

**RADIOGRAPHIC WASTE MANAGEMENT - AN OVERLOOKED
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ABSTRACT

Radiography is an indispensable diagnostic aid in the medical and dental field. Conventional radiography involves usage of radiographic films and processing solutions which eventually produce radiographic wastes. The wastes produced are toxic and needs to be disposed off safely which unfortunately is not the case in most private practices and teaching institutes. Radiographic wastes can be broadly differentiated as solid wastes and effluents, the chief solid wastes are silver and lead and the primary effluent is soluble silver which when discharged unchecked is extremely hazardous to the environment. The article aims

to educate dental practices and institutions utilizing conventional radiography on the ideal disposal technique of these wastes to avoid damage to our fragile ecosystem.

KEYWORDS: Radiographic waste, Silver recycling, Conventional radiography, Lead.

INTRODUCTION

Radiographic examinations are one of the primary diagnostic tools used in dentistry to determine disease status and formulate appropriate treatment. Radiographs often confirm what is observed clinically and many times reveal findings not apparent from the clinical examination alone. Digital radiography is a commendable advent which considerably lowers the patient exposure and does not require the usage of processing chemicals or darkroom, in spite of these advantages dental practitioners in most developing countries and teaching institutes continue to use conventional radiography for either educational purposes or due to financial constraints.

The benefits of conventional radiography is not without its share of drawbacks namely radiation exposure and the radiographic waste generation, while the former has received sufficient attention with operators taking due precautions the latter has been largely ignored. This articles aims to enlighten dental practices, hospitals and educational institutions on the hazards of the radiographic waste generated and the methods to manage them.

RADIOGRAPHIC WASTE MANAGEMENT

Wastes from conventional radiography can be broadly categorized as solid wastes and effluents.

Management of Solid Wastes

The solid waste components associated with conventional radiography are the film box made of cardboard, vinyl wrap, black paper, lead foil, film, end boards, used lead aprons, lead boxes and packaging components of processing solutions. The methods discussed below details management of each of the waste generated.

Intraoral Dental Packets

Intraoral dental film packaging and film packet components should be segregated. The plastic end boards that are packaged with the intraoral packets should be discarded in the regular trash. The outermost layer of individual film packets is either vinyl or paper and the film inside rests between layers of black paper. Outer vinyl covers, paper packet covers and interior black paper should be discarded with regular trash. It is preferable that components made of plastic or paper be sent for recycling rather than be disposed off to landfill.^[1]

Intraoral dental packets that contain human blood, blood components or saliva should be considered a regulated medical waste and be discarded into specific red color coded disposal bag.

Packaging Components of Processing Solutions

Chemicals are packaged in bottles with caps. The caps are discarded with regular trash while the bottles are rinsed thoroughly and then recycled.

Silver recovery from radiographs

Exposed radiographs and unexposed x-ray films contains recoverable silver. The amount of silver in film will vary based on the product type, whether or not it has been processed, and the density of the image. After the developing process, approximately 55–65% of metallic

silver still remains on the developed radiograph. Used films and films beyond the expiry date are eventually discarded and the silver in these films can be retrieved.^[2, 3]

The risk from silver containing waste is primarily to the environment but since man is an integral part of the ecosystem the silver eventually finds its way into our body. Soluble silver compounds are more readily absorbed than metallic or insoluble silver and thus have the potential to produce adverse effects on the human body. Chronic symptoms from prolonged intake of low doses of silver salts are fatty degeneration of the liver and kidneys and changes in blood cells. Long-term inhalation or ingestion of soluble silver compounds or colloidal silver may cause permanent bluish-gray discoloration of the skin (argyria) or eyes (argyrosis). Soluble silver compounds are also capable of accumulating in small amounts in the brain and in muscles.^[4]

There are four common methods used to leach silver metal from X-ray films, they are thermal, biological, mechanical or physical, and chemical treatments. The first method utilizes combustion for the recovery of silver while the other methods help recover silver and also recycle the film base. The silver sludge (a muddy deposit), obtaining from the latter three methods, is smelted (melted to separate metal) and further refined to form silver ingot (metal cast into a suitable shape for further processing).^[2]

Lead foil in intraoral radiograph film packets and used lead aprons and collars

Lead foil is used in intraoral films to protect the film from backscatter and secondary radiation. The lead content of this foil is 69% to 85%. A study estimated that as much as 11.2 g of lead waste would be produced during full mouth radiographic examination. Lead when disposed with regular trash would end in the soil and under conditions like low pH, dissolution of lead from the radiographic foil occurs thereby entering the ecosystem. Lead being a heavy metal is an extremely toxic element. Prolonged exposure to low doses is generally the risk associated with lead as radiographic waste. Chronic poisoning of 40–60µg/dl presents with persistent vomiting, encephalopathy, lethargy, delirium, convulsions and coma.^[5, 6]

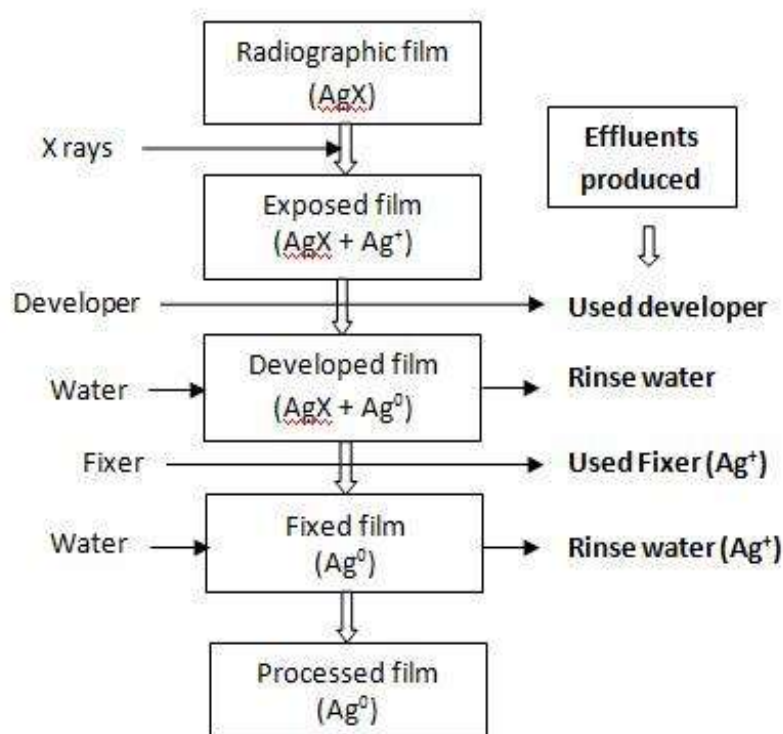
Lead foil in intraoral film packets and lead aprons and lead collars that are no longer used should be collected and transported for recycling where it is melted and formed into ingots.⁷

Steps in production of effluents

Radiographic films contain greater amounts of silver than in any other types of film due to the radiation sensitive silver halide (AgX), which is scattered on the gelatin of the emulsion layer on both sides of the film base. In the developing process of X-ray films, light-exposed silver ions (Ag^+) are reduced by a developer solution to metallic silver (Ag^0) and retained on the film while the unexposed silver is then dissolved in the form of silver thiosulfate into the fixer solution. The wastes formed during processing are used developer, rinse water and used fixer.^[2]

Steps in processing and the effluent produced at each step

Steps in processing and the effluent produced at each step



Management of Radiographic Effluents

Effluents are defined as liquid waste products that are discharged into a body of water. The harmful effluents that are associated with radiography are unused/used developer solution, used fixer solution, wash water and developer tank cleaning solutions. Wastes having a silver concentration of 5.0 parts per million (ppm) or more are hazardous because they display the characteristic of toxicity. Wastes that typically contain silver in concentrations greater than 5 ppm include fixer solutions, rinse waters following fixer baths, solutions from cleaning developer tanks (they clean dissolved precipitated silver).^[8]

Fixer

Used fixer is a dangerous waste because it contains high concentrations of silver—3,000 to 8,000 ppm and anything over 5 ppm is dangerous waste. Because of these high silver levels, it's illegal to pour used fixer down the drain, into a septic system or into the garbage.^[9]

Silver in used fixer solutions is in the form of silver thiosulphate complexes, which are extremely stable and have very low dissociation constants. There is virtually no free silver ion (Ag^+) in used fixer solutions. Waste water treatment processes convert the silver thiosulphate into mostly silver sulfide, which settles in the sludge.^[7]

It is advisable to store the used processing solutions in appropriately labeled containers and kept away from other solutions and later transported to a suitable silver recovery services.

The pH and concentration of silver will vary depending on the type of processing (e.g., batch or replenished system), chemical replenishment rates, and wash water usage.^[1]

Silver can be recovered from the spent fixer solution by electrolysis, metallic replacement, chemical precipitation, reverse osmosis and ion exchange. Electrolytic silver recovery is the most efficient technique for removing silver from silver-rich waste solutions, metallic replacement cartridges need to be used as a secondary (tailing) recovery method subsequent to the electrolytic recovery equipment.^[1, 3]

Electrolytic Recovery

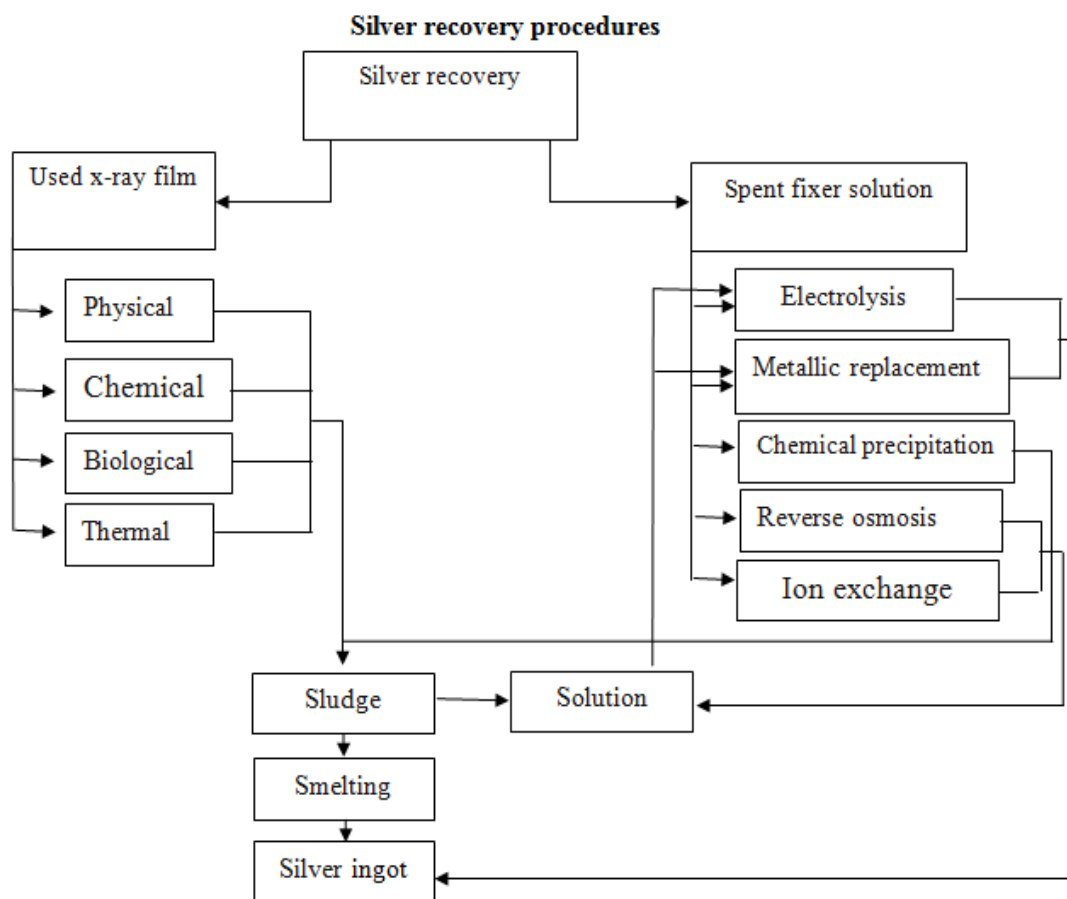
This is an active method suitable for treating medium to large volumes of fixer effluent. The silver-bearing solution is passed between two electrodes attached to a source of direct electric current. Silver then plates out on the cathode as almost pure metal. This method is most efficient for very large offices, clinics or dental schools.^[1]

Metallic Replacement

It is a passive method suitable for treating small to medium volumes of effluent. The silver-bearing solution is poured over a more reactive solid metal, such as iron. The silver in solution and the solid metal (iron) interact and the more active metal (iron) goes into solution. The less active metal then becomes solid (silver sludge), which settles to the bottom of the cartridge. For economy and convenience, steel wool (bundle of very fine and flexible steel filaments) is the metal most often used in this type of silver recovery.^[1]

The units are gravity fed closed plastic buckets containing steel wool mesh that adsorbs silver ions from the spent fixer solution. After treatment through the silver recovery units, fixer solution is released to the sanitary sewer as a non-hazardous waste.^[10]

Silver recovery procedures



Developer

Used developer is not typically a hazardous waste. Unused developer, if discarded, may be hazardous because of a high pH of 12.5 or more which is corrosive. Its COD (chemical oxygen demand) which is an analytical method for measuring the oxygen demand of an effluent is also about twenty times above that allowed by the law for discarding. Therefore, this solution should also be treated before discarding in the sewage because it contains several components or forms products in its reactions which are harmful to the environment, such as 1-5% hydroquinone, quinone, methol, sodium thiosulfate, sodium sulfite, elemental sulfur, acetic acid, sodium acetate, boric acid among others, as well as silver, in the form of complex ions ($S_2O_3^{2-}$).^[9, 11]

Developer effluent has a high pH and is therefore alkaline or caustic, while fixer effluent has a low pH and is therefore acidic. When combined as the total process effluent, the resulting effluent is neutral and within the limits. Discharging the developer solution with the waste fixer solution that leaves the recovery unit enable to bring the pH to close to neutral or safe limits.^[1, 8]

Photo-Fenton oxidation is utilized for the destruction of organic compounds in effluents and utilizes ultraviolet light, iron and hydrogen peroxide and is considered environment friendly and relatively cheap.^[12]

Managing Developer System Cleaners

Some developer system cleaners contain sodium dichromate making them hazardous, accidental ingestion causes nausea, vomiting, abdominal pain, burning sensation, diarrhea, shock or collapse. During the cleaning process, they may also dissolve silver.^[8]

Wash water management

The removal of silver from wash waters requires still more sophisticated technology such as ion exchange, nanofiltration or reverse osmosis these methods provide a way of increasing silver concentrations in a waste solution, so they are suitable for solutions with low silver content.^[5, 1]

According to different radiographic effluent treatment alternatives have been proposed, as follows: chemical precipitation and sedimentation, chemical oxidation, carbon adsorption, biological oxidation, and reverse osmosis. Combination of methods have also been utilized, such as chemical-biological, chemical-electrochemical oxidation, and oxidation-separation processes. Besides such processes, recycling of radiographic effluents has also been performed by means of several procedures, such as Cl₂-biological treatment, filtration-chelation treatment and adsorption-reverse osmosis.^[9]

CONCLUSION

Radiography is a bastion in diagnosis and has come a long way since its incorporation into the medical field. Film based analog radiographic technique which requires chemical processing to display the latent image results in radiographic wastes of both solid and liquid nature which are potentially harmful to both the personnel and the environment. Knowledge on radiographic waste management is sadly poor amongst the dental practitioners who

dispose the wastes in the same route as other non toxic wastes inadvertently polluting the environment. Analog radiographs are slowly being phased out owing to the advances in digital modalities. Digital radiography apart from its evident advantages like ease of usage, non requirement of films, lower radiation exposure also eliminate the chemical burden on the environment arising from radiography. Eventual transition to digital radiography will completely abolish radiographic wastes, until then practices utilizing analog radiography need to strictly adhere to the disposal protocols and help conserve natural resources through processes like recycling.

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