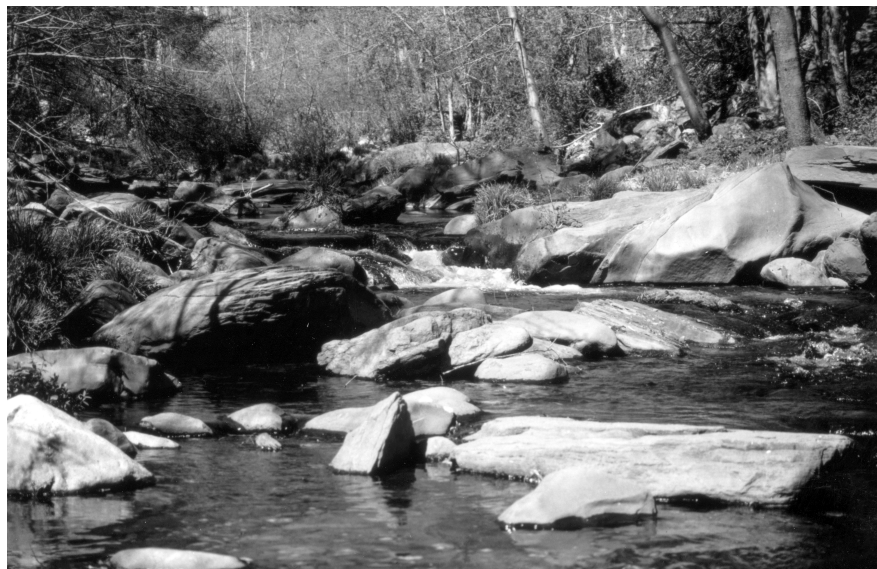




Environment

I N F O R M A T I O N F R O M K O D A K

The Fate and Effects of Silver in the Environment



Discharges from photographic processing facilities to municipal wastewater treatment plants are typically regulated by limiting the quantity, either in concentration or mass, of various chemicals, including silver. Silver regulations, administered by the United States Environmental Protection Agency (USEPA), are often based on the environmental properties of silver. An understanding of these environmental properties will help you better understand how and why discharges of silver are regulated.

This publication summarizes the current information on the environmental fate and effects of silver.

"Environmental fate" information describes how a chemical changes and moves once it enters the environment. "Environmental effects" information describes the potential for a chemical in the environment to exert an effect on various organisms.

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Kodak's health, safety, and environmental publications are available to help you manage your photographic processing operations in a safe, environmentally sound and cost-effective manner. This publication is part of a series of publications on silver management designed to help you optimize silver recovery. It will help you understand the fate and effects of silver in the environment.



In order to understand the potential effects of silver in the environment, it is essential to know the form of silver present (because each form has different toxicity), the concentration in the environment (because all toxicity is dependent on concentration), and how the silver changes in the environment (because the movement of silver in the environment will determine concentrations).

ENVIRONMENTAL FATE

The environmental fate of silver involves a series of changes in chemical and physical properties that determine the ultimate disposition of the silver in the environment. Several forms of silver are important in the manufacturing and processing of photographic materials.

The manufacturing process begins with silver metal. Silver metal is first converted to silver nitrate. During the preparation of photographic materials, the silver nitrate is converted to silver halides, which are salts with very low water solubility. It is the silver halide form that is present in unprocessed photographic films and papers. During processing, some (for black-and-white processes) or all (for color processes) of the silver is removed from the film or paper in the

fixing step by the formation of a chemical complex of silver. This chemical complex holds silver very tightly, which is necessary to remove the silver from the film or paper. The chemical complex is water-soluble, but it differs from most silver compounds in that the chemical complex remains chemically bound together, even in solution. The silver from the photographic process may be recovered by a variety of techniques; the recovered silver is returned to a refiner who converts and purifies the metal. This cycle of silver use is depicted in the diagram on page 3.

Although most photographic processing facilities use silver-recovery techniques that are efficient (>90% recovery), there will usually be a small amount of silver discharged, as a tightly bound chemical complex along with wastewater from the processing activities.

These discharges are treated by wastewater treatment plants, along with other domestic and industrial waste. Most wastewater treatment plants operate by biological treatment of the waste, a process where the waste is treated with naturally occurring microorganisms that break down the waste products. During this waste treatment, the silver complex is

converted into silver sulfide and silver metal—both very insoluble forms of silver—and separated from the water as part of the normal treatment process. Typically, over 90% of the silver reaching wastewater treatment plants is removed. The silver that is separated from the water is then contained in the biological (biosolids) solids (called sludge), which are disposed of through land application, landfilling, or incineration. Because of the very low water solubility of the silver contained in the sludge, it does not leave (leach from) the sludge to any significant extent in landfills or soil when used as a fertilizer.

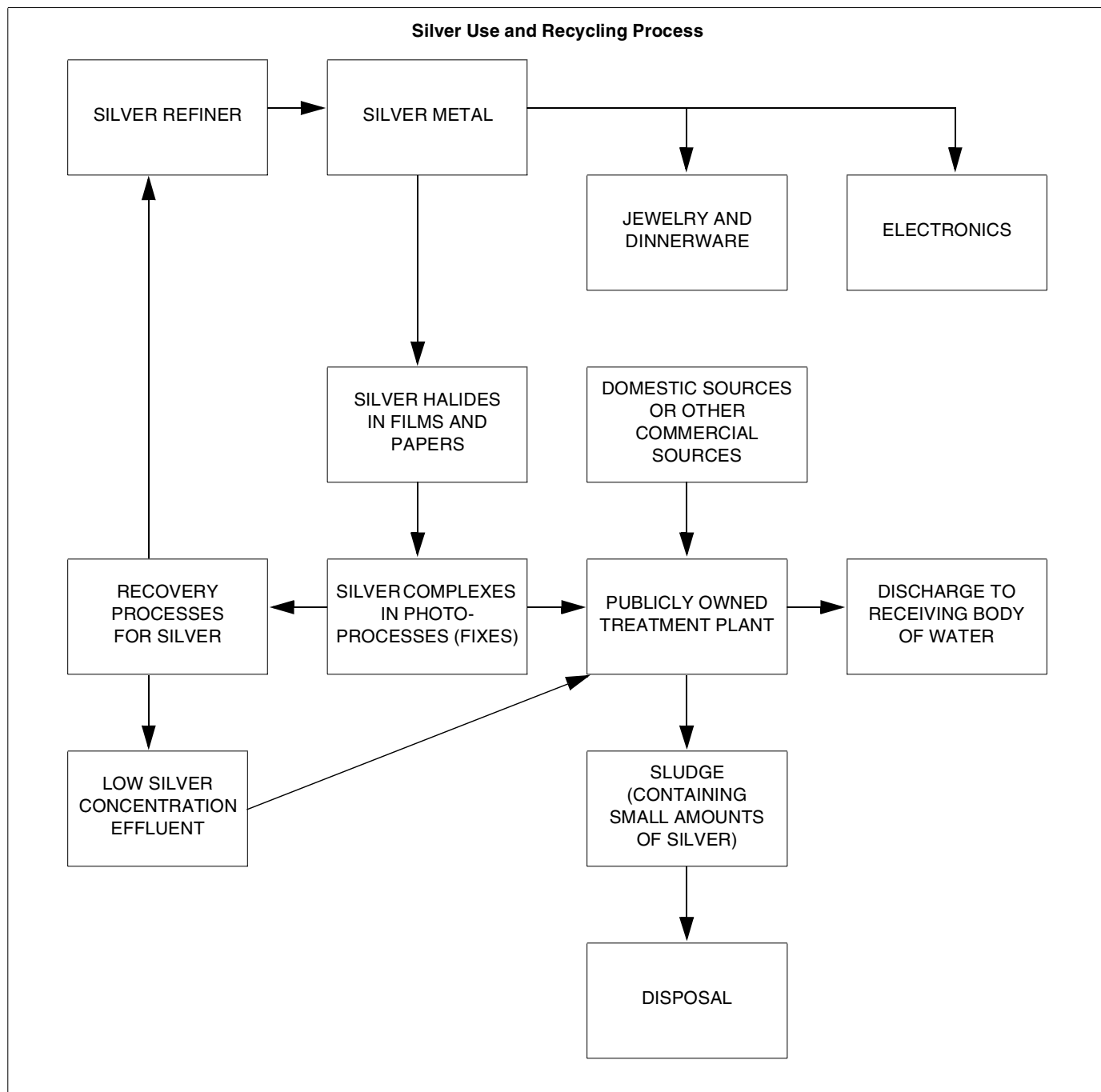
The very small amount of silver that is released from treatment plants to bodies of water is in the form of either tightly bound, soluble silver complexes or insoluble silver forms such as sulfide. The soluble silver complex may react with a variety of naturally occurring substances such as chemical constituents of the water (e.g., chloride), organic constituents of the water (e.g., humic acids) and solid particles suspended in the water. These processes quickly render any soluble silver forms insoluble, and remove them from the water. Insoluble silver forms settle to the bottom (sedimentation). Silver discharged from wastewater

treatment plants is generally removed from the water by these processes. Insoluble silver sulfide does not adversely affect organisms that live in the sediment.

Silver from photographic processing activities has several

possible environmental fates. Most of it is captured in the photographic processing facility via silver-recovery treatment technologies and returned to the refiners for smelting. Silver discharged to the sewer is converted

to insoluble forms and removed from water at a wastewater treatment plant. The small amount of silver not removed at a treatment plant reacts quickly with a variety of naturally occurring materials to form insoluble materials that often precipitate from water.

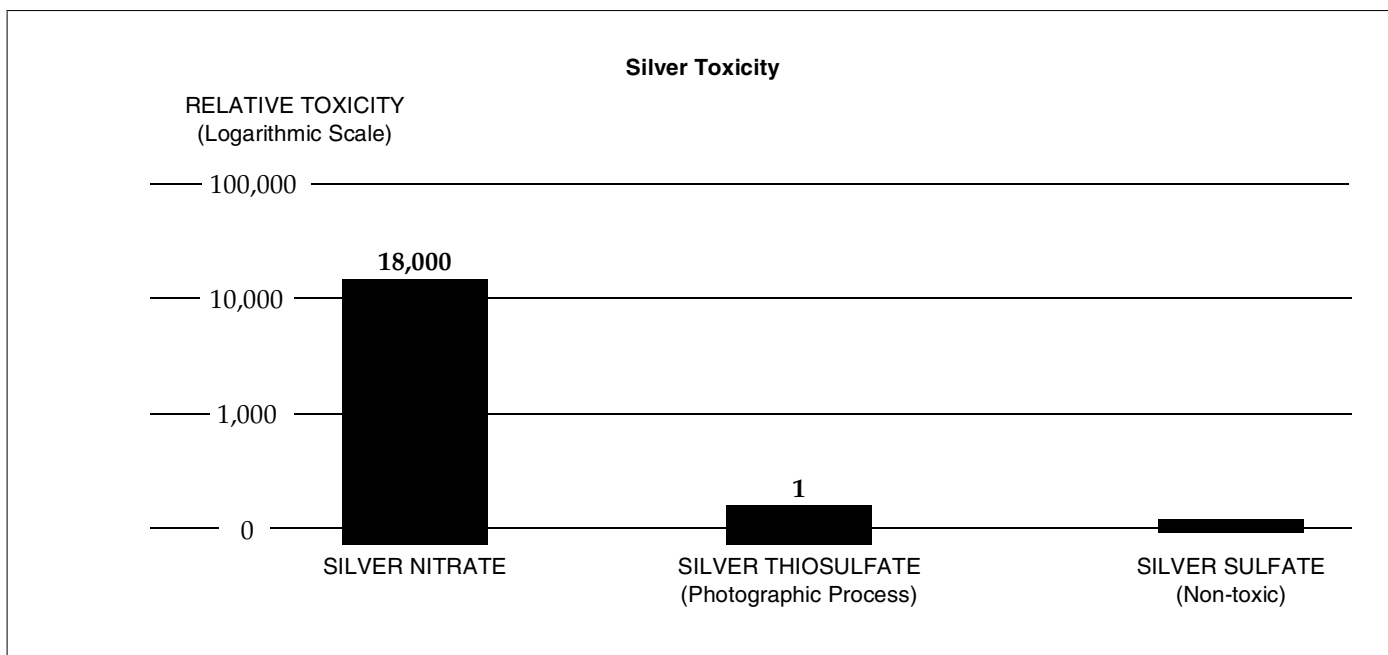


ENVIRONMENTAL EFFECTS

Toxicity is the measure of adverse chemical effects on an organism and is governed by several factors, including the form and amount of the chemical present in the organism. Different forms of silver display different degrees of toxicity. Silver that is soluble in water, and unattached to any other atoms while in solution, is known by several names including

free silver, ionic silver, and hydrated silver ion. In general, it is the free silver that is the most toxic form. This toxicity is the basis of regulations on silver discharge compounds. Silver compounds release free silver very slowly due to insolubility (e.g., silver sulfide) or complexation of the silver (e.g., silver thiosulfate). These compounds are over 15,000 times less toxic than silver nitrate. This relationship is depicted in the diagram below.

Because of the tendency for silver to form insoluble chemicals in natural waters, the chance for organisms to be affected long term is minimal. Work done by scientists at Kodak and at universities around the world continues to add to our understanding of the potential effects of silver in the environment.



ENVIRONMENTAL CONCENTRATIONS

Accurately measuring silver in the environment and determining the form of silver are critical in predicting the potential for adverse effects. Unfortunately, measuring silver in the environment and determining the form of silver present is very difficult because silver is present in such low concentrations.

Recent scientific advances in analyzing very low concentrations have given us a better understanding of background levels of silver, and the effect of human usage of silver on the quantity of silver found in the environment. There is silver present in all waters, even in those that have been minimally affected by human

activity. Wastes reaching wastewater treatment plants contain silver (parts per million or ppm) from domestic sources (e.g., silverware) as well as industrial sources (e.g., electroplating and photographic processing). Wastewater treatment plants remove greater than 90% of the silver in the wastewater, and the small amount of silver (parts per billion or ppb) left is quickly removed (or at least bound) from the water by sedimentation (natural settling), dilution and precipitation within a short distance from the discharge point. This means there are very low concentrations of silver in receiving waters after wastewater treatment. Reliable methods still need to be established to determine the form of silver present at these very low levels (parts per trillion or ppt).

The form of the silver is key in being able to predict the potential effects of the silver at a given level in the environment. Because the concentration of silver is so low, only the total silver can be accurately measured. A negligible amount of silver ion is present, due to low solubility and tight binding to solids.

Understanding Parts Per

1 ppm is about 1 second in 11 days

1 ppb is about 1 second in 32 years

1 ppt is about 1 second in
32,000 years

MORE INFORMATION

If you have environmental or safety questions about Kodak products or services, contact Kodak Environmental Services at 1-716-477-3194, between 8 a.m. and 5 p.m. (Eastern time) or visit KES on-line at www.kodak.com/go/kes.

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The following publications are available from Kodak Customer Service or from dealers who sell Kodak products.

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| J-210 | <i>Sources of Silver in Photographic Processing Facilities</i> |
| J-211 | <i>Measuring Silver in Photographic Processing Facilities</i> |
| J-212 | <i>The Technology of Silver Recovery for Photographic Processing Facilities</i> |
| J-213 | <i>Refining Silver Recovered from Photographic Processing Facilities</i> |
| J-214 | <i>The Regulation of Silver in Photographic Processing Facilities</i> |
| J-215 | <i>Recovering Silver from Photographic Processing Facilities</i> |
| J-217 | <i>Using Code of Management Practice to Manage Silver in Photographic Processing Facilities</i> |

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