Naval Medical Research Unit San Antonio Captures Mercury-Containing Amalgam Waste

Chairside Filter Acts as First Line of Defense at Dental Treatment Facilities

PERSONNEL FROM THE Naval Medical Research Unit San Antonio (NAMRA-SA) are exploring an innovation to capture mercury-containing amalgam and to ensure ongoing environmental compliance in Navy dental treatment facilities (DTF).

A large number of cavities are filled each year by Navy dentists to ensure Sailors are ready for deployment. The dental amalgam waste produced from placing or removing amalgam restorations can result in a large release of mercury into publically owned wastewater streams if it is not controlled at the dental clinic site.

With the U.S. Environmental Protection Agency's (EPA) legislation regarding dental amalgam waste pending, new efforts to develop novel materials to increase the efficiency and specificity of contaminant removal from dental wastewater have been accelerated.

In response to this complex environmental challenge, Navy dental facilities across the globe are being armed with a novel amalgam filter technology—a chairside amalgam separator (Navy U.S. Patent No. DD2011)—developed at NAMRU-SA and sponsored by the Navy Bureau of Medicine and Surgery that may establish Navy dental facilities as models of environmental stewardship.

tigator and Head of NAMRU-SA's Biomaterials and Environmental Surveillance Department.

Dental amalgam is a metallic mixture consisting of about 50 percent liquid mercury and a powdered alloy that contains silver, tin, and copper. When mixed, the two components harden and become a solid material (commonly referred to as silver fillings), which is used to fill cavities in teeth. Dental amalgam is completely safe for use in adults and children over the age of six. Because dental amalgam is safe, cost effective, strong, and durable, it is frequently used to fill cavities.

> The DD2011 chairside amalgam separator is designed to remove up to 96.7 percent of amalgam from dental wastewater.

The DD2011 chairside amalgam separator is designed to remove up to 96.7 percent of amalgam from dental wastewater. It is inexpensive, easy to install, and available for use across all services. "In this separator design, we focused on minimizing and mitigating the Navy's amalgam waste impact on water, land, air quality, and even biodiversity. We worked on a systemic solution to reduce mercury load into the wastewater stream," said Dr. Amber Nagy, Principal Inves-

Since 2006, the Navy has enforced instructions mandating the use of

dental amalgam separators since 2006. In fact, the Navy developed and patented the International Organization for Standardization (ISO) certified DD2011 chairside amalgam separator which is now widely used in Navy DTFs and in the private sector.

The DD2011 chairside amalgam separator is installed on individual dental chairs and acts as the first line of defense for capturing amalgam waste. Recently, the EPA released a draft rule that included the mandatory use of amalgam separators in all DTFs to reduce mercury emissions into publicly-owned wastewater streams.

The DD2011 chairside amalgam separator is installed using existing dental chair hoses. Several adaptors with various diameters are available to accommodate dental hose specifications.
Flisa Stevenson

Effective Lifetime of Chairside Amalgam Separators & Effects of Storage

NAMRU-SA conducted a clinical field study to evaluate the effective lifetime of DD2011 chairside amalgam separators. The intent of the study was to determine the length of time that each separator could remain installed before requiring replacement using quantitative parameters such as vacuum strength. Metal concentration in effluents collected downstream of the separator was also evaluated. Using data from this study, the effective lifetime of the DD2011 dental amalgam separator is now designated as 60 days for high volume DTFs.

The effect of DD2011 chairside amalgam separator storage on metal retention was also studied to simulate mobile DTF deployment. Results revealed that storage of used DD2011 chairside separators should be minimized (less than one year). For mobile dental units, separator exchange should be performed approximately every three months.

Lastly, storage conditions are being tested to determine if inorganic mercury can be converted to organic mercury, which is more toxic and can accumulate in the aquatic food chain.

More About the Naval Medical Research Unit San Antonio

NAMRU-SA WAS DESIGNATED to lead mercury abatement efforts for DTFs in 2011. NAMRU-SA's Department of Biomaterials and Environmental Surveillance encompasses not only mercury abatement efforts, but also investigates novel solutions to ensure Navy DTFs comply with federal and local environmental conservation laws. The department is led by Dr. Amber Nagy and utilizes interdisciplinary expertise of dentists, microbiologists, toxicologists, chemical engineers, and analytical chemists. The main goal of the department is to manage the dental waste burden from dental clinics and reduce mercury release.

The NAMRU-SA laboratory is fully functional and has expert capabilities in heavy metal analysis by atomic absorption spectrophotometry, small molecule quantification by high performance liquid chromatography/mass spectrometry (HPLC/MS), automated microwave digestion and dilution systems, and cytotoxicity assays. Additional capabilities to measure metals at part per billion levels using inductively coupled plasma mass spectrometer are expected to be completed by September 2015. NAMRU-SA's environmental surveillance team takes full advantage of these capabilities.

The NAMRU-SA environmental surveillance team has several projects underway aimed at improving the current amalgam separator systems and developing novel, more efficient waste filtration solutions. These projects include investigating the effects of DD2011 storage, utility of DD2011 in removal of Bisphenol A (BPA), improvements for a quick disconnect of the DD2011, an alarm system to signal time to change the separator, educating and training Navy DTFs and the public about the availability and proper use of the DD2011, and the development of next generation filtration strategies.

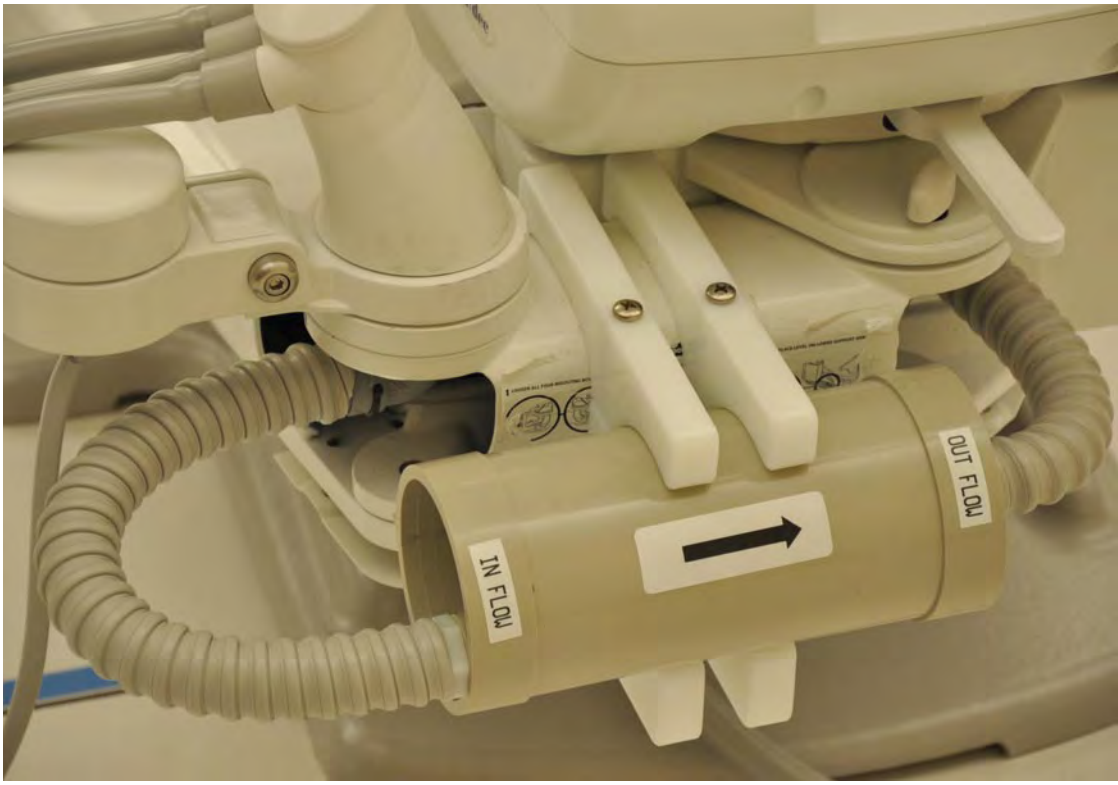
LEFT: Female connector attached to end of the DD2011 chairside amalgam separator.
CENTER: Dental chair hose with male adaptor that will clamp onto the female end and form a seal with the o-ring.
RIGHT: Fully connected hose and separator, secured with pin.
Flisa Stevenson

The NAMRU-SA team is developing a highly sensitive method for organic mercury detection using HPLC/MS. This method will allow for fast identification of mercury species in wastewater. Data from these studies will lead to better filtration systems that may reduce mercury conversion into the more toxic organic forms by capturing mercury and other metal ions before entering the public wastewater systems.

Utility of Chairside Amalgam Separator Against Bisphenol A

Environmental effects of chemicals originating from dental wastewater are not limited to amalgam. Filling materials such as dental resin composites can also contain parent materials that can degrade into BPA. BPA is listed on the EPA's chemicals of concern list due to its hormone disrupting properties. An EPA-developed action plan aims to reduce input of BPA into the environment and will likely result in the development of a BPA best management practice. Recognizing the impact of BPA on the environment, NAMRU-SA is evaluating the BPA retention efficiency of the DD2011 chairside amalgam separator. For more information about EPA's efforts to minimize the potential environmental impacts of BPA, visit the following page on the Agency's website: www.epa.gov/opptintr/existingchemicals/pubs/actionplans/bpa.html.

Based on data reported in scientific literature, NAMRU-SA hypothesized that the contact angle of the filter inside amalgam separators is an important factor to consider

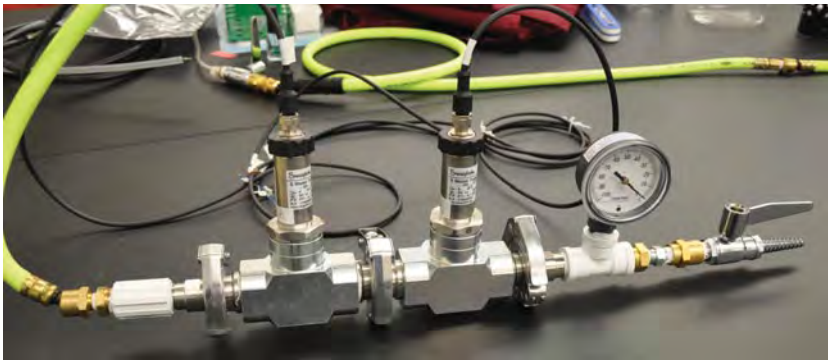


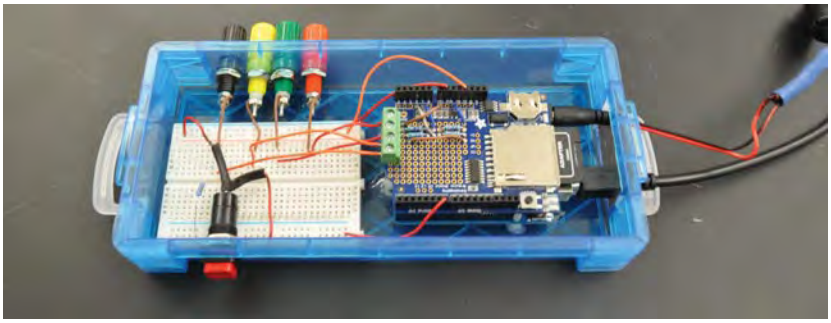
The chairside amalgam separator is easily installed on a dental chair and secured by brackets to reduce leakage and minimize tripping hazards.
Flisa Stevenson

when assessing retention efficiency of filtering material against organic chemicals such as BPA. The contact angle of a filter determines if the filter media is hydrophilic (low contact angle) or hydrophobic (high contact angle). Current studies are underway to better understand the utility of DD2011 amalgam separators to remove BPA and BPA-derived contaminants.

Quick Disconnects for Chairside Amalgam Separators

Results from a recent field survey revealed difficulties with the installation and replacement of the chairside amalgam separators. The survey identified the need for new quick disconnects to secure the separator onto vacuum tubing to expedite separator removal and reinstallation efforts.





Prototypic vacuum pressure transducers and data logger.
TOP: The vacuum transducer setup assembly and calibration.
CENTER: Prototypic pressure transducer installed on a dental chair for validation experiments.
BOTTOM: Computing device for data logging and output for subsequent data conversion to pressure values.

Flisa Stevenson

The survey also identified the need for bracket clamps to secure the separator to dental chairs, reduce tripping hazards and other safety related issues associated with storing separators on the floor. No commercial off-the shelf products are available.

Quick disconnect adapter fittings have been developed to resolve separator removal and reinstallation efforts for Navy DTFs worldwide. The quick disconnects are expected to be available for bulk purchase by the fall of 2015.

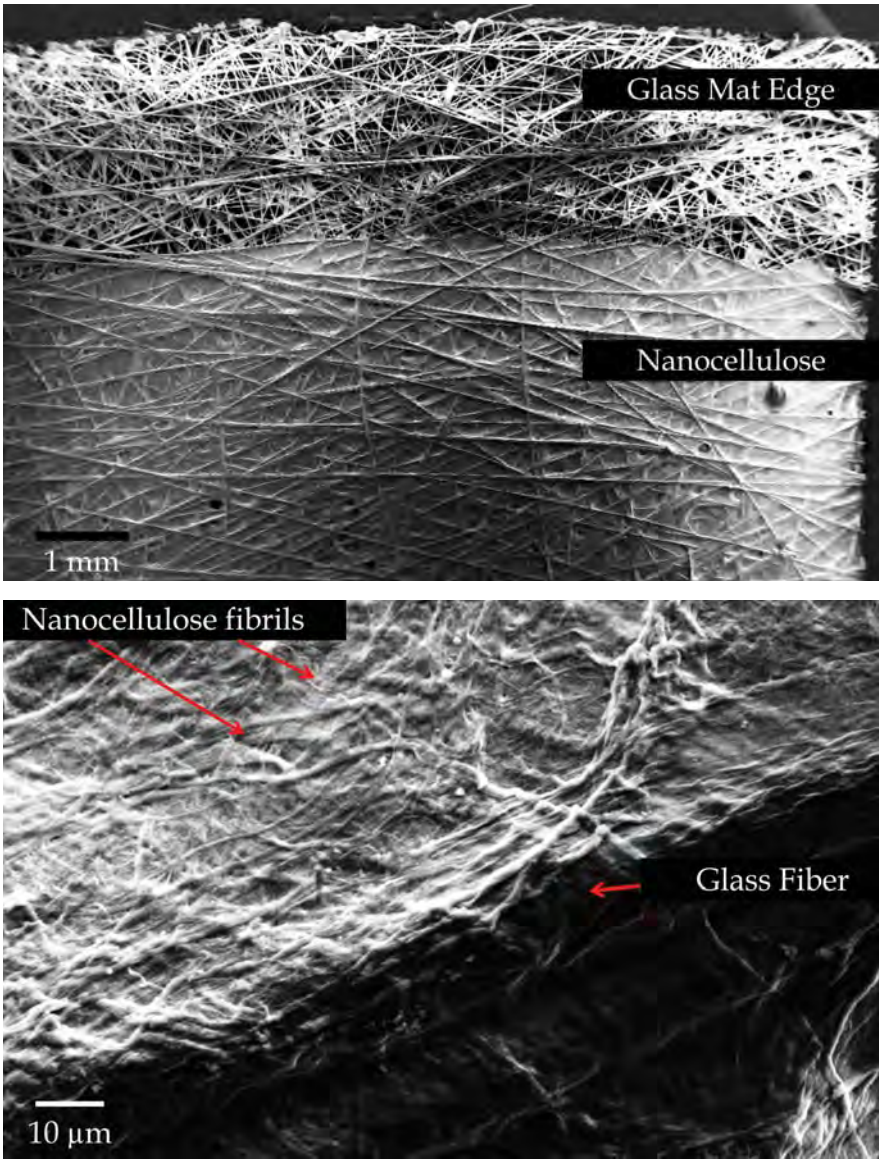
Alarm System Development for Chairside Amalgam Separators

One of the major issues plaguing nearly all of the amalgam separator systems on the market is the fact that none contain alarm systems to alert dental staff when the system has reached its effective lifetime. The current mode of operation is to exchange separators based on the amount of time they are in service. The proposed maintenance protocol of the amalgam separator calls for replacing individual filters every 60 days, regardless of use.

To better understand the lifetime effectiveness of the DD2011 chairside amalgam separator, NAMRU-SA executed a method to convert and record vacuum pressures. Specifically, NAMRU-SA designed a prototypic vacuum sensor that uses pressure transducers to convert pressure measurements upstream and downstream of the chairside amalgam separator into electrical signals. These signals are then digitized, logged, and converted to pressure values. Data are recorded in real time, and if vacuum levels fall below pre-programmed numbers, an audial alarm alerts users that the DD2011 amalgam separator

may be clogged and should be replaced. This prototype will be instrumental for testing the performance of new amalgam separator materials and designs.

NAMRU-SA is also developing a minimally invasive flow sensor that monitors the lifespan of individual chairside separators, thereby reducing maintenance cost and waste. The monitoring system will implement a flow meter, which is an effective and economical method to quantify the volume of fluid in the dental chair system. The flow meter system, positioned downstream of the separator, calculates the total volume of fluid serviced through the separator and notifies the users, visually and audibly, of scheduled cleaning and maintenance. By quantifying the lifespan of individual separators, DTFs can extend the use of the chairside amalgam separator without sacrificing the separator efficacy. These projects are crucial for implementing dental amalgam separation strategies to maintain environmental compliance.

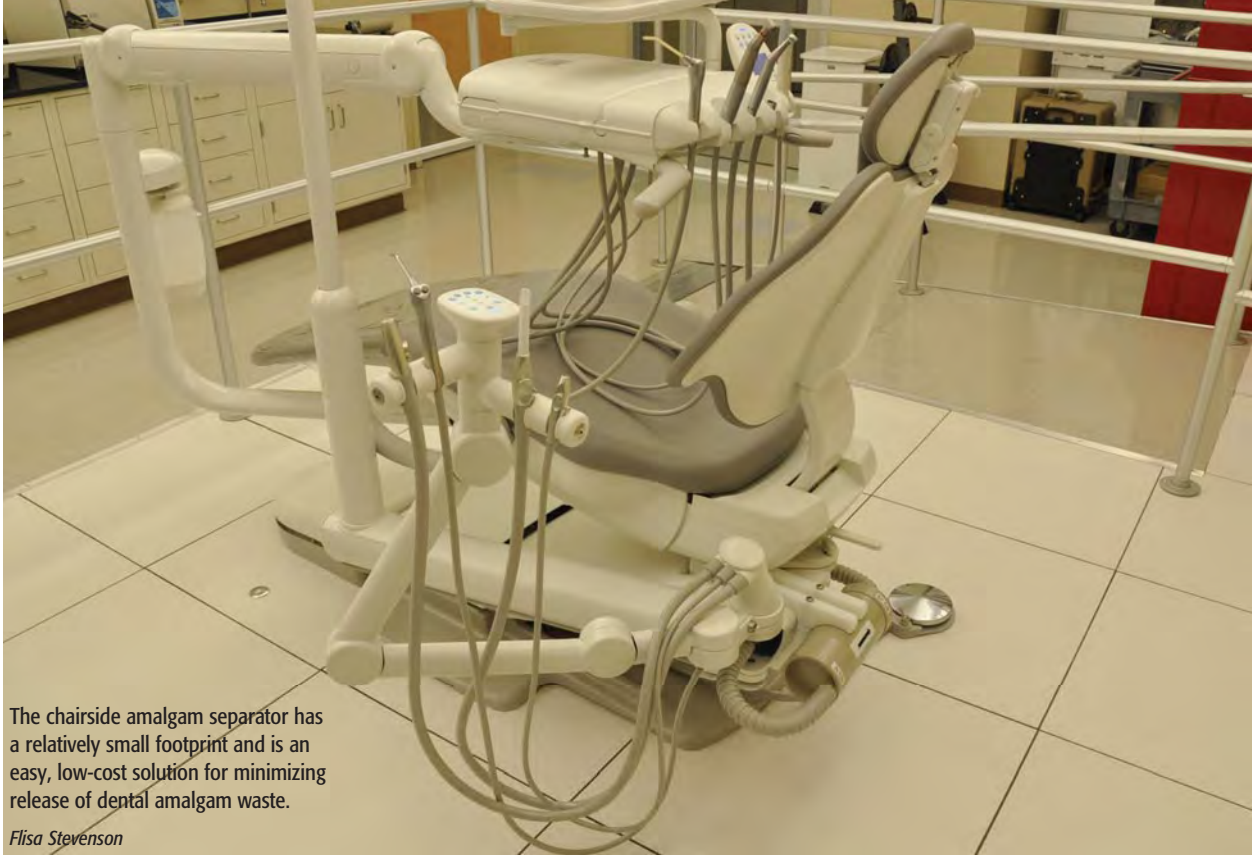


Scanning electron microscopy of nanocellulose filter membranes.
TOP: Glass mat substrate that supports nanocellulose membrane deposits.
BOTTOM: Higher magnification of nanocellulose membrane supported by glass fibers.
Dr. Joyce Breger

Education & Training on Chairside Amalgam Separators

One of the most important goals of the NAMRU-SA environmental surveillance team and the dental waste mercury abatement program is educating Navy DTFs and the public about the availability and proper use of the DD2011 chairside amalgam separator. Commands can purchase the DD2011 along with brackets to secure the separator onto dental chairs. Additionally, NAMRU-SA supports a mercury abatement website at www.med.navy.mil/sites/nmrc/Pages/mercury_pgfin.html.

The website highlights the importance of EPA compliance and provides links for training manuals and a presentation to share with dental staff. Commands should take special care to dispose of used separators by following their Command's hazardous waste disposal instructions. Important information regarding safe and proper disposal of the separators and details for ordering replacement separators can be found online in the training manuals. The NAMRU-SA mercury abatement program has a dedicated hotline available to answer questions regarding DD2011 purchase, installation, and disposal.



The chairside amalgam separator has a relatively small footprint and is an easy, low-cost solution for minimizing release of dental amalgam waste.

Flisa Stevenson

The Next Generation of Filtration Strategies

With the EPA's legislation regarding dental amalgam waste pending, new efforts are underway to develop novel materials to increase the efficiency and specificity of contaminant removal from dental wastewater. NAMRU-SA and Dr. Michael Daniele and Dr. Joyce Breger from the Naval Research Laboratory's Center for Bio/Molecular Science & Engineering in Washington, D.C. have forged a new collaboration to develop a functionalized filter medium consisting of nanocellulose to enhance the efficiency of amalgam separators. Customization and functionalization of the nanocellulose platform will provide additional measures to remove harmful substances from dental waste. Further, nanocellulose is an excellent candidate material to use because it is sustainable and is amenable to chemical modifications. This approach will not only remove metal contaminants, but also be effective against BPA.

The researchers are hopeful that development and functionalization of nanocellulose as an alternative, biocompatible filtration strategy can be incorporated into other practical applications that enhance the health, safety, and operational readiness of Sailors. ⚓

Note: The data discussed in this article were collected using resources provided by the Bureau of Medicine and Surgery.

Contact the Mercury Abatement Program

Website: www.med.navy.mil/sites/nmrc/Pages/mercury_pgfin.html

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