CONTROL OF DENTAL AMALGAM IN WASTEWATER AT THE NAVAL DENTAL CLINIC, NORFOLK, VIRGINIA

by

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TECHNICAL REPORT

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1.0 Introduction

In a growing number of cities and towns across America, local governments have been citing dental offices as prime contributors of toxic metals in sewage systems such as in Grand Rapids, Michigan; Tucson, Arizona; Marshall, Michigan; and Seattle, Washington (McCann, 1993). Occurrences are not limited to cities and towns. Military installations in Massachusetts, Illinois, South Carolina and Texas have experienced problems with exceeding EPA discharge standards for total mercury, and in some cases silver, in clinical wastewater. One of the most recent military cases occurred at the Naval Dental Clinic in Norfolk, Virginia (Gielda, 1993).

In all of these cases, dental amalgam, a mixture of mercury, silver, tin and copper used in restorative dentistry, is the item of concern. Unlike other pollutants that break down into nontoxic substances during wastewater treatment plant process, metallic compounds such as amalgam either become part of the sludge or pass through the plant and are discharged to surface waters. There is concern that amalgam will break down into its components, such as mercury, during the treatment process or after release into surface waters. Increasing knowledge of the risk of the toxic effects of mercury has led to increased pressure from regulatory agencies and the public for a reduction in the discharge of mercury.

Regulatory compliance is not the only reason for the Navy to be concerned with controlling the release of amalgam. The Navy is extremely conscious of its public image. It desires to be viewed as a "good neighbor." Current regulations authorize the publication in newspapers of a list of "Dischargers of Significant Non-Compliance" (40 CFR 403.8). This is the type of publicity the Navy would like to avoid.

Therefore, it is necessary for all Navy dental clinics operating in violation of federal, state and local regulations to take steps to minimize the discharge of amalgam into the wastewater system.

1.1 Objectives

The objectives of this report are as follows:

1. Summarize the problem at the Norfolk Naval Dental Clinic.
2. Review local, federal and Navy infectious and hazardous waste regulations and their application in this situation.
3. Perform a literature search to identify and evaluate potential temporary and permanent solutions to the problem in Norfolk.

1.2 Scope

This study used resources available from the University of Texas, the Department of the Navy Bureau of Medicine and Surgery, and the U. S. Army Environmental Hygiene Agency. The study also incorporated an analysis of federal, state and local regulations germane to the problem at the Navy Dental Clinic in Norfolk, Virginia.

Dental amalgam is lost to the environment in three ways. One major source is the particles created from surplus titration capsules and carved surplus, which are generally collected for recycling or disposal. A second source is lost or extracted teeth with amalgam fillings and amalgam contaminated waste such as cotton rolls, which are discharged with solid waste and in most cases subjected to combustion. Amalgam waste from these two sources is outside the scope of this study.

This report is concerned only with the third source of amalgam, which is those minor particles produced during high speed drilling and polishing procedures. These particles are sucked up and transported by the oral evacuation system to a holding tank and then released to the local sewer. Figure 1 summarizes the mercury cycle in dentistry (Horsted-Bindslev et al., 1991).

1.3 Rationale

The mercury waste problems of dental clinics have received increasing attention in several countries (Arenholt-Bindslev and Larsen, 1990; Hogland et al., 1990; Graf et al., 1988). The Navy operates several dental clinics throughout the United States, Europe and Asia. It is essential that the Navy implement an effective method of mercury waste reduction as soon as possible. This method must not only effectively reduce mercury waste, but in light of the rapidly shrinking military budget, it must do so at a reasonable cost. By studying and solving the problems at the large clinic in Norfolk, and applying the lessons learned to other clinics around the world, the Navy can take a proactive stance in the reduction of mercury from dental amalgam in wastewater. This stance would portray not only a willingness to comply with regulatory agencies, but would also reinforce the Navy's commitment to be a leader in the environmental arena.

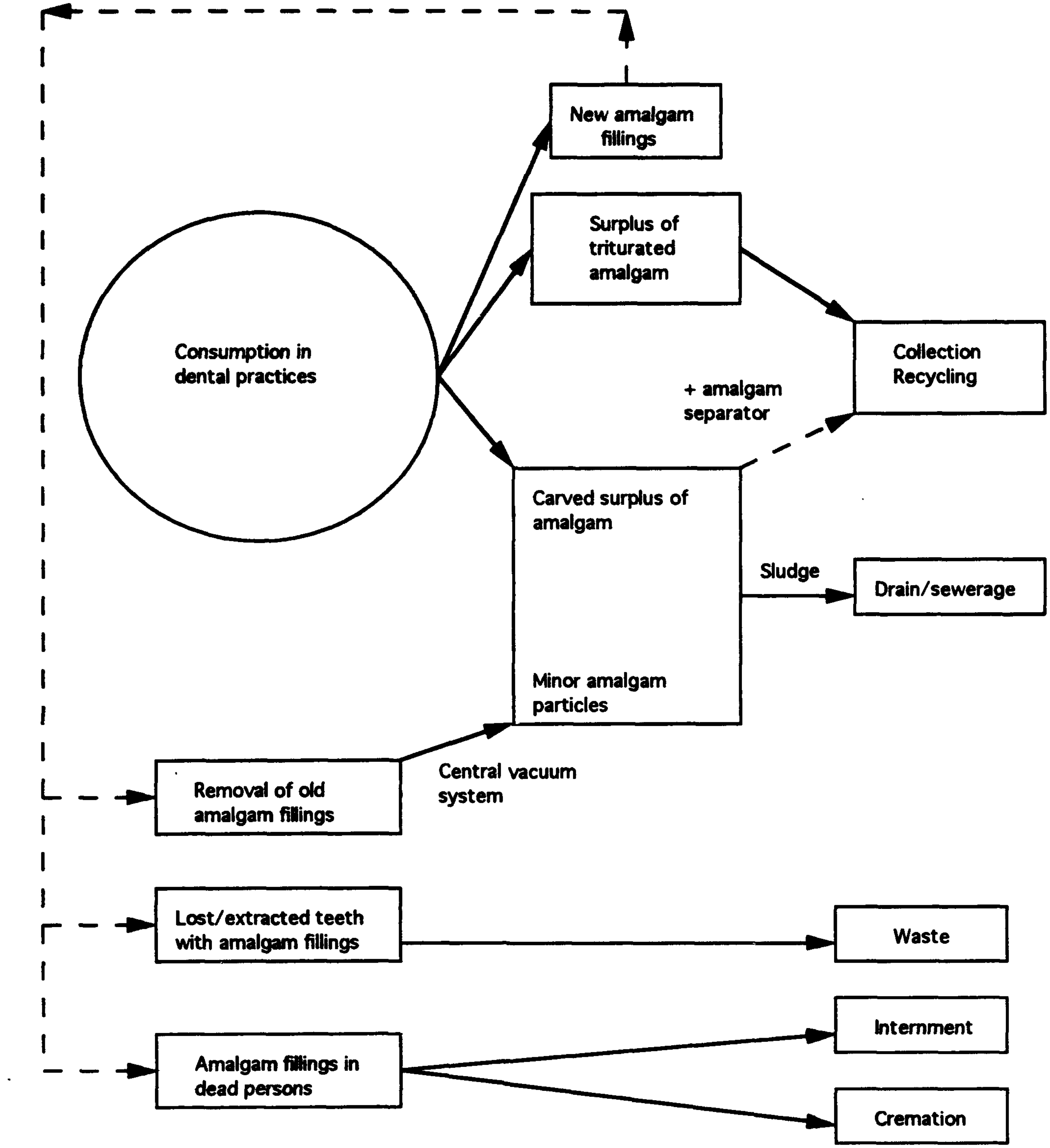

Figure 1 Mercury Cycle in Dentistry (from Horsted-Bindslev et al., 1991)

2.0 Background

The Clean Water Act was intended by Congress to constitute a national water quality policy for the entire U.S. This chapter contains a brief review of the Act, background on the problem at the Naval Dental Clinic in Norfolk, and a discussion of how the Act applies specifically to this problem.

2.1 The Clean Water Act

In 1972, the Federal Water Pollution Control Act Amendments (PL 92-500) were passed by Congress with the stated objective of restoring and maintaining the "chemical, physical, and biological integrity of the Nation's waters." Elaborating on that position, the Act also identified a series of national goals and policies, one of which was to prohibit the discharge of toxic pollutants in toxic amounts.

In December of 1977, Congress completed its first major revision of PL 92-500 and the Act became known as the Clean Water Act. Section 307(a) of the Act required EPA to publish a list of toxic water pollutants for which toxic pollutant effluent standards were to be established and to implement control standards providing an "ample margin of safety" for any potentially affected organisms. The list was published as Table I of Committee Print Number 95-30 of the House Committee of

Public Works and Transportation. Included on the list is "mercury and compounds" which is the focus of this report.

The possible toxic effects of mercury are strongly dependent on the form in which the mercury is available. At this time, there is no conclusive research which proves that the mercury constituent of amalgam particles becomes bioavailable and enters the food chain (Rodgers, 1989). However, studies have determined the existence of anaerobic bacteria in sediments that are capable of transforming elemental mercury into soluble monomethylmercury and volatile dimethylmercury ions which can be accumulated in both aquatic, and to a lesser extent, terrestrial food chains. In the aquatic environment, a biological magnification of up to 100,000 times from the algae level to predators has been reported (Arenholt-Bindslev, 1992).

The toxicokinetics of mercury compounds vary considerably in different species. Due to the basic chemical properties of mercury, several basic biological mechanisms are affected in living organisms in general. Because mercury possesses a strong affinity for sulfur and sulfhydryl groups, studies have shown that it may interfere with membrane and enzyme functions in living organisms (Berlin, 1986). In humans, excess amounts of mercury cause Minamata disease. People with Minamata disease suffer from weakening muscles, loss of vision, impairment of cerebral functions, and eventually paralysis (Forstner, 1983).

In addition to the toxic standards discussed above, Section 307(b) of the Clean Water Act provides for EPA establishment of pretreatment standards for wastes that are to be introduced into municipal treatment systems rather than being discharged directly into waters. These pretreatment standards are to prevent introduction of substances that cannot be adequately treated by public facilities or that might damage those facilities. Specifically, Section 307(b)1 requires that the standards "prevent the discharge of any pollutant through treatment works..., which pollutant interferes with, passes through, or otherwise is incompatible with such works." The need for this requirement arises from the fact that publicly owned treatment works (POTWs) generally are not designed to treat many industry generated pollutants, particularly heavy metals and other toxic pollutants. If introduced into POTWs, such pollutants may impair the work's operation, pass through without effective treatment, or settle in and contaminate the POTWs' sludge, causing sludge disposal problems. For example, sludge contaminated with heavy metals may be unusable as a soil conditioner because of danger to crops and drinking water. A 1979 study indicated that approximately thirty percent of all municipal sludge is applied to land (Federal Register, 1979).

2.2 Naval Dental Clinic Norfolk

Sanitary sewage for the majority of Naval Base Norfolk is collected at the 99th Street monitoring station prior to discharge to the Army Base Wastewater Treatment Plant, one of eight POTWs operated by the Hampton Roads Sanitation District (HRSD). This treatment plant has no connection to the U.S. Army. It is located on land that was once part of an Army fort that no longer exists. After treatment to standards prescribed in the plant's Virginia Pollutant Discharge Elimination System (VPDES) permit, wastewater from the plant is released into the Elizabeth River which in turn flows into Chesapeake Bay.

After the Base was cited twice by HRSD for exceeding federal, state and local limits for mercury in a sewer system, the Navy Public Works Center investigated and determined that the problem originated at the Norfolk Naval Dental Clinic which is the military's largest free standing dental clinic and is among the largest dental clinics in the United States, if not the world. On average, 1200 patients per month are treated in the clinic's 116 operatories.

In order to get some idea of the range of total mercury concentrations in the dental clinic wastewater, grab samples were taken from a random combination of one, two or three of the oral evacuation system collection tanks at random times on random dates. The wastewater mercury investigation revealed that the clinic was discharging between 0.1 and 10,500 mg/liter of total mercury (Table I). Even when diluted by combination with other base wastewater in the sewer system, the clinic discharge still caused the Naval Base discharge at times to be well in excess of the daily maximum limit of 0.1 mg/liter and the monthly average limit of 0.05 mg/liter established by HRSD in accordance with 40 CFR 403.5.

The mercury contamination is a result of dental amalgam processed through the building's High Volume Oral Evacuation (HVE)

Table I Total Mercury Analysis, Building CD-3 Collection System, Norfolk Naval Dental Clinic (1)

Date	Results (PPM) (2)
12/14/92	1.4
12/14/92	1130.0
12/14/92	3970.0
12/14/92	576.0
12/15/92	280.0
12/15/92	260.0
12/15/92	11.6
12/17/92	94.4
12/17/92	459.0
12/17/92	10500.0
12/17/92	0.356
12/21/92	537.0
12/21/92	44.6
12/22/92	494.0
12/28/92	0.107
12/28/92	188.0
12/28/92	114.0
01/04/93	26.0
01/04/93	0.361

Notes: (1) Samples were grab samples taken at random times on random dates from a random combination of one, two or three of the oral evacuation system collection tanks, located inside the dental clinic.
(2) PPM = mg/liter

unit. Amalgam fillings used in restorative dentistry contain approximately 50% mercury, 35% silver, 13% tin, and 2% copper. An average of 8-10 chairs per day are dedicated to amalgam work. The oral evacuation system at the clinic scavenges and collects liquids, solids, and aerosols from the patients mouths and vacuums this waste through a mesh strainer and into three 125 gallon collection tanks (each serving a separate zone of the building) located in a mechanical room. Large amalgam particles, produced during the fabrication of restorations, are removed daily from the mesh strainers at each dental chair and combined with other amalgam scraps for turn in to the Defense Reutilization and Marketing Office (DRMO) for disposal and/or recycle. Fine amalgam particles, produced during high speed drilling procedures, pass through the strainers into the collection tanks which are discharged simultaneously to the sanitary sewer at the end of each working day when the system is shut down, or when (and if) the tanks ever become overfilled. It is highly unlikely that the tanks would become overfilled as the clinic only collects approximately 8 gallons per day of amalgam wastewater. Since amalgam particles are denser than the liquid component of the dental wastewater, the possibility exists for the particles to settle in low areas of the evacuation system lines and collection tanks.

On 6 January, 1993, after learning of a possible shut down of the clinic ordered by the Hampton Roads Sanitary District, the Navy disconnected the drain lines from the clinic's oral evacuation system to the sanitary sewer and started collecting the approximately 8 gallons per day of dental chair wastewater in 55 gallon plastic drums double lined with red plastic "infectious waste" bags. At this time, the waste was seen not only as a hazardous waste because of the mercury, but also as a potentially infectious waste because it included saliva and blood from dental treatment procedures.

The Navy was now faced with two problems. In the short term, they had to deal with the drums of amalgam wastewater now being collected. In the long term, they had to find a method of removing the amalgam from the wastewater so that the drain lines from the evacuation system could be reconnected to the sanitary sewer.

3.0 Regulations Applicable to the Handling and Disposal of Dental Amalgam Waste

Once the clinic started collecting the amalgam wastewater in drums, the Navy faced a whole host of questions which had never been considered while the waste stream was being released to the sanitary sewer. Specifically, the Navy had to determine if the wastewater was a solid waste and/or a hazardous waste and/or an infectious waste. If any or all of the preceding were true, then the Navy, as the generator, had to determine how to properly handle, store, transport and dispose of the waste (Loehr, 1993).

3.1 Solid Waste Regulations

As a secondary material being held for disposal, the amalgam wastewater now being stored in drums qualified as a solid waste under the Resource Conservation and Recovery Act of 1976 (RCRA) (40 CFR 261). Prior to disconnection from the sanitary sewer, the wastewater was excluded from qualification as a solid waste by 40 CFR 261.4(a) which lists materials that are not considered solid wastes regardless of whether they fit the definition. Under this section, "domestic sewage or any mixture of domestic sewage and other wastes that pass through a sewer system to a publicly owned treatment works (POTW)" are excluded from regulation as solid waste. These types of discharges are regulated under the Clean Water Act discussed in Chapter 2.1 of this report.

Both the Commonwealth of Virginia and the Navy have regulations on solid waste. However, since there is little doubt that the drummed amalgam waste classifies as solid waste under RCRA and since the Virginia and Navy regulations are based on and have primarily the same requirements as RCRA, a detailed discussion of them is not included.

3.2 Hazardous Waste Regulations

Any solid waste can be designated as a hazardous waste if it is either listed by the EPA or if it exhibits any of the four characteristics: ignitability, corrosivity, reactivity, or toxicity (40 CFR Part 261). Dental amalgam has not been specifically listed as a hazardous waste under federal regulations, nor has it been determined to be ignitable, corrosive or reactive.

The test required by the EPA to measure the likelihood of toxic substances getting into the environment is the Toxicity Characteristic Leaching Procedure (TCLP). As summarized from 40 CFR 261, the TCLP test is designed to determine the mobility of both organic and inorganic contaminants present in liquid, solid, and multiphasic wastes. For analysis of toxic species, a solution is leached from the waste and is designated as the TCLP extract. The extract is then analyzed for 39 specific volatile organic compounds, semivolatile organic compounds and metals to determine if the waste exceeds specified levels of these contaminants.

According to U.S. Army Environmental Hygiene Agency 1992 guidance for waste amalgam disposal, TCLP tests performed by the American Dental Association on cured amalgam have demonstrated that the leachable heavy metal content of amalgam is below regulatory thresholds stated in 40 CFR 261.24 (USAEHA, 1992). However, in February 1993, a TCLP test performed on dental amalgam scraps generated at the Marine Corps Recruit Depot, Parris Island, South Carolina was found to exceed the toxicity characteristic level for silver. Also in February 1993, a TCLP test performed on collected dental wastewater from the Navy clinic in Norfolk was found to exceed the toxicity characteristic level for mercury.

In light of the above, the drummed amalgam wastewater would have to be designated as a hazardous waste. The Navy was thus obligated to comply with all of the requirements of the RCRA "cradle to grave" management system for hazardous waste. These requirements include being permitted by the EPA to generate the hazardous waste, complying with storage limitations, and finding both a certified transporter and a certified treatment, storage and disposal (TSD) facility that were permitted to handle the specific waste (Loehr 1993). A complete review of these requirements is beyond the scope of this report.

Again, both the Commonwealth of Virginia and the Navy have regulations on hazardous waste. However, since there is little doubt that the drummed amalgam waste classifies as hazardous waste under RCRA and since the Virginia and Navy regulations are based on and have primarily the same requirements as RCRA, a detailed discussion of them is not included.

3.3 Infectious Waste Regulations

Initially, because of the presence of blood and saliva in the waste, there was some concern that the drums of wastewater could be considered as infectious waste. The definition of infectious waste and the terminology used to describe it vary widely from state to state and even within organizations (Hamilton, 1992). Other terms used to describe infectious waste include: medical waste, regulated waste, regulated medical waste, bio waste, biological waste and biohazardous waste. Throughout this report, the term infectious waste is used as defined by EPA, as indicated below. However, some of the sources consulted and quoted have used other terms. A short review of applicable regulations follows.

3.3.1 EPA Guide for Infectious Waste Management

The EPA defines infectious waste as a "waste capable of producing an infectious disease" (EPA, 1991). Consideration of certain factors necessary for induction of the disease is required. These factors include:

a) presence of a pathogen of sufficient virulence
b) dose
c) portal of entry

d) resistance of host.

The EPA further goes on to list categories of infectious waste (Table II). The only category that might possibly apply to the drummed amalgam waste is "Pathological waste" which is defined below (EPA 1991).

> Pathological Wastes- Pathological wastes consist of tissues, organs, body parts and body fluids that are removed during surgery and autopsy. All pathological wastes should be considered infectious because of the possibility of unknown infection in the patient or corpse.

Table II EPA Categories of Infectious Waste

Isolation Waste
Cultures and stocks and associated biologicals
Human blood and blood products
Pathological waste
Contaminated sharps
Contaminated animal carcasses, body parts and bedding
Wastes from surgery and autopsy
Contaminated laboratory waste
Dialysis unit waste
Contaminated equipment

Italicized items are optional under EPA guidance

SOURCE: U. S. Environmental Protection Agency et al, Medical Waste Management and Disposal (Park Ridge, New Jersey: Noyes Data Corporation, 1991).

In this definition, the term "body fluids" could be taken to mean saliva. However, there is some question as to whether a routine dental procedure is considered to be "surgery." The guidelines leave a considerable amount of decision and authority to the healthcare facility in determining what exactly is to be considered infectious. The above would suggest however, that there is no requirement from the EPA to classify the drummed amalgam waste as infectious waste.

3.3.2 Standards for the Tracking and Management of Medical Waste (40 CFR 259)

Waste dental amalgam does not meet the definition of regulated medical waste as stated in the above CFR. Categories of regulated medical waste identified in this regulation were:

a) cultures and stocks of infectious agents
b) human pathological waste, including tissues, organs and body parts
c) human blood and blood products
d) used and unused sharps
e) contaminated animal carcasses and isolation wastes.

The purpose of this CFR was to establish a demonstration program for tracking medical waste shipments pursuant to the Medical Waste Tracking Act (MWTA) of 1988. The MWTA was passed by Congress in response to the crisis caused by beach washups of medical waste during the summer of 1988 (Hamilton, 1992). This demonstration program was effective between June 22, 1989 and June 22, 1991 when Congress decided not to extend the program. Currently, there is no federal regulation for the management of medical waste. Many states have adopted the categories of regulated medical waste as previously identified under 40 CFR 259.

3.3.3 Occupational Safety and Health Act (29 CFR 1910.1030 Bloodborne Pathogens)

This amendment to the Occupational Safety and Health Act was passed in December, 1991. It is applicable to all occupational exposure to blood or "other potentially infectious materials." Under this rule, saliva from dental procedures is a body fluid that is listed as one of the "other potentially infectious materials." However, in addressing the disposal of regulated wastes, the regulation states only that: "Disposal of all regulated waste shall be in accordance with applicable regulations of the United States, States and Territories and political subdivisions of States and Territories." Therefore, the only impact of this regulation is to provide packaging, labeling, storage and handling requirements while the waste is in the workplace where it was generated. Since there is no federal regulation for the management or disposal of medical waste (see Chapter 3.3.2), the Navy turned to the Commonwealth of Virginia for guidance.

3.3.4 Commonwealth of Virginia Infectious Waste Management Regulations (VR 672-40-01)

These regulations, updated in May, 1992, describe an infectious waste as:

"Any solid waste, as defined in these regulations and which is not excluded from regulation is an infectious waste if it is identified by the healthcare professional in charge as capable of producing an infectious disease in humans, or if it is one of the controlled infectious wastes listed in subsection 3.5."

The list in subsection 3.5 is almost identical to the list provided by the EPA (Table II) with the exception of "isolation wastes" which are not included.

In addition to the wastes described above, the Commonwealth of Virginia waste regulations also list several wastes that are considered to be infectious. This list includes:

"Pathological Wastes - All pathological wastes and all wastes that are human tissues, organs, body parts, or body fluids are infectious waste"

Note in this definition, unlike that of the EPA, there is no mention of surgery. In light of the above, the drummed amalgam wastewater might be classified as infectious as well as hazardous as established in Chapter 3.2. However, subsection 3.3.B.3 of the regulations lists as an exception to classification as an infectious waste "Garbage, trash and sanitary waste from septic tanks..." A letter from the Commonwealth of Virginia Department of Waste Management dated March 9, 1993, confirmed that the

> "material is considered to be sewage and the container for its collection is considered to be a septic tank. The situation is similar to cases where sewage is collected in tanks for transport to sewage works or other cases of septic tank solids being transported to fields for land disposal. In either case, the Department does not consider the waste to be regulated as infectious waste... The waste should be managed in accordance with the rules of the Department of the Navy..."

3.3.5 Chief of Naval Operations Instruction 5090.1A (OPNAVINST 5090.1A) Environmental and Natural Resources Program Manual

OPNAVINST 5090.1A, dated 2 October 1990, states as its purpose:

> "To discuss requirements, delineate responsibilities, and issue policy for the management of the environment and natural resources for all Navy ships and shore activities."

The definition of infectious waste provided in Section 10-3.1 is essentially the same as the EPA definition minus the optional categories of infectious waste. Section 10-4.5 requires federal facilities to comply with state infectious waste regulations. This presents somewhat of a dilemma as the state of Virginia requires the Navy to comply with "the rules of the Department of the Navy."

OPNAVINST 5090.1A also provides authority and assigns responsibility to the Navy's Bureau of Medicine for the issuance and revision of BUMEDINST 6280.1 Management of Medical Waste.

3.3.6 Bureau of Medicine and Surgery Instruction 6280.1 (BUMEDINST 6280.1) Management of Medical Waste

BUMEDINST 6280.1, dated 25 March 1991, provides the following definition of infectious waste:

> Definition: Infectious waste is liquid or solid waste that contains pathogens in sufficient numbers and with sufficient virulence to cause infectious disease in susceptible hosts exposed to the waste. Examples: ...

The definition goes on to list a set of examples that is similar to the categories defined by the EPA. It is interesting to note however that there is no specific mention of body fluids as an example of infectious waste. Therefore, it seems safe to conclude that there is no basis in Navy instructions to classify the drummed amalgam waste as infectious waste.

4.0 Short Term Alternatives

As stated Chapter 2.2, the immediate problem facing the Navy was what to do with the drums of wastewater. For the following reasons, the only option that was investigated and pursued was contract disposal:

(a) The Navy already had hazardous waste contracts in place in the Norfolk area. It would be relatively easy to incorporate this disposal into a current contract or to write a new one.

(b) The Navy had a maximum of 90 days to dispose of the waste (40 CFR 262).

(c) The problem was seen as temporary, and not worth investing a lot of time and effort.

(d) The Navy is not normally in the business of treating and disposing of its hazardous waste. Contract disposal is the method of choice for all Navy hazardous waste.

Once the clinic started collecting the wastewater in drums, it was classified as a hazardous waste, and became subject to the requirements of 40 CFR 262. Naval Base Norfolk was permitted as a hazardous waste generator by the EPA for many different wastes being generated there. It was a small matter to get a permit for the amalgam wastewater. The Naval Base was also familiar with the handling, storage, manifesting, record keeping and reporting requirements of RCRA. A transporter and a disposal facility permitted for mercury were located and the proper arrangements made. The total cost for transportation and disposal of the amalgam wastewater is approximately $2700.00 per 55 gallon drum.

It is interesting to note that before the waste was classified as strictly a hazardous waste (not as a hazardous/infectious mixture), the Navy had contacted every EPA approved mercury disposal facility in the United States and one in Canada and none of them would accept it. Once the classification of the mixture was determined to be strictly hazardous, though the contents were unchanged, it became a routine matter to locate a disposal facility. It is also interesting to note that although there are dual permitted transporters that can transport the dual waste, there are no permitted disposal facilities to which the hazardous/infectious waste mixture can be transported.

5.0 Long Term Alternatives

Compliance with existing regulations will involve some combination of changes to the process used in the transfer of the wastewater/saliva mixture from the patients' mouths to the sanitary sewer and/or a change to the material used to fill teeth. Other considerations include requesting a variance from the current regulations or challenging the EPA and the test used to determine the toxicity of dental amalgam.

5.1 Separation Devices

Any solution to compliance problems with the current regulations will require removal of the metals from the dental wastewater stream. Indeed, the Hampton Roads Sanitation District requires the discharger to "take all reasonable steps to minimize, correct or prevent any discharge in violation of" the HRSD Industrial Wastewater Discharge Regulations, and has agreed to allow the reconnection of the oral evacuation system collection tanks to the sewer if the concentration of the mercury discharged from the clinic can be "significantly reduced." Unfortunately, there is no description of "all reasonable steps" required for the removal of amalgam from dental clinic wastewater streams in the U.S.

Installation of amalgam particle separating devices with 90 to 99 percent removal efficiencies are now mandatory in Switzerland, Germany, Sweden, and Denmark. Data from European studies investigating sewage from dental clinics equipped with amalgam separators demonstrated that the mean mercury level in wastewater is about 10% of the values obtained in studies including clinics without separators (Arenholt-Bindslev and Larsen, 1990: Hogland et al., 1990; Graf et al., 1988). Neither the European studies nor a study done at Goodfellow Air Force Base (Binovi, 1989) suggest that local discharge limits could be met by any practical means, but both indicate that a significant reduction in mercury could be accomplished with physical separation devices.

In February, 1993 the Naval Dental Research Institute was tasked by the Bureau of Medicine (BUMED) to undertake an evaluation of amalgam separator systems. The situation at the clinic in Norfolk could not wait for the results of this research. Therefore, a preliminary literature review of currently manufactured separation devices was completed and is provided in this section.

5.1.1 Filtration

Method of Operation: Filtration is the process of separating and removing suspended solids from a liquid by passing the liquid through a porous medium. If a filter unit was used, it would have to be installed after the collection tank and would have to be properly sized to accept the surge gravity flow when the collection tank is emptied and flushed at the end of each work day. The tanks are emptied only after working hours because the process requires breaking the vacuum on the tanks which precludes use of the HVE system during the time required for clean out.

Efficiency: A Parker filtration unit equipped with 0.001 mm filter bags housed in a cartridge system was temporarily installed at the Branch Dental Clinic, South Weymouth, MA. One pre-filter sample of 0.38 mg/liter total mercury was reduced to 0.039 mg/liter after passing through the unit.

Disposition of Collected Particles: Disinfectant currently used in the oral evacuation system can be routinely used to run through the filter bag. Once the bag has become full, the filtered amalgam would be turned over to DRMO for recycle or disposal.

Cost: The Parker model costs $1,600.00 for the cartridge filter bag system. The bags cost $25.00 to $45.00 each, based on material composition.

Advantages:

(1) Filtration is a simple amalgam separating device. There are no moving or electrical parts that would be subject to breakdown.

Disadvantages:

(1) No alarm or automatic system shut-off when the filter bags fill up.

(2) No indication of the required replacement and disposal cycle of the filter bags.

5.1.2 Centrifugation

Method of Operation: Using centrifugation, the amalgam particles in the dental wastewater would be physically separated based on their relative densities, by rapidly rotating the fluid mixture within a rigid vessel. Solid amalgam particles, which are approximately nine times denser than the fluid medium, are deposited farthest from the axis of rotation while the liquid supernatant lies separated near the axis (Figure 2). In the unit researched, the Durr Dental Model #7801, the separated amalgam particles were then rinsed into a removable cassette. Both visual and audible alarms signal when the cassette is 95% full. In the

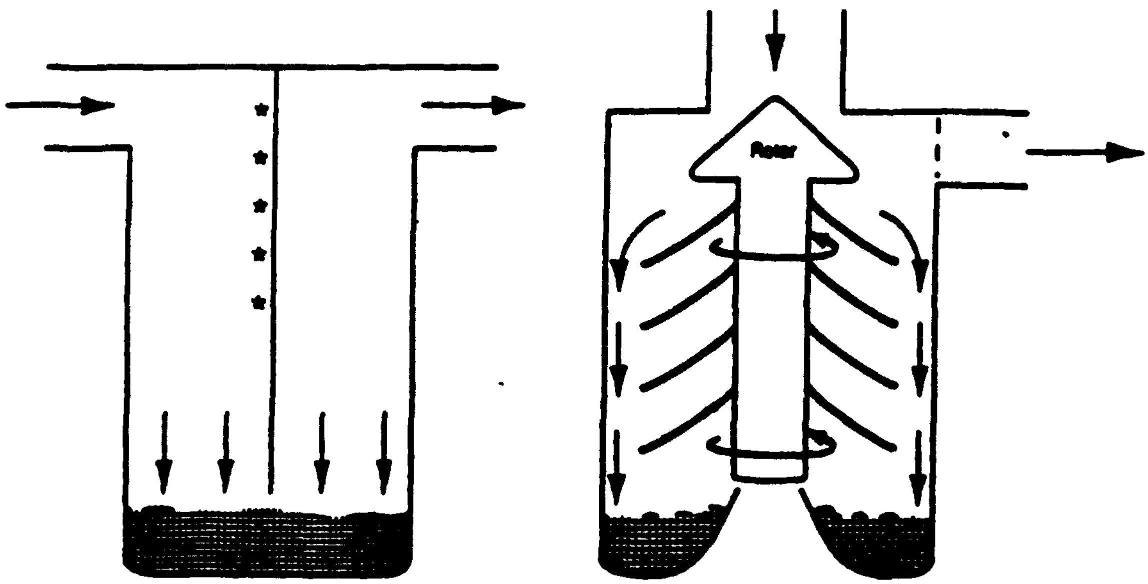

Figure 2 - Main Principles of Amalgam Separation. (a) Sedimentation: * indicates individual constructions (i.e., filters, slats, granular material) facilitating sedimentation. (b) Centrifugation: container or central rotor rotates to separate amalgam particles from the water stream (from Horsted-Bindslev et al., 1991)

event that the cassette is not changed, at 100% the audible alarm sounds continuously and the centrifuge is inactivated. If a centrifuge were used, it should be installed after the collection tanks. The wastewater from the evacuation system collection tanks would have to be metered to ensure that the wastewater would not exceed the maximum flow rate that could be handled by the centrifuge. In the case of the Durr Dental Model #7801, the maximum allowable flow rate is 12 liters per minute.

Efficiency: The Durr Dental Model #7801 offers 95% separation efficiency based on the German standard amalgam particle size distribution presented in Table III (Rotgans, 1986). The same Durr Dental centrifuge unit has been in operation at the Branch Dental Clinic, South Weymouth, MA since January, 1993. Preliminary sampling analyzed an inlet concentration of 20 mg/liter mercury and a post separator concentration of 0.17 mg/liter mercury, a reduction of over 99%.

Table III German Standard Amalgam Particle Size Distribution

Particle Size	Percent
0.5 mm to 3.0 mm	16% particles
0.1 mm to 0.5 mm	4% particles
< 0.1 mm	80% powder

SOURCE: Rotgans, J., "Particle Size Distribution of Ground Dental Amalgam Waste." Presented at the International Association for Dental Research, Stockholm, Sweden, June 1986.

Disposition of Collected Particles: Disinfectant currently used in the oral evacuation system can be used to run through the centrifuge without any expected decrease in the level of removal efficiency. Once a cassette is full, it can be turned over to DRMO for recycle or disposal.

Cost: The Durr Dental Model #7801 costs $2,500 each. The cost of the replacement cassettes is unknown.

Advantages:

(1) Audible and visible alarms which indicate when the amalgam collection cassette is 95% full and needs to be replaced.

(2) Replacement cycle for the cassettes is expected to be not less than every two months.

(3) The centrally located Durr Dental Model #7801 amalgam separator has been in successful operation for the past two years in Europe.

(4) The Durr model centrifuge is sold in the U.S. by Air Techniques, Inc., a well respected company which has been in the dental equipment business for over 30 years and has the technical support capable of installing and providing service for this system.

Disadvantages:

(1) Technology relies on electrical/mechanical operation and is therefore subject to downtime. The Naval Dental

Research Institute, Great Lakes, IL has experienced some mechanical problems with one of the new product lines from Durr, an individual dental chair separating device called the "Combi Unit." However, no problems have been reported with the Durr Dental Model #7801 centrifuge.

5.1.3 Sedimentation

Method of Operation: Sedimentation is a gravity settling process which allows heavier solids to collect at the bottom of a containment vessel resulting in their separation from the suspending fluid (Figure 2). In the unit researched, the Sweden Recycling AB sedimentation unit, inlet and outlet are located in the top of the lid of the separator. Two partition walls divide the separator into 3 chambers which end approximately 2 cm below the lid which cause the dental wastewater to run down along the walls (Figure 3). The bent chamber wall has been designed to allow the largest particles to settle in the first chamber which contains a coarse-meshed, C-bent wire netting. The second chamber contains balls of aluminum oxide and the third chamber contains plastic balls which have been designed to enhance sedimentation. This unit is also designed for installation after the collection tanks. The wastewater from the evacuation system collection tanks would have to be metered to ensure that the wastewater would not exceed the maximum flow rate that could be handled by the unit. In the case of the Sweden Recycling AB sedimentation unit, the maximum allowable flow rate is 6 liters per minute. Also, routine monitoring of the effluent out of the unit would be required to determine when amalgam particles are passing through and the unit has become full.

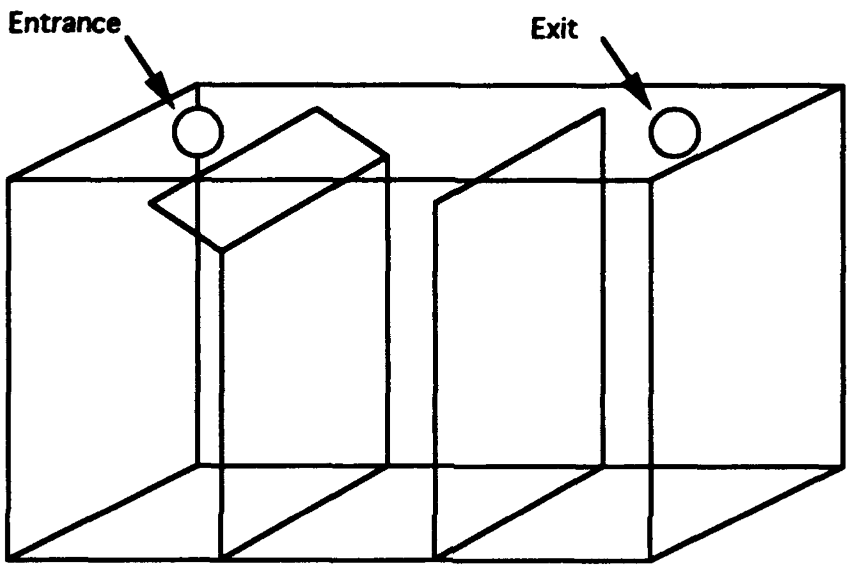

Figure 3 Sweden Recycling AB Sedimentation Unit

Efficiency: The Swedish National Authority for Testing and Inspection has achieved 99.5% separation efficiency with the Sweden Recycling AB sedimentation unit based on the Swedish standard particle size distribution presented in Table IV (Rotgans, 1986). The Swedish test procedure has been criticized for being unrealistic, since the standard amalgam particles used for testing differ considerably from naturally derived amalgam sludge (Toepper, 1986). The Swedish test procedure is currently under revision (Arenholt-Bindslev, 1992). However, preliminary bench scale studies conducted by the Municipality of Metropolitan Seattle Sanitary District have verified removal efficiencies of 99% (Municipality of Metropolitan Seattle, 1991).

Table IV Sweden Standard Amalgam Particle Size Distribution

Particle Size	Percent
1.0 mm to 2.0 mm	50% particles
0.35 mm to 1.0 mm	25% particles
0.04 mm to 0.35 mm	15% particles/powder
0.02 mm to 0.04 mm	10% powder

SOURCE: Rotgans, J., "Particle Size Distribution of Ground Dental Amalgam Waste." Presented at the International Association for Dental Research, Stockholm, Sweden, June 1986.

Disposition of Collected Particles: Disinfectant currently used in the high volume oral evacuation system can be used to run through the centrifuge. However, one Swedish study reports that disinfection has been demonstrated to reduce the removal efficiency of the unit (DiDomenico, 1993). Once the unit is full, it will have to be emptied and the contents turned over to DRMO for recycle or disposal.

Cost: U.S. Dental Recycling Inc. has been set up in this country by the Alpha International Management Company for the purpose of marketing the Sweden Recycling AB sedimentation unit in the U.S. Alpha International Management is currently planning to have dental clinics lease the sedimentation units and to set up a service contract for the pick up and recovery of the contents at a refinery in Sweden. At this time, the cost and the details have yet to be worked out.

Advantages:

(1) A sedimentation unit is a simple separating device based on enhanced sedimentation with no electrical or moving parts that would be subject to breakdown.

Disadvantages:

(1) The Naval Dental Research Institute, Great Lakes has experienced problems with the Sweden Recycling AB unit leaking.

(2) The replacement cycle for the sedimentation unit has been advertised to be up to 12 months for a single dentist office. The replacement cycle could be significantly shortened when processing a combined flow from 10 dedicated dental chairs performing amalgam restorations all day at the Norfolk clinic.

(3) There is no provision for an alarm or automatic shut off system when the sedimentation unit is full. Routine monitoring of the effluent out of the unit would be required to determine when amalgam particles are passing through and the unit has become full.

(4) Clean out of the unit would be a difficult and potentially hazardous process. The amalgam would not be

conveniently contained in a bag or a cassette as was the case with filtration and centrifugation described previously (Sections 5.1.1 and 5.1.2).

(5) The details of the service contract for the pick up and recovery of the contents at a refinery in Sweden have yet to be worked out. Because it involves the shipment of a potentially hazardous material from one country to another, it is likely to be a difficult and time consuming process to finalize the details of the proposed service contract.

5.1.4 Electrolytic Water Treatment

Method of Operation: This method of technology requires the dental wastewater to be passed through an electrolytic cell with an applied potential between electrode plates immersed in the waste stream which cause the ions to move as follows:

* At the cathode: Reduction occurs with the gain of electrons. In this case it is assumed that mercuric ions are reduced.

$$Hg^{2+} + 2e^- \rightarrow Hg$$

* At the anode: Oxidation occurs with the loss of electrons.

$$H_2O \rightarrow \frac{1}{2} O_2 + 2H^+$$

The unit researched is the Enviromed - ILSA-ZD (Integrated Logic Self Auditing - Zero Discharge) manufactured by Advanced Water Systems Inc. The unit is a self contained, skid mounted unit which is designed to interface with a computerized control console. It functions on a batch swing basis to process the wastewater. The electrolytic system reverses the polarity of the electrodes on a regular basis. The cathodes become anodes and vice versa (Figure 4). This technology assumes that mercuric Hg^{2+} ions exist in the dental waste stream and are attracted to the cathode which, when the polarity reverses, then releases the agglomerated metal into a <0.001 mm filter bag. The waste stream is then passed through a 0.001 mm filter bag before discharge. The cathode plate would need to be replaced when the potential across the electrodes decreases significantly.

Efficiency: Theoretically, with enough multiple passes through the electrolytic cell, the monthly average discharge limit of 0.05 mg/liter could be met. Without actually testing the unit at the clinic, it is impossible to tell how many passes would be required.

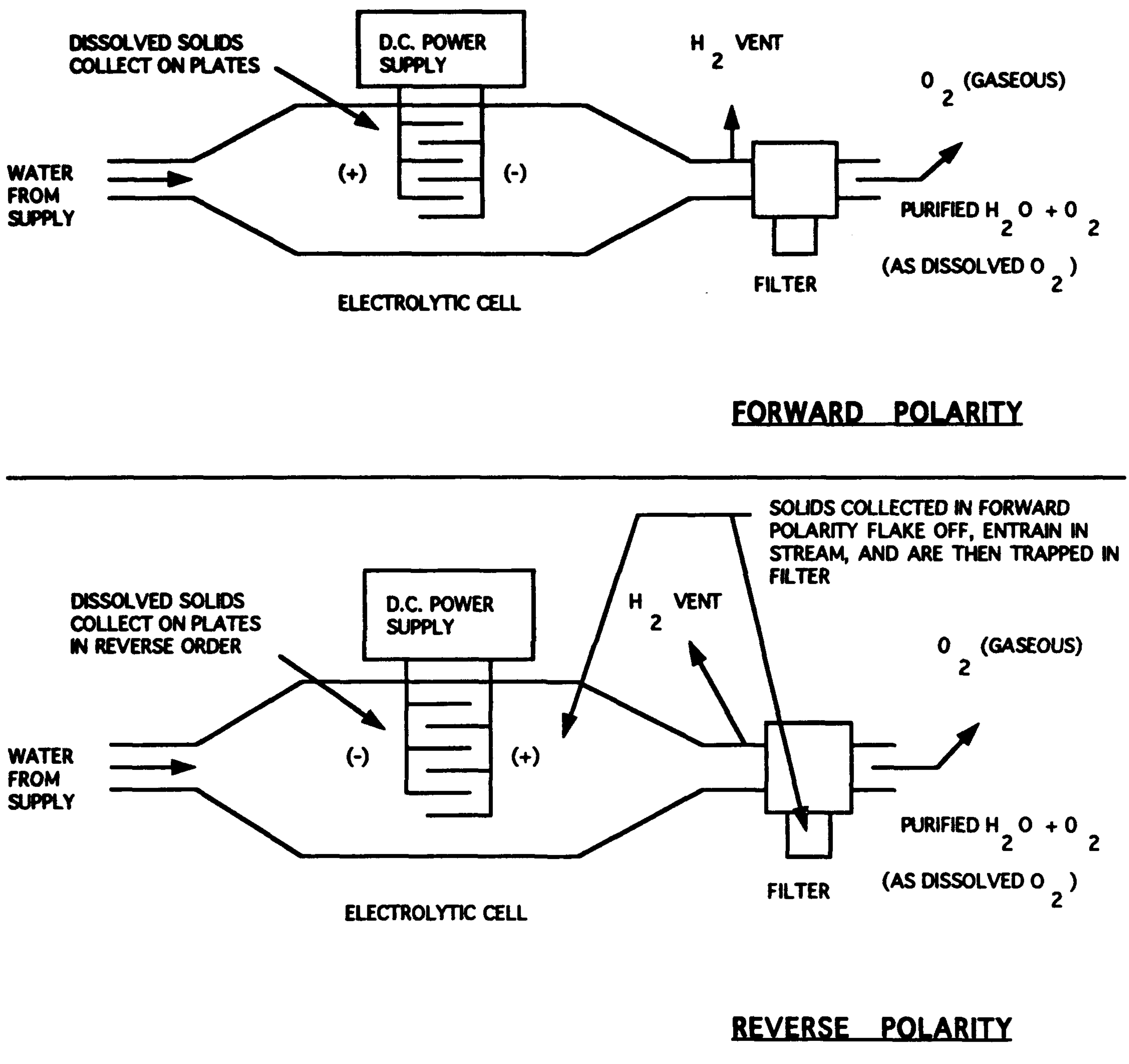

Figure 4 Advanced Water Systems Standard Electrolytic Function

Disposition of Collected Particles: Disinfectant currently used in the high volume oral evacuation system can be used to run through the electrolytic cell unit. However, it is not known whether or not this would reduce the removal efficiency of the unit. Once the filter bag becomes full, the filtered amalgam would be turned over to DRMO for recycle or disposal.

Currently there is not a program in place for recycling the amalgam particles that would be collected on the cathode plate. Advanced Water Systems proposes to have the customers send the cathode plate to a refinery where the metals could be reclaimed.

Cost: The skid mounted, self contained Enviromed unit costs approximately $5,000. The cost of replacement cathode plates and filters is unknown.

Advantages: None

Disadvantages:

(1) Although this process may be good at removing Hg^{2+} ions, it is assumed that the majority of the mercury is bound up in the dental amalgam and does not exist as Hg^{2+} ions.

(2) This system would require close surveillance to ensure proper operation.

(3) This technology relies on electrical/mechanical operation and is therefore subject to downtime.

(4) The replacement cycle for the 0.001 mm filter bags and the cathode plates is unknown, but could be as often as

(4) The replacement cycle for the 0.001 mm filter bags and the cathode plates is unknown, but could be as often as every month for the filter bags and every 4 to 6 months for the plates.

(5) There is no provision for an alarm or automatic shut off system when the unit is full. Routine monitoring of the effluent out of the unit would be required to determine when amalgam particles are passing through and the unit has become full.

5.2 Discharge Alternatives

In addition to the installation of separation devices, there are *other changes to the process* that can be made with little or no capital expenditure. Considered here are changing the screen mesh size in the HVE unit, staggering the discharge from the three tanks, and dilution.

5.2.1 Changing Screen Mesh Size in HVE Unit

The clinic's current evacuation system calls for an in-line strainer with a 40 mesh screen. The Goodfellow study (Binovi, 1989) recommends the installation of a finer mesh screen. 80 and 100 mesh strainers are available to capture smaller particles than are being removed now. However, fine materials associated with high speed drilling will still pass through.

The Goodfellow study did not speculate on how much of a reduction in mercury levels could be achieved by installation of a finer mesh screen. Since the majority of the amalgam particles are substantially smaller than 100 mesh (opening size of 0.147 mm) based on the more realistic German standard amalgam particle size distribution, it is not clear that installation of a smaller mesh screen would do much good. The use of a finer screen may also necessitate the use of a more powerful pump.

5.2.2 Staggering Discharge

The current practice of discharging the three collection tanks is to empty them all at the same time. This produces a large, short term spike in the amalgam concentration of the wastewater that enters the sanitary sewer at the 99th Street Monitoring Station. If the tanks were emptied one at a time and at a slower rate than they are now, the spike in the amalgam concentration could be significantly lower. However, testing would be required to determine how much the concentration of amalgam (and thus the mercury) would be lowered.

5.2.3 Dilution

Both 40 CFR Part 403 and Section 301 (f) of the Hampton Roads Industrial Wastewater Discharge Regulations specifically prohibit dilution as a substitute for treatment. 40 CFR Part 403.6(c)(1)(d) states:

"...no...User shall ever increase the use of process water, or in any other way attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with a Pretreatment Standard or Requirement."

However, dilution is allowed if it is incident to or part of the normal process or operation of equipment.

Unrelated to the current amalgam problem at the clinic, three new evacuation tanks had been ordered as part of a normal tank replacement program. A review of the manufacturer's literature which accompanied the new tanks indicated that they contained a water flushing system. The tanks were designed to be flushed on a periodic basis to prevent clogging of valves and associated piping which was part of the reason the existing tanks were being replaced. A comparison of the new tanks with the existing ones revealed that they too were designed to be flushed. However, the system had either never been employed or had been disconnected at sometime in the past, perhaps as a measure to conserve water, long before the amalgam problem surfaced.

Therefore, proper installation and operation of the tanks (new or existing) would require periodic flushing which would be in compliance with wastewater treatment regulations. If the tanks were flushed daily prior to discharge, the concentration of amalgam (mercury) could be reduced. Depending on the amount of water used to flush the tanks, this reduction in concentration could be quite significant, keeping in mind that the amount of amalgam waste collected each day is approximately 8 gallons, while each tank can hold 125 gallons.

5.3 Regulatory Variance

As mentioned in Chapter 5.1, the Hampton Roads Sanitation District requires the discharger to take "all reasonable steps" to minimize the concentration of mercury in the wastewater. If the Navy meets the European industry standard (since there is no U.S. standard) by installation of one of the physical separation devices, and takes additional steps described in Chapters 5.1 & 5.2, and still does not meet the required discharge concentration, they then should be able to apply for and receive a variance from the concentration requirement. It would seem at that point that the Navy would have taken all "reasonable steps" to minimize the mercury concentration in the wastewater.

Part VI, *Section 601 of the HRSD Wastewater Discharge* Regulations describes the review and appeal procedures available to permittees. The process includes the submission of a written request by the permittee, a hearing in the presence of a hearing officer appointed by the District's General Manager and a decision by the General Manager based on the recommendation from the hearing officer. The decision of the General Manager can be appealed to the Commissioners of the District.

The HRSD regulations do not list any specific factors which may be considered in appeal procedures, however, 40 CFR 403.13 allows for the approval of variances from concentration limits based upon "fundamentally different factors." One of the factors considered to be fundamentally different is "The nature or quality of pollutants contained in the...User's... wastewater." While it is uncertain to what extent mercury bound in released amalgam particles becomes bioavailable, studies conducted in both Europe and the U.S. on the solubility of amalgam suggest that, in pure water as well as in sewage, only minute amounts of mercury (<0.004%) are released from set amalgam (Heintze et al., 1983; Beckert, 1988; McCann, 1993). Using data from these studies as well as other information, dentists in both Michigan and Arizona have recently been able to convince local wastewater departments to grant variances from local mercury concentration level limits (McCann, 1993).

5.4 Challenging the Standard

The method used to identify toxic pollutants in a material is the "total recoverable" metals standard, which was devised by the EPA. It involves collecting samples of metallic substances discharged into wastewater and subjecting them to a strong acid. Any harmful metals released by the acid test are potentially subject to wastewater regulations.

There is a less stringent test called the "dissolved" standard, which measures only those metals that escape a 0.45 micron filter. Local governments usually rely on the total recoverable method, which is considered to be the safer alternative.

There is some doubt as to whether the total recoverable test is valid in the case of dental amalgam. It assumes that everything dissolved by acid is going to be available to the environment. The studies mentioned in Chapter 5.3 and others indicate that this is not true in the case of dental amalgam. Dental amalgam is an alloy - a solid solution or mixture of metals in which the component metals unite by occupying spaces within each other's atomic structures. Alloys are stable physically and chemically, meaning that they do not spontaneously or readily break down into their component elements. Alloys generally, and dental amalgam specifically, are not identified as hazardous substances in the EPA lists and other federal environmental statutes (Rogers, 1989). Indeed, Charles Delos, with the EPA's Ecological Risk Assessments Branch, noted that the total recoverable method "tends to be overconservative and it doesn't accurately measure toxicity because the [toxic] metals in compounds are not bioavailable" (McCann, 1993). Doubts about the total recoverable test have caused the EPA to initiate a *review* of the standard.

The American Dental Association (ADA) has taken an interest in the amalgam/wastewater regulation issue. In October, 1992, the ADA House of Delegates approved a resolution (127H-92) appropriating $150,000 to fund a three pronged plan to deal with amalgam regulation (McCann, 1993). The measure calls for the ADA to:

- continue to fund studies that accurately identify whether amalgam wastewater discharge affects the environment, and to fund the ADA's investigation of technologies to remove amalgam from dental office wastewater;

- provide information to dental societies to help them deal with attempts to impose unscientific regulations;

- take action to persuade the EPA to revise its policy to recognize the difference between combined and other chemical states and forms of mercury, and adopt a scientific alternative to the total recoverable test.

Challenging the standard should be used only as a last ditch effort by the Navy. Matters such as these are better left to experts such as the ADA. The Navy has enough other challenges and controversies to handle. However, the situation warrants close monitoring and the Navy should not hesitate to assist by providing data or other information *if the ADA requests it*.

5.5 Alternate Materials

Amalgam has been used as dental restorative material for more than 150 years (U.S. Department of Health and Human Services, 1993). Even though there are many new synthetic non-metallic materials such as composite resins, glass ionomers and ceramics, amalgam is still the most widely used and cost effective material used in restorative dentistry. As discussed in Chaptors 5.3 and 5.4, mercury is not readily released from amalgam in wastewater and there is no scientific evidence that would justify the discontinuation of the use of amalgam.

6.0 Conclusions and Recommendations

From this study of the Navy Dental Clinic Norfolk and the regulations concerning the discharge of dental amalgam particles in the wastewater, the following conclusions and recommendations can be made:

(1) From both a regulatory and a public relations standpoint, the Navy should act quickly to resolve the amalgam/wastewater problem in Norfolk.

(2) The wastewater currently being collected in drums is not an infectious waste, but it is a hazardous waste and must be handled, stored, treated and disposed inaccordance with RCRA requirements.

(3) The best way to dispose of the drummed amalgam/ wastewater is via contract disposal.

(4) Should the Navy consider meeting the wastewater concentration limits for mercury mandated by the Clean Water Act and the Hampton Roads Industrial Wastewater Regulations, the following steps should be taken:

(a) Clean out all the lines and traps leading from the operatories to the collection tanks.

(b) Install new evacuation tanks complete with an operating flushing system.

(c) Stagger the discharge of the three evacuation tanks.

(d) Install a Durr Dental Model #7801 centrifuge (or equivalent) in the discharge lines of each of the three evacuation tanks.

(5) In the event that the steps listed in 4 (a) - (d) above do not bring the mercury concentration of the wastewater into compliance with required regulatory levels, the Navy could seek a variance based on taking all "reasonable steps" to minimize the discharge of amalgam into the wastewater and on the fact that only minute amounts of mercury become available from amalgam.

(6) Owing to the large number of Naval dental clinics around the world, the Navy should continue to monitor efforts by the ADA in the amalgam/wastewater area and should provide data or other information if requested by the ADA.

(7) It is likely that the dental amalgam problem in Norfolk is just the "tip of the iceberg" in this area of regulatory compliance. The same or similar problems may surface at Naval dental clinics in other locations. Therefore,

the Naval Dental Research Institute should continue to evaluate amalgam separator systems for potential future use at clinics around the world.

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