately, to address the environmental issues with a sense of reality.

However, when the properties and pathways of dental waste amalgam are viewed in the above continuum, logic can emerge. The authors believe it is reasonable to state that the primary focus of dental amalgam waste treatment activity should be the prevention of the incineration of dental amalgam waste. Secondarily, the minimization of amalgam-derived mercury discharged from the vacuum system needs to be further evaluated. Any such activity should not only include studies of technologies and their effectiveness, but also studies of actual reduction potential affected at the wastewater plant as well as in the environment.

Why Aren't Treatment Plants Solving the Problem?

Conventional waste treatment practices concentrate wastewater sludge, which is then incinerated, landfilled, or sometimes consolidated and used as fertilizer. None of these processes eliminates mercury. Facilities with incinerators face a problem in that emissions control systems (scrubbers) may be effective at capturing mercury, but do not facilitate complete removal. Also, the captured mercury is only moved from one environmental medium to another. The estimated costs of even more advanced treatments have led treatment facilities to become interested in source reduction through either regulation or by cooperative efforts.

Practical Source Reduction Solutions

A number of dental communities have been introduced to the issue of amalgam/mercury waste reduction in the form of threatening actions taken by POTWs. Cursory review of articles and reports generated from some communities shows a pattern of initial antagonism, protracted periods of bilateral posturing and, frequently uneasy resultant truces that beg the question of whether the best possible outcome resulted. On the other hand, recent examples demonstrate the effectiveness of cooperative, collaborative efforts in bringing about practical solutions.

<u>The N.E.D.D.S. - W.L.S.S.D. Collaborative Project</u>

Duluth, Minnesota has been the site of a uniquely effective program that has been exported throughout the state, and has attracted attention nationally. In 1992, WLSSD invited representatives of the Northeastern District Dental Society (NEDDS) to meet with WLSSD staff and discuss environmental waste concerns relating to dentistry. Rather than prefacing the meeting with threats of looming regulation, injunctions or imposition of costly in-office waste treatment plants, WLSSD delivered the following message: "We (WLSSD) have a problem, and would appreciate the help of the Duluth dental community in finding a solution." With that background, a collaborative working relationship was quickly established, and an initial survey of scrap amalgam handling patterns was completed. The working group concluded that a voluntary program could be propitiously developed, with likelihood of achieving significant results. Such a program soon evolved and was promptly implemented. The first stage consisted of the publication of "A Guide for Dentists, How to Manage Waste from Your Dental Practice" a colorful, supplied by means of electric heating elements or steam coils. As with batch type distillation equipment, the heat chamber will also be equipped with a means to facilitate collection of the unusable residue which has been separated from the reclaimed solvent. The units can also be equipped with vacuum attachments which allow for recovery of a higher boiling point solvents which are taking the place of acetone.

Just as with batch type units, there are a number of cost factors to be considered in the selection of continuous feed distillation units. In comparison to conventional disposal techniques, the quantities of materials which must be disposed of by hazardous waste handlers may be greatly reduced. Since usable solvents are produced, the outside purchase of materials can be dramatically reduced. Long-term liabilities for waste disposal are also reduced. The units do require an initial investment that is much larger than that for smaller batch type units. Installation costs for large units are likely to exceed $50,000. These types of units are not likely to be justifiable for firms with recovery needs of less than 100 gallons per day.

Because of the major capital investment required, selection and installation of continuous feed distillation systems requires careful analysis and planning. Suppliers listed in Appendix C will normally provide expert advice about the merits of the systems they carry. Merits of the units available should be evaluated on the basis of compatibility with company needs. Demonstrations of equipment should be requested and carried out using actual samples of contaminated solvents taken from the facility. Insurance requirements, safety, and fire codes should be taken into consideration before a system is selected. Because acetone vapors produced during distillation can be highly flammable, the units and surrounding equipment should be of an explosion proof design and well ventilated. Your solvent supplier can provide additional information on distillation processes particularly if you are planning to reclaim an acetone replacement solvent.

Ongoing Developments -- Solvent distillation processes are steadily improving. Equipment manufacturers are highly competitive in research and development as well as marketing approaches. Firms that have experienced poor results with older in-plant distillation processes will find that the newer designs offer efficient processing, reliable control systems, improved materials handling systems, and less operator involvement. These units also feature many improved safety features.

Out-of-Plant Solvent Recovery

Recycling Agreements -- Some North Carolina fiberglass fabricators are successfully using supplier based solvent recovery as a cost efficient means of dealing with contaminated solvents. In firms where in-plant-recycling has not proved feasible or gained favor with management, successful arrangements have been made for outside recovery of solvents. Often these arrangements are made with solvent suppliers who can reclaim the contaminated solvents at a cost attractive guide for the proper disposal of bulk mercury and waste amalgam. The publication contained additional recommendations for the proper disposal of x-ray fixer, lead foil, and a variety of other commonly used dental materials. Included, also, was a list of resources from which dentists might select to have these materials collected for processing and proper disposal.

Subsequently, a voluntary program specifically taylored to the recycling of waste amalgam was developed. The Duluth Amalgam Recycling Program[14] centers on principles of efficacy, efficiency, simplicity, cost effectiveness, and presents a compilation of transport and processing resources. The program includes professional education components provided at several levels. In effect, every dentist and dental auxiliary in Northeastern Minnesota has been the recipient of one or several forms of educational material regarding program details. Broadly embraced by the dental community, the amalgam-recycling program has been credited for a 50% reduction in potential dental waste mercury emissions over a two-year time period. Based on this high level of local success, the program has been shared with other communities, achieved publication in a multi-state dental journal, and has been endorsed and seen its impact enhanced by the involvement of the Minnesota Dental Association. A complete and simple pathway for the recycling of amalgam is now available to virtually every dental facility in the state of Minnesota.

Programs such as the one developed in Duluth can be accomplished cooperatively and in an environment where the best available science is put to use to find best practices solutions that are quick, simple, and cheap. The last word was carefully chosen over the word inexpensive, because the Duluth program has proven relatively cheap to run.

WLSSD operates on the edge of Lake Superior, a massive body of fresh water it is responsible to protect. By way of its recycling collaboration, the Duluth dental community is effectively assisting WLSSD to achieve compliance with its very stringent discharge permit. Area dentists are also participating in voluntary testing and design modification of advanced treatment options. A goal of this latter involvement is the creation of new alternatives that may offer higher level effectiveness, at substantially moderated costs, if and when such advanced treatment becomes warranted for this community. Voluntarily, it is anticipated that some dental offices may choose to install such devices based on individual considerations.

Costs of Removing Amalgam-derived Mercury within the Dental Office

The Duluth pilot project focuses on waste that has the largest mass of mercury available for proper management or potential release to the environment. The chair-side traps carry the largest portion of mercury, followed by vacuum pump traps and, last of all, the water that contains fine particles that pass through the traps. Table 1 shows the range of estimated cost per dentist, cost per pound of amalgam-compounded mercury removed, and total amalgam-compounded mercury removed for the 2343 dentists in Minnesota, as extrapolated, based on currently available systems. It is not the authors' intention to minimize the importance of any portion of the waste stream, but to show the relative cost and outcome of each activity.

considerably lower than the cost of producing virgin materials. Contracts and arrangements for these services take a variety of forms.

In some cases "toll" arrangements are made to insure that the waste generator's solvents are handled separately. The reclaimed solvents are then returned to the generator along with virgin stock. This arrangement helps reduce the likelihood of solvents becoming contaminated by undesirable substances produced by other waste generators. Some firms have developed service agreements which do not place restrictions on the source of the reclaimed solvents which they purchase. Other companies may elect to specify the purchase of virgin materials only. Separate arrangements, whereby new solvents are purchased from one source and contaminated solvents shipped to another firm, are also common

Features of Out-of-Plant Recycling -- As with in-plant recovery techniques, out-of-plant recycling requires an efficient management and control system. Contaminated solvents must be collected in tanks or drums as a part of normal employee clean-up operations. The contaminated solvent collection system must be carefully monitored. A filtering screen should be placed in the inlet collection system to separate solids and sludge. The collection tank, or drums, should be sealed to prevent evaporation and contamination. Water and trash will drive up, the cost of recovery.

Where more than one type of solvent is used, special care must be taken to prevent mixing of dissimilar materials. Each container should be clearly marked with a chemical identification label and a permanent tag. The label on the waste container should include composition and the method by which the waste was generated. A record of this information should be maintained for each container and kept in a central location. Containers should not be labeled as waste unless the materials they contain are no longer in use. In order to avoid requirements for special permits, a management system should be developed to assure that containers are not kept in storage for more than 90 days. Drums should also be stored in a manner that protects them from the weather and physical damage. Leaking drums are a major source of contamination of storm water run off from a plant site. Drums must be in good physical condition or they will not be accepted by the waste hauler.

Out-of-plant recovery has a number of drawbacks. Shipment of solvent waste must be carried out by a licensed transportation firm. The waste generator's responsibility for the contaminated solvent does not end when it is loaded on the truck. The RCRA "cradle-to-grave philosophy" places ultimate liability for proper handling and disposal of waste with the generator of that waste. For this reason short-term transportation liabilities and long-term disposal liabilities have driven up insurance costs.

Selection of a recycler and transportation firm should be done with care. A number of waste management companies have ceased operations due to legal actions against them or bankruptcy. Failures of this type frequently result in clean-up and dump site management costs being passed on to the waste generator. This may occur years after the waste has been shipped. The waste

Table 1

Estimated Effectiveness of Amalgam Recycling Activities

Source, Tuominen T. Western Lake Superior Sanitary District. Duluth, MN

Recycling Activity	Potential mass of recyclable amalgam-compounded mercury (grams per day)	Estimated cost per dentist per year	Estimated Cost per pound of compounded mercury removed	Estimated capturable pounds of compounded mercury in Minnesota
Chair-side Traps	0.6-1.2	$6-12	$25	586-1172
Vacuum Pump Traps	0.25-0.50	$18-35	$350-700	258-516
Wastewater Settlable Particles	0.05-0.25	Low End $50	$450-2,273	52-258
		High End $1500	$13,600-68,200	
Wastewater Soluble Particles	0.005	$1,500	$682,000	5.2

Costs vary most widely within the realm of advanced recovery systems intended to capture fine amalgam particles that pass through the traps. Options for low cost systems include a simple sedimentation tank (capable of being produced for as little as $50-300, depending on the system, with some commercially marketed for up to $650) which must be maintained by draining the supernatant and sludge on a periodic basis. High-end equipment, such as centrifuges, may carry installation costs as high as $3000, as well as ongoing waste disposal contract expenses. Among commercial vendors, one complete capture system is marketed for an installed cost of $1895, with an annual service fee of $325-380. A service claiming capability to provide below detection discharge (200 parts per trillion) which includes full service waste management is currently marketed for about $1500 per year. Manufacturers' claims of 90-99% removal rates remain largely unsubstantiated by published data, thus making accurate cost-effectiveness comparisons impossible. A number of units have passed a "Seattle Standard" of 90 percent removal of mercury. One unit being tested in Duluth was constructed for under $350 and has, through initial phase testing, shown potential for up to 99.9% removal. Most available advanced treatment units are based on the fact that the density of amalgam will result in a high sedimentation rate. Gravity has always been free. Even when used in the dental office, it should be inexpensive. Since there is such a wide range of design and cost per level of effectiveness, numeric standards would be appropriate in determining the value of such systems. Prior to acceptance of any systems for general use, evaluation should be performed which would provide gauges as to effectiveness, efficiency, practicality, dependability, ultimate destination of removed wastes, as well as relative cost scale analysis. While not addressing specific units, Table 1 dramatically demonstrates the potential escalating cost impact to dentistry and the dental public at each higher level of amalgam waste removal. Dental site variability described previously shows that management firm's financial status and approaches to handling incineration, still bottoms, and storage should be thoroughly investigated before any business agreements are reached.

Hatteras Yachts in New Bern, North Carolina, has elected to use supplier based solvent recovery as the primary means of managing and disposing of contaminated solvents. Hatteras buys acetone in bulk and a proprietary non-flammable chlorinated solvent in 55 gallon drums from The Prillaman Company in Martinsville, Virginia. The company also purchases clean drums from Prillaman for the purpose of collecting and shipping contaminated acetone. Contaminated chlorinated solvents are also collected and shipped back to Prillaman in drums.

Prillaman charges Hatteras $10.00 for each clean barrel and issues a credit of $6.00 when the solvents are returned for recycling. The net cost to Hatteras for disposal of each drum of contaminated solvent is $4.00. The company does not purchase reclaimed solvents from Prillaman but does have an agreement for purchase of virgin solvents. Hatteras feels that this arrangement provides for satisfactory disposal of waste at a reasonable cost and insures delivery of a good supply of high quality solvents.

Case Study No 13

Type:	Supplier based solvent recovery Acetone and high boiling point solvents
Company:	Hatteras Yachts
Location:	110 N. Glenburnie Road New Bern, NC 28560
Contact:	Andy Misky, Jr., Manager, Facilities Engineering
Phone:	(919) 633-3101
Purpose:	Reduction of waste disposal costs
Motivation:	Limiting long-term liability for waste disposal
Service Supplier:	The Prillaman Company (703) 638-8829 P.0. Box 4024 Martinsville, VA 24115
Payback Period:	Immediate in comparison to other out-of-plant methods.

considerations for removal of amalgam in wastewater may also be site specific. Though, in some areas, data is currently being analyzed, the effects at the wastewater treatment plant or on the environment, based on use of amalgam separators, are not yet well documented. It may be expected that, if there are other substantial sources of mercury discharge to a given wastewater system, the use of amalgam separators may make little difference. On the other hand, if most of the mercury sources are eliminated, as in the case of some European cities, then there may be a measurable effect when separators are used in dental clinics. Studies have shown that dental offices equipped with sedimentation-type amalgam separators have mean amalgam-derived wastewater mercury levels at about 10% or less than those of offices without separators.[15,16]

What Is the Best Path for Dentistry?

It is the authors' shared opinion that collaborative efforts are capable of developing effective, voluntary programs, which are easy to implement, and can deliver quantitatively measurable results. It is likewise a shared view that educated, effective voluntary action proactively deflects impetus for regulation.

Too often, regulatory efforts have become embroiled in debate over numerical data which, when viewed from any distance, are inherently inaccurate due to potentially irresolvable matters which include:

1) Disagreements over how dental amalgam should be defined and characterized
2) Variations among community waste treatment processes
3) The highly variable nature of dentistry from office to office and from day to day and
3) Unresolved issues of ultimate destiny of amalgam particles that leave the dental office and enter the waste water treatment collection system.

<u>Arguing numbers is a wasteful exercise undermining the potential for meaningful results.</u>

Dentistry has long been shown as a leader of change for the public good. Preventive health care was an original dental concept. Dentistry has shown the way in the area of infection control. Dentistry has the knowledge and the capabilities to initiate meaningful procedures to enhance the environment, as well. Regulation is expensive and unnecessary.

A Proposed Pathway to Successful Dental Waste Collaborative Development

1. Jointly identify issues.
    a) Determine waste materials to be included during program development.
    b) Jointly accept the definition of amalgam as a potential source of elemental mercury, but distinctly different from elemental mercury.
2. Evaluate the path dental waste currently follows within the community.
3. Develop
    a) Simple, effective, least expensive reclamation/recycling procedures.
    b) Lists of transporters and processors available to create a complete system.
4. Educate the dental community.
    a) Provide dental personnel the tools they need to facilitate quick and simple implementation of the voluntary program.

Case Study No 13, Continued	
Comments:	The Prillaman Company will take contaminated non-chlorinated solvents for distillation at their facility. The distilled solvent is sold for reuse under name of "Rock" solvent.
Source:	Plant visits during November, 1986 and April, 1987 and phone conversations with the Prillaman Company in December, 1994.

Incineration of Contaminated Solvents

Incineration is also an option for disposing of contaminated solvents, such as acetone. Acetone can serve as a fuel source for heat recovery because of its high BTU value and low halogen content. In some industries, companies have installed in-plant incinerators to burn waste solvents. Chapter 3 discusses some of the regulatory issues that a manufacturer must deal with in order to lawfully incinerate waste. Generally in-plant incineration is too expensive in both equipment and administrative costs to be profitable for most open molders. Therefore, out-of-plant incineration may be more attractive to molders.

Waste solvents may be sent to cement or light aggregate plants for use as a fuel. This option may be particularly attractive to small producers. Companies, such as Oldover Corporation, can send their trucks to the customer's facility, to pick up waste solvents. These waste solvents must be pumpable. Collection can be made from large tanks or drums. Cost per gallon for the service is somewhat dependent on the nature of the waste collected. When high BTU value is maintained, costs are reduced. Some contaminants, such as halogen, can prevent the solvents from being disposed of by incineration.

Still bottoms may also be disposed of by incineration. Burning contaminated solvents and/or still bottoms in an aggregate or cement kiln produces no ash. This effectively relieves the generator from further liability, since no solid or liquid waste remains.

Just as with out-of-plant recycling, out-of-plant incineration requires an efficient management and control system. Contaminated solvents must be collected in tanks or drums as a part of normal employee clean-up operations. The contaminated solvent collection system must be carefully monitored. A filtering screen should be placed in the inlet collection system to separate solids and sludge. The collection tank or drums should be sealed to prevent loss of BTU value through evaporation and contamination. Water and trash will also drive up the cost of the service.

Record keeping obligations are not relieved simply because solvents are being collected for incineration. Each container of solvent purchased should be accounted for. Containers should be clearly marked with a chemical

b) Deliver information in a manner that makes compliance seem both logical and desirable.

5. Jointly promote the program and share results.
6. Continue communications, facilitating additional planning as needed.

Conclusions

Issues regarding wastewater and dental amalgam have been floating around for quite some time. Lack of understanding of the nature of dental amalgam continues to cause problems. Potential environmental impact associated with dental amalgam waste varies by the pathway waste follows, as well as by treatment mechanisms to which it may be subjected. Contributing factors vary from dental office to dental office and from day to day.

Chair-side and central suction trap recycling is quick, simple, and capable of inexpensively achieving up to 80% removal of the waste amalgam as a potential source of environmental mercury. Information on advanced amalgam removal systems is largely derived from commercial vendors of such equipment and, as such, critical evaluation of such treatment systems, subject to independent validation, is needed. In addition to dental office solutions, additional, practical POTW solutions should likewise be sought.

Once a community dental waste treatment problem has been identified, the dental profession creates its own risks if it chooses inaction. The waste treatment community creates public risks if improper choice of direction solves a treatment plant dilemma by imposing ill-advised regulation or by adding unnecessary cost burdens, ultimately borne by the public. It is incumbent upon the dental community to demonstrate that the greatest potential for public good is found in effective solutions that do not substantially increase the cost of dental care to the dental public.

To achieve success, it is imperative for all parties to communicate and collaborate. Substantive points to be considered include the following:

1. The primary purpose of dental waste treatment activity should be the prevention of dental amalgam waste from being incinerated.
2. Minimization of amalgam-derived mercury discharged from dental vacuum systems deserves further evaluation.
3. Studies of technologies and their effectiveness should include measurement of actual reduction potential affected at the wastewater plant as well as in the environment.
4. Numeric standards would be appropriate in determining technology effectiveness.
5. Successful outcomes depend on collaboration occurring within an environment of shared learning and cooperative planning.

Duluth and the Lake Superior basin area are not unique. A number of regions from coast to coast, including Seattle, San Francisco, North Carolina Michigan currently have educational, as well as waste management, programs. If these issues haven’t visited a particular region yet, they may arrive soon. It is no longer a matter of time. It is now more a matter of place.

identification label and a permanent tag. The label on the waste container should include composition and the method by which the waste was generated. A record of this information should be produced for each container and maintained in a central location. Containers should not be labeled as waste unless the materials they contain are no longer in use. In order to avoid requirements for special permits, a management system should be developed to assure that containers are not kept in storage for more than 90 days. If drums are used for shipment of waste, they must be in good physical condition or they will not be accepted by the waste hauler.

Transportation remains a drawback of out-of-plant incineration. Shipment of solvent waste must be carried out by a licensed transportation firm. The waste generator's responsibility for the contaminated solvent does not end when it is loaded on the truck. The RCRA "cradle-to-grave philosophy" places ultimate liability for proper handling and disposal of waste with the generator of that waste. For this reason short-term transportation liabilities are not relieved.

Selection of a waste management or transportation firm should be done with care. A number of waste management companies have ceased operations due to legal actions or bankruptcy. Failures of this type frequently result in clean-up and dump site management costs being passed on to the waste generator. This may occur years after the waste has been shipped. The waste management firm's financial status and approaches to handling incineration, still bottom, and storage should be thoroughly investigated before any business agreements are reached. Ideally, the waste generator should inspect the incineration facility and observe the operations carried out there. A system for either reclaiming all barrels shipped or insuring their absolute disposal is desirable. This step may help assure that the waste generator does not bear the expense cleaning up waste placed in these containers, at a later date, by another generator. Records related to collection and disposal of the waste should be maintained forever. A form that would be useful for internal record keeping and tracking of solvents is pictured in Figure 5-3.

In addressing amalgam waste management, genuine concerns exist, and real answers are readily available. Cooperation and collaboration breed success.

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Company Name Facility Location Page Number ___

Unit	Drum ID #	Type Waste	Date Placed	Storage Area	Date Removed	Quantity Gals.	Quantity Lbs.	Holding Area	Date Shipped	Shipped To	Manifest No.	Date Rec'd

FIGURE 5-3 Internal record for tracking waste solvents and disposal.