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Silver Recovery from X-Ray Film Waste: A Review

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Abstract: This paper highlights the techniques for silver recovery from X-ray films. Silver could be an element with the symbol Ag. The metal is found within the Earth's crust within the pure, free element. Silver metal is employed in many bullion coins. Silver is especially soft. Silver could be a rather unreactive metal. Silver was one in every of the seven metals of antiquity that were known to prehistoric humans and whose discovery is thus lost to history. Methods for recovery of silver from x-ray waste – Chemical Precipitation, Electrolysis, Metal replacement cartridges, Biological method by enzyme production, extraction of silver by glucose, Electrolysis Process. The waste photographic films, X-ray contains 1-2% (w/w) black metallic silver which is recovered and reused. Silver may be a valuable, further silver has wide used like in jewellery, dentistry, photography, mirrors, optics, industries, etc. Silver may be a valuable widely employed in the photographic, electrical, electronics, chemical and jewellery industries. Silver recovery is the technique by which pure metallic silver may be recovered from old x-ray films. The fashionable process is extremely efficient with a recovery of higher than 99.8% silver. The photographic film was initially incinerated, and then the ash melted to recover the silver. The resulting silver then had to have several stages of purification. The method was inefficient, costly, and environmentally unfriendly.
Keywords: Absorption, Effluent, Electrolysis, Photographic film, Radiation, Silver recovery, Waste, X-ray films

I. INTRODUCTION

The first X-rays machine was discovered accidentally in 1895 by the German scientist Wilhelm Roentgen. X-ray is also a kind of radiation. They behave in much the identical way as light rays, but at much shorter wavelengths. X-radiation is made by taking energy from electrons and converting into photons with appropriate energies. The middle of an X-ray apparatus is an electrode pair a cathode and an anode. X-ray extremely short wavelength and high frequency with wavelengths starting from about 10^{-8} to 10^{-12}metre and corresponding frequencies from about 10^{16} to 10^{20}hertz.

Conventional fixing of AgX in photographic and X-ray films has been extensively employed in the photo-industry for over than two centuries [12]. X–rays pass through air and soft tissue of the body. The foremost important application of the X-rays used in medicine. The three major elements that compose an X–rays' machine are the tube, the high – voltage power source and, the operating console. Modern medical X-rays machines are groped in to two categories – people that generate hard x–rays and other people that generate soft X-rays.

The Silver extraction from X-rays could be a business nowadays. Silver extraction from used photographic film may be a big and arranged exchange India. Almost in every Indian city, you'll find plenty of people engaged within the business of silver recovery from X-rays. The additional point of this work is that the washed X-ray sheets after silver has been recovered from them even have resale value since they find use within the readymade shirt industry. Good shape washed X-ray sheets can fetch you around 90rs. per kilogram. As for silver extraction methods from X-rays many methods are often wont to extract silver from them. But Indian silver recovery units from X-rays use just one traditional method, which is that they prepare a hot bath and immerse X-rays in it for about twelve hours and so wash them. But in my opinion this method is extremely time consuming and creates pollution also. rather than putting them in a very hot bath for such long hours they will be treated with another chemicals to get rid of silver from them. And this might be even less time consuming and more economical as compared to the standard method utilized by these units [8].

II. LITRATURE REVIEW

Hydrometallurgical process is a unique, simple, fast, low-cost and also a pollution free method for over environment was produced for recovering the silver from X-ray films waste. This process has a number of benefits because it obviates the requirement for burning, oxidizing, electrolysis or purifying steps. Other than this, all experiments were disbursed within the identical flask, unlike other methods than silver recovery conditions were optimized and purity level of silver was 99.8% recovered [11]. Hydrometallurgical process is highlighting the chemical precipitation process for silver recovery from X-ray films waste. The decline in silver resources has increased the value of sourcing for pure silver.

The ecological problem induced by the disposal of radiographic waste may be a huge motive for increased regeneration, recovery and recycling methods. The effect of Hydrometallurgical processes like metallic replacement, electrolysis, chemical precipitation is often used to provide high purity and efficiency. A proposed research work for silver recovery supported chemical precipitation method [15]. About 2 billion radiographs each year are taken around the world which include chest X-rays and CT scans. 95-99% of the X-rays taken are within the medical fields producing photographic chemicals and scrap films as waste. Because of the high photosensitivity of silver halide, about 8.5% of silver is employed in photography. The effluent of X-ray films processing facilities can reach a silver content of 1-10g/l. The strategy for silver recovery in broad terms are either hydrometallurgical or pyro-metallurgical processes. Absorption is additionally a possible technique for silver recovery which could be a physico-chemical and metastasis supported absorption, adsorption, and natural action and precipitation mechanisms. Pyro-metallurgical method is the classical method for silver recovery from X-ray films waste include dossing, incineration, smelting, melting and sintering at high temperatures. This method has been generated to be less efficient with a recovery 96% and temperature 955°C at which X-ray film polymers are destroyed. The hydrometallurgical processes, which is able to be discussed briefly have >99% recovery efficiency and warmth requirement can be as low as 100°C counting on the tactic chosen. The substance of silver recovery is concentrated most importantly to cut back emission of pollutant from the recovery methods and for economic profit. The three major silver recovery techniques reviewed, chemical precipitation has been highly investigated and used thanks to the simplicity of the method and various leaching reagents available. Adsorption and membrane techniques are still at the experimental or laboratory research stage. The proposed work is to develop an integrated process using chemical precipitation technique for silver recovery which needs less heat. The selection of ethanedioic acid over other leaching agents is because of possible 100% silver recovery, low toxicity; high efficiency on product purity, short retention time, reusability, low CO2 the research will investigate various leaching conditions like pH, leaching time, mass to volume ratio, efficiency of reused leaching agent and temperature, on silver recovery and purity. The recoverable silver within the x-ray films is mostly present within the fix and therefore the bleach-fix solutions. Mostly photographic and X-ray wastes contain silver thiosulfate with silver at an amount of 4 parts per million [7]. Different process exists to recover silver from x-ray waste like burning the film, electrolysis, metal replacement, bacterial methods and chemical precipitation. Except chemical methods, the opposite methods are expensive and time consuming to recover the silver [6,14].

III. ENVIRONMENT AND HEALTH IMPACT OF SILVER

Silver is relatively rare within the Earth crust 67th so as of natural abundance of elements. The silver element is slowly absorbed by body tissues with the resultant bluish or blackish skin pigmentation. Eye contact may cause severe corneal injury if liquid comes in touch with the eyes. Skin contact may cause skin irritation. When silver is repeated and prolonged contact with skin it may be very harmful and cause allergic dermatitis. Inhalation hazards exposure to high concentrations of vapors may reason dizziness, breathing difficulty, headaches or respiratory irritation. Very high concentration reason to highly toxic to aquatic life forms, like fish. Silver within the surroundings comes from its multiple uses in industry, in medical applications, in water disinfection and in user products. Silver as nanoparticle depicts particularly a limited fraction of the full volume of silver that enters into the environment. However, silver during this type is additionally more readily absorbed by some species, posing a possible problem [13].

IV. SILVER RECOVERY METHODS

Silver recovery from x-ray film is a technique in which at the end of it the silver on x-ray films is recovered in a purity of 99.8% of silver in order to reuse the silver on same or new applications, the silver is sold back to the market in forms of bars or billions [5].

1) *Electrolysis*: Electrolysis, or more specifically electrowinning, is that the most generally used and universally applicable method for silver recovery within the photo processing industry. Electrolytic silver recovery cell consists of a cathode and anode. Oxidation at the anode is (positive) and reduction at the cathode is (negative). Silver is deposits on the cathode during electrolysis [1]. and immediate charge is undergone the silver bearing photo processing solution. After sufficient silver has been plated, the cathode is removed from the system and also the silver stripped off. This method is capable to producing silver with purity greater than 98%. Raw metal to be refined on the anode and the pure metal is deposited on the cathode [10]. A heavy current of up to 300 Amperes is passed through the cell, and the silver is deposited as metallic silver at the cathode. Electrochemical experiments were carried-out in a rectangular cell made of acrylic plates with groves cut along the sides to mount the electrodes at specific distance of separation between them. A mesh type IrO2-coated-Ti as the anode and a Ti as the cathode (5 cm *8.5 cm *0.5 cm of geometric area 68 cm2) were used in an undivided cell configuration for all the silver recovery studies [17].

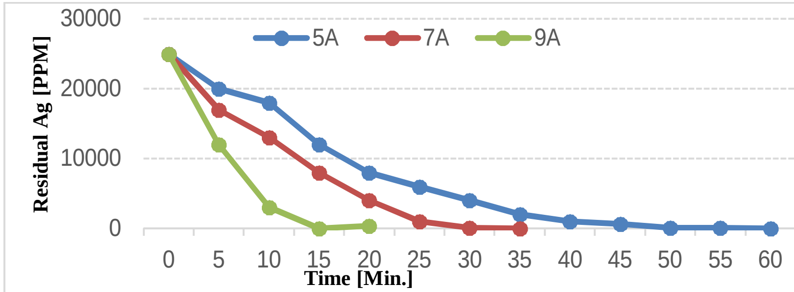

Fig. 1 Time course of residual silver ion concentration at different operating currents in electrolysis process [3]

2) *Chemical Precipitation:* Precipitation is defined as the creation of a solid from a solution. The chemical precipitation method is one among the mostly used and researched methods for silver recovery. Silver will be readily resumed from photographic chemical effluent by sulphide precipitation with concentration as low as 0.1-1 mg Ag/l. The procedure of precipitation method easy to handle additionally because the sulphide dosing method is required to stop the discharge of poisonous hydrogen sulphide gas. The employment of peroxide only in the silver recovery technique was highly exothermic with high catalytic decomposition rate, making the method costly. The addition of ethynediol reduced consumption rate to but 27% and also improved recovery efficiency by 19%. Increasing pH reduced the number of potassium boro hydride required to achieve the required purity and recovery. The utilization of acid has also been reported to be highly efficient in the silver recovery process. The utilization of acid, malonic and ethanoic acid in silver recovery process. ethynediol acid achieved the highest recovery and efficiency. At 100°C and 5% (w/v) acid, 100% recovery was achieved after 20mins. It has been also observed that increasing the acid concentration and operating temperature increased the efficiency of the method [16].

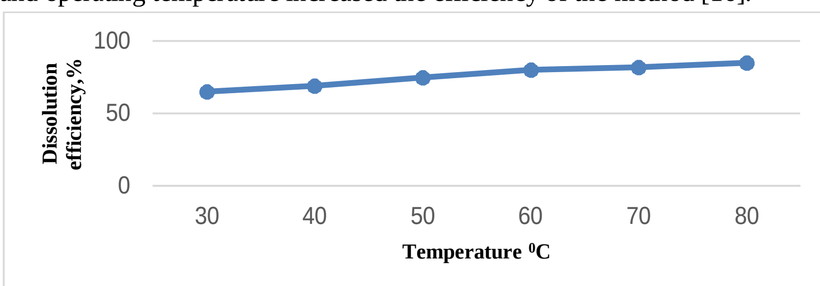

Fig. 2 Effect on temperature on the dissolution efficiency of the silver (0.1-1 mg Ag/l ,1 hour) [7]

a) *Effect on the Temperature:* The effect of temperature on the dissolution efficiency of silver from waste radiographic films. Figure (2) show that the effect of temperature on the dissolution efficiency of silver. As can be seen from the figure (2) temperature plays a very important role in the dissolution of silver from the waste radiographic films. At 30°C, an efficiency of 64% was obtained although at 70°C an efficiency of 79% was obtained. After 70°C, there was no change in dissolution efficiency of silver [7].

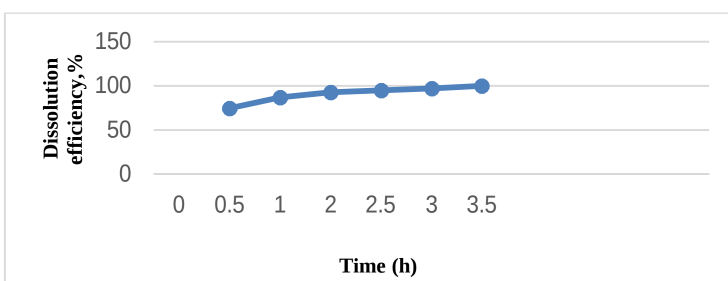

Fig. 3 Effect on time on the dissolution efficiency of the silver (0.1-1 mg Ag/l ,1 hour) [7]

b) *Effect on the Time:* Figure (3) is show that the effect of time on the dissolution efficiency of silver. Show in the figure that contact time plays a very important role in the dissolution of silver from the radiographic films waste. A dissolution efficiency of 88% is obtained for a duration of 1 hour at 65°C although under the identical conditions [7].

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3) *Metallic Replacement:* The process is based on the use of metals such as iron, zinc and copper which are more active metals than silver for effective recovery from effluent. So, this metallic replacement process is also called cementation process. Ions of the more active metals are discharged into the solution. Impurities of the active metals e.g. Fe^{2+}, Zn^{2+} and Cu^{2+} to the effluent and silver sludge which require a costly process for remediation. The reaction is commonly formed of two redox half reactions: reduction of the more active metal ion and oxidation of the less active metal. In this process, a pH 5-7.8 was recommended. This method is produced 98% silver recovery at 90°C within 50 minutes retention time [4].

Every year, the photography sector gives about 35% of its silver to radiographic applications, which is discarded completely after it's used. Some technologies have attempted to recover the silver contained in these x-ray waste.

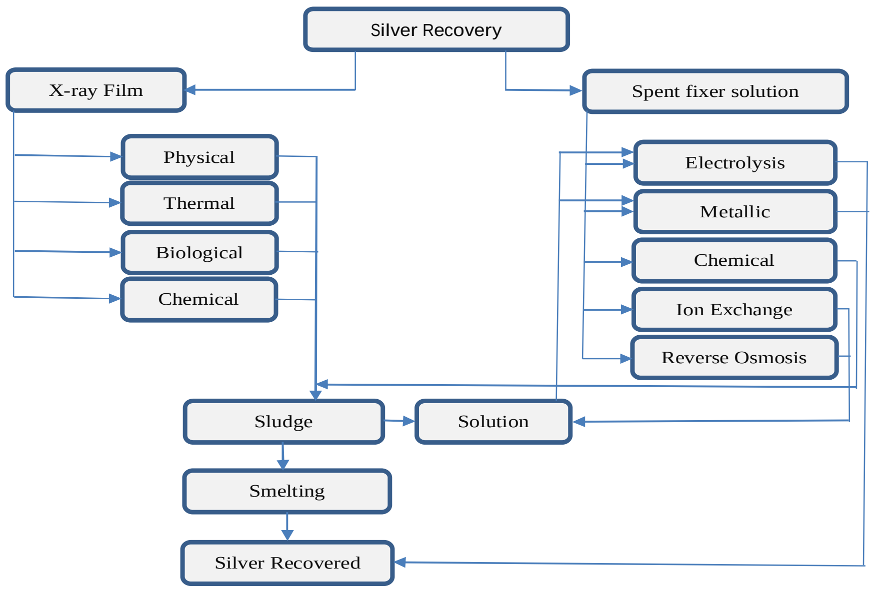

Fig. 4 General method for the recovery of silver from X-ray waste [18]

TABLE I
Comparison of Silver Recovery Techniques [2]

Method	Recovery Efficiency	Advantages	Disadvantages
Electrolysis	>90%	98% purity is achievable. The cathode can be cleaned and reused. Does not produce any new pollutant.	High capital cost of equipment. Operating cost due to electricity requirement.
Metallic replacement	>95%	Low initial investment cost. Low operating cost. Relatively high recovery efficiency.	Agitation is required to improve efficiency. Not as efficient as other process.
Chemical Precipitation	>99%	Low silver concentration in effluent. Easy to monitor performance.	Require stringent control measure to avoid emission of poisonous hydrogen sulphide

V. CONCLUSION

The process has proved that silver can be recovered or recycled from X-ray film waste. Using chemical precipitation technique for silver recovery which needs less heat. Oxalic acid used as the leaching agent. The sludge is filtered, dried and heated further to recover pure silver. Additive chemicals will be added to improve the efficiency of the method. Three major silver recovery techniques reviewed, chemical precipitation has been highly investigated and used due to the simplicity of the method and various leaching reagents available. The utilization of electrolysis techniques, which is also a common technique for large facilities, is limited if silver concentration is a low in the effluent.

Electrolysis process does not produce any new pollutants and 98% purity is achievable, The Metallic replacement process is Low maintenance cost due to no mechanical parts and electrical connections. Relatively high recovery efficiency. The Chemical precipitation process is Low silver concentration in effluent and easy to monitor performance. By the use recovery process to get maximum benefit like we reduce the solid waste which can be generated by the used X-ray films, and we get the precious metal i.e. silver. We can try to find out the chemical composition to get the maximum recovery nearly to the 90-100%. We will analyze the process to get the best from all and which will be more economical for recovery.

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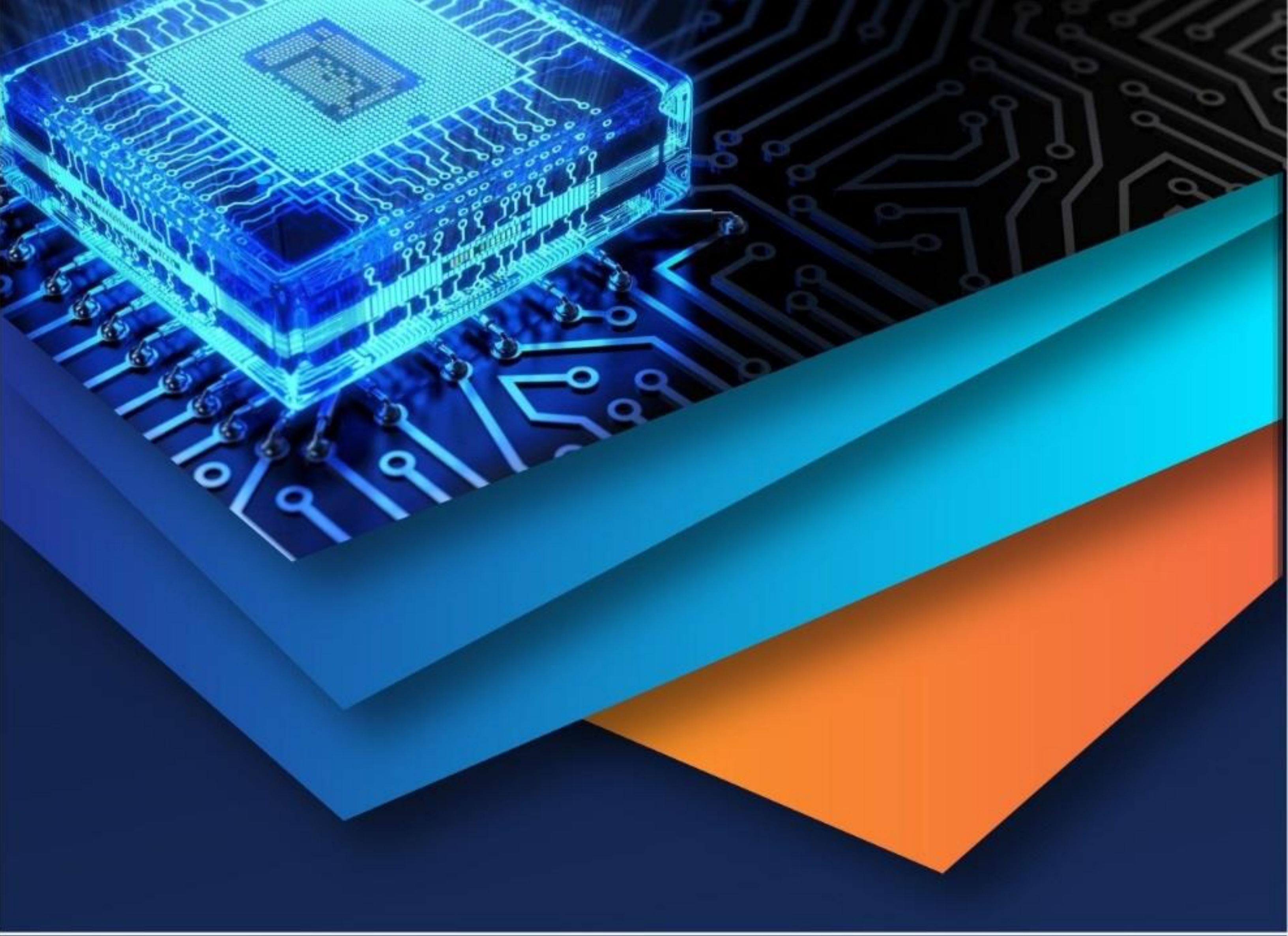

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