Aluminum Removal from Photographic Waste

Submitted to Dr. Tony Bi

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Abstract

Recent testing of treated photographic waste has shown elevated levels of aluminum in the fixer, which exceed sewer discharge standards. Preliminary lab-scale testing was performed to determine the aluminum content of the photographic waste from various generators on campus. Samples from the following facilities were available for lab-scale testing: Michael Smith Laboratories, Life Sciences (Cellular and Workshop), Detwiller Pavilion (Psychiatry), and the Animal Care Centre. Each sample exhibited different levels of turbidity, where samples from the Detwiller Pavilion and Animal Care Centre were the most opaque and most translucent, respectively.

Aluminum quantification was performed using colorimetric analytical strips, specific for aluminum, from Merckoquant®. Testing was done at pH and temperature of approximately 13 and 25^{o}C, where the pH of the acidic waste solutions was adjusted using a buffer solution. From this analysis, the aluminum content in the waste solutions generated by Michael Smith Laboratories, Life Sciences (Cellular and Workshop), Detwiller Psychiatry, and the Animal Care Centre were estimated to be 8, 8, 8, >250 and 8 mg/l, respectively. Hence, it was determined that the Detwiller Pavilion contributed significantly to the aluminum concentration in the waste.

It is recommended that further research and experimentation be conducted to identify the aluminum-intensive chemicals in the photographic fixing process, as well as scale-up and design of an aluminum precipitation and filtration process for pre-treatment of the photographic waste.

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I. Introduction

Since the Brundtland Report in 1987, researchers and policy-makers have placed progressively more emphasis on sustainable development, a global scale initiative. However, minimizing energy use, material consumption, and waste production, as well as environmental and human health impacts requires an integrated multi-scale approach. Through advances in science and technology, manufacturers are able to design safer and cleaner products, as well as more efficient processes, plants, and complexes. For chemical processes, waste management is a major issue, as the handling and accumulation of waste impacts nearby ecosystems and communities. Pollution prevention has progressed from "end-of-pipe" treatments to source reduction, where process modifications are made to eliminate hazardous chemical feeds or wastes, while encouraging life-cycle thinking.

As a large research institution, UBC produces a variety of chemical wastes, including photographic waste (fixer and developer). According to UBC SEEDS, the Environmental Service Facility receives approximately 4,000 L of photographic waste for disposal every year. The treatment process involves the recovery of silver from the fixer using ion exchange columns, neutralization, and disposal through the sewer drain; however, analysis from last year shows elevated levels of aluminum in the fixer (4-18 mg/L). Accordingly, the goal of this project is to reduce elevated aluminum concentration in waste fixer to meet sewer discharge standard (2 mg/L). This report studies the green engineering tools used to reduce the environmental impact of aluminum in the fixer wastes, including source reduction and "end-of-pipe" treatments, as well as environmental impact and health risk assessments, and life cycle analyses.

II. Theory

Aluminum is the most abundant metal in the earth's crust, and the third most abundant element on earth, only surpassed by oxygen and silicon. Aluminum is mainly present in aqueous form as Al^{3+} under acidic conditions, and as $Al(OH)_4^-$ under neutral to basic conditions, as shown in Figure 1. Aluminum oxides, which are the most common form of aluminum in aqueous solution, are the least soluble in water at pH between 6 and 7. The solubility of aluminum compounds increase under extreme pH conditions.

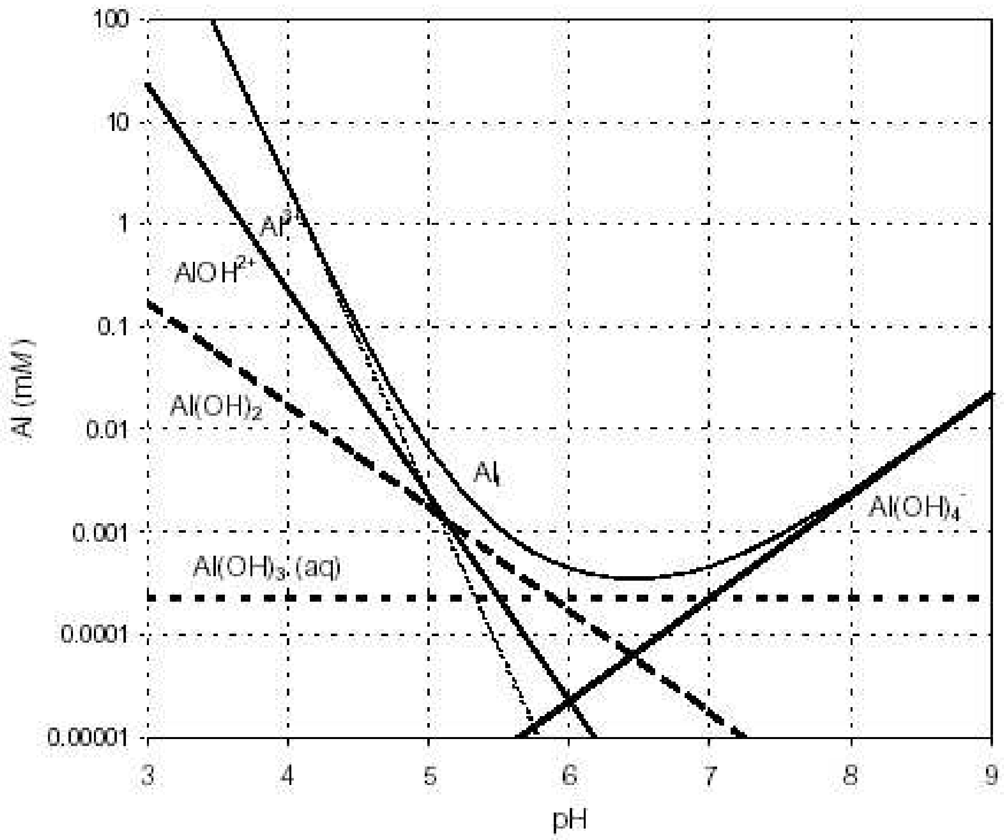

Figure 1. Solubility of Aluminum

Contamination of water by aluminum may negatively impact the ecosystem and human health. Its impact on ecosystem and human health can be quantified using various parameters, such as LC_{50} and BCF.

LC_{50} represents the lethal concentration for 50% of target mammal population over 14 days of exposure period. This can be obtained from CHEMINFO database by the Canadian Centre for Occupational Health and Safety or can be calculated from its water-octanol partition coefficient (K_{ow}). K_{ow} represents the ratio of activity coefficients in water and n-octanol (which is a widely used organic solvent). The equation for calculating LC_{50} is shown below.

$$\log(LC_{50})=4.87-0.871\ \log(K_{ow}) \qquad (1)$$

The accumulation and persistence of aluminum in animal tissue that live in aluminum contaminated water can be quantified using the BCF factor. The BCF is defined by the EPA guidelines as "the ratio of chemical concentration in the organism to that in surrounding water". This, again, can be calculated from K_{ow} as shown below.

$$\log(BCF)=0.79\ \log(K_{ow})-0.40 \qquad (2)$$

III. Background

Aluminum occurs naturally in soil, water, and air. The concentration of aluminum in surface water is generally below 0.1 mg/L, and the concentration of aluminum in soil varies from 7-100 g/kg (ATSDR 2008). One of the most important factors for determining the environment fate of aluminum is pH, where the concentration of soluble aluminum increases in very acidic or alkaline environments.

For Canada, the total and dissolved aluminum concentrations in natural waters were measured upstream and downstream of industrial facilities. According to the Canadian Environmental Protection Agency, the mean total aluminum levels varied from 0.002 to 2.15 mg/L, with a maximum value of 28.7 mg/L, while the mean dissolved aluminum concentrations ranged from 0.01 to 0.06 mg/L (CEPA 1999). For Metro Vancouver, the total and dissolved aluminum concentrations in influent and effluent water for fiver wastewater treatment plants were measured. The influent concentrations ranged from 0.47 to 2.74 mg/L and 0.04 to 0.25 mg/L for total and dissolved aluminum, respectively (GVRD 2006), and the effluent concentrations ranged from 0.05 to 0.97 mg/L and 0.02 to 0.16 mg/L for total and dissolved aluminum, respectively (GVRD 2006). It is common practice for wastewater treatment plants to use aluminum salts as coagulants or flocculants to treat organic or microbial wastewater components, and although this does not appear to affect the total aluminum concentration, it does influence bioavailability or the uptake of aluminum by organisms (Health Canada 1998).

With respect to regulations, the Metro Vancouver standards for dissolved and total aluminum concentrations are 2 mg/L and 50 mg/L respectively. According to Health, Safety, and Environment at UBC, the dissolved and total aluminum concentrations were measured to be 4 to 18 mg/L and 90 mg/L, respectively, for the photographic wastes.

Like any chemical, the release of aluminum into an ecosystem impacts plants, animals, and their environment. This impact is quantified using several tools including the ecosystem risk index and bioaccumulation factor. With respect to plants, aluminum has been shown to inhibit growth in acidic soils (Horst 1995). According to the Canadian

EPA, the bioconcentration factor (BCF), an indicator of chemical extraction and concentration in liquid tissues, varied for different plants. For hardwood and coniferous species, the BCF ranged from 20 to 79,600 for roots, and 5 to 1,300 for foliage (CEPA 1999). For grain crops, the BCF ranged from 200 to 6,000 for roots, and 4 to 1,260 for foliage (CEPA 1999).

Due to the presence of aluminum in natural waters, ecosystem impact studies are common for many species of fish. Concentrations of aluminum above 4 to 8 μmol/L are toxic to fish, where aluminum accumulates on the gills, inhibiting respiratory function (Gitelman 1989). The lethal concentration to 50% of the population over a certain exposure period (LC_{50}) for a wide range of pH values range from 0.36 to 0.79 mg/L, and BCF values range from 400 to 1,365 (CEPA 1999). Like plants, fish are the most sensitive to aluminum in acidic environments, where the LC_{50} is approximately 54 μg/L for Atlantic salmon at pH 5.2 (CEPA 1999).

Human health risk is quantified using several tools including exposure pathways and potential, as well as hazard classification. Exposure pathways include the inhalation exposure to air-released chemicals, ingestion exposure to surface water released chemicals, and dermal exposure. Major sources of aluminum for human exposure include drinking water, residues in food, cooking utensils, food and beverage packaging, antacid formulations, and acidic leaching into groundwater (Lewis 1989). Factors that influence the bioavailability of aluminum in humans include pH, dietary factors, formation of lipid complexes, and the route of exposure (ATSDR 2008).

With respect to hazard identification, there are no studies regarding reproductive toxicity or carcinogenicity in humans, and aluminum does not appear to affect animals in either case (Golub 2006, CEPA 1999). However, there are studies indentifying aluminum as a neurotoxic agent in animals and humans. Several studies have linked proximity to water sources with elevated aluminum levels and the increased risk of Alzheimer's disease, however there is not conclusive evidence indicating that increase aluminum exposure is a causative agent of the disease (ATSDR 2008).

IV. Methodology

Experimental Apparatus and Techniques

Currently, end-of-pipe treatment is the chosen method of managing photograph waste from various generators on the UBC campus that use photographic fixer and developer. Refer to Table A-1 for a comprehensive list of generators. Since photographic processing solutions contain silver, which is considered a toxic heavy metal by EPA (Environmental Protection Agency), it must be removed before being discharged. Furthermore, the removed silver can be sold for a profit.

Spent fixer and developer are sent to the Health Safety & Environment (HSE) treatment facility in plastic waste containers with the appropriate identification tags. Both fixer and developer, which are kept separately in their respective containers, are mixed before silver is removed. Prior to mixing, all photographic waste solutions are stored outdoors by the loading dock.

The setup for silver removal is shown in Figure 2. The reservoir on the left contains a mixture of developer and fixer. The mixed solution is then pumped through a series of columns, which remove and contain the silver. The silver-free photographic waste mixture is then stored in another reservoir, as shown in the right side of the figure. Once all the fluid has been processed for silver removal, it is sent to the neutralization room where the pH is regulated to emission standards. Developer and fixer are expected to neutralize each other when mixed. Typically, the end-of-pipe treatment would conclude at this point; however, the effluent was tested and elevated aluminum levels were found. Furthermore, the pH of the treatment mixture was tested to be approximately 8, which is more basic than expected.

Since all the developer and fixer are treated for silver removal as one solution, it is difficult to determine the exact source of the aluminum. However, previous external testing for metals revealed that aluminum levels in raw fixer are much more significant than those found in developer which could collectively contribute to the elevated levels. Hence, testing for aluminum is to be focused on any fixer sent from generators.

Figure 2. Silver Removal from Developer/Fixer Mixture

Waste Audits (Aluminum Testing)

The source of the elevated aluminum levels is currently unknown. Hence laboratory experiments in quantifying aluminum in waste samples were conducted. The main method employed was the use of the Merckoquant® aluminum test kit. This technique allows for a quick summary of the aluminum content present in the waste samples, using colorimetric comparisons by visual inspections.

Fixer samples were acquired from a variety of generators, namely: Michael Smith Laboratories, Life Sciences (Cellular and Workshop), Detwiller Psychiatry, and the Animal Care Centre from the UBC campus. Approximately 30mL of sample was taken from each corresponding plastic waste container, from which smaller samples of 5mL were extracted using pipettes. Following the recommendations made by the manufacturer of the test kit, samples were tested at temperatures between 15-30^{o}C using a hot plate.

The test vessel was first rinsed the test solution then filled to the indicated level. With the 5mL sample, the pH is measured using an automatic Accumet pH/temperature probe from Fisher. Adding small amounts of the provided buffer, Reagent Al-1, the pH is constantly monitored until a pH of approximately 13 is achieved. Any resulting precipitation is removed by filtration. Next, the reaction zone of the analytical test strip was submerged into the test sample for 1 second. Excess liquid was allowed to run off and absorbed on a paper towel. The second provided solution, Reagent Al-2, was used to form the color complex. One drop of this solution allows the free aluminum ions to react and form aluminate, which in turn, react with aurin tricarboxylic acid, which is red in color. The reaction was allowed to take place for 1 minute, after which any excess liquid is absorbed. The shade of the reaction zone was then compared to the color field on the label of the test strip container. Hence, the corresponding aluminum content (mg/L) was estimated. If the color zone was out of the color field range, dilutions were performed using distilled water. The lab setup for quantifying aluminum in photographic waste is shown in Figure 3.

Figure 3. Experimental Apparatus

Waste audits and inventories for aluminum, on a lab scale, were tested using the procedures described above. Quantifying aluminum levels on a commercial level is possible through external testing facilities. In doing so, a more comprehensive study involving all metals present, can be performed. Refer to results from Cantest in the appendix. Focusing on the photographic waste treatment facility, the only waste stream consists of the developer/fixer mixture. Waste streams are generated on one-time events, depending on the needs of photographic solutions on campus. As mentioned, aluminum makes up a small portion of these solutions; however, it is suspected that there are external sources contributing to the elevated levels. Limits of aluminum for discharge are found to be 2ppm. External testing revealed that aluminum content range from 4-19ppm.

Pollution prevention for the process of waste collection and treatment should be considered to ensure all requirements are met for waste emissions. Considering the unit operations involved, photographic developing and fixing solutions are standard. Using alternative solutions would not provide any immediate resolutions. However, a variable that needs to be further investigated is how the chemicals are being used. Once the major sources of aluminum have been identified, the use of photographic chemicals from those generators should be critically examined. In doing so, the factors that contribute to the elevated aluminum levels are identified, which can aid in the development of an aluminum removal process.

V. Results and Discussion

The collected photographic waste from the sources enlisted in Table A-1 had been sent to analytical laboratories to test for aluminum contents. The obtained results are presented in Table 1. From the results, it is noted that the aluminum content is negligible in the developer solutions compared to fixer solutions that contain average of 224mg/L of aluminum in the May 2008 sample. It is also worthwhile to note that the treated fixer sample from February 2008 contains less aluminum, possibly due to coincidental removal of aluminum during the silver removal process. This indicates that removing aluminum from the solution is feasible.

Table 1. Aluminum Content Testing Result for Mixed Waste by CANTEST

Date	Sample	Al (mg/L)	pH
2008-02-29	Raw Developer	0.08	9.8
2008-02-29	Treated Fixer (Silver removed)	18.6	5.72
2008-03-04	Fixer Developer Mix	4.23	8.47
2008-03-19	1/8 Fixer Developer	6.88	4.8
2008-05-08	Fixer	224	8.17

In order to identify the major contributor to the high aluminum content observed in the previous laboratory testing, the fixer waste from each source was collected separately to test for its aluminum content. An aluminum testing colorimeter kit (Merckoquant® Aluminum Strips), which provides suitable degree of precision and is a more economically viable option than hiring laboratory services, was adopted for aluminum concentration testing. The experiment was done at pH close to 13 and temperature between 15°C to 30°C. All tested samples, listed in Table 2, were relatively clear without any cloudiness except for the Detwiller Pavilion Psychiatry fixer sample, which has higher turbidity and precipitates settled at the bottom of the collection beaker. The sample was filtered with Whatman 1 filter to rid of the precipitates for duplicate run. The sample from Animal Care Centre had an unidentifiable odor compared to the other samples.

Table 2. Aluminum Content Testing Result for Source Specified Fixer Waste

Sample Source	Sample	Barcode	Dilution Factor	Initial pH	Initial T(°C)	Adjusted pH	Final T(°C)	[Al] (mg/ml)
Detwiller Pavilion Psychiatry (Andy Shih)	Original	G0018	1	4.46	28.7	13.1	30.1	**>250**
			1/2			13.1	30.1	**>250**
			1/4			13.06	30.1	**>250**
	Filtered w/ Whatman 1 (Cat no 1001 185)		1/3	4.65	23	13.36	24.5	**>250**
			1/6			13.11	23.6	**>250**
			1/12			13.17	23.6	**200**
Michael Smith Laboratory (Victor Luk)	Original	G0134	1	4.61	24.6	13.13	29.6	**8**
Life Sciences Cellular & Physiological Sciences (James Johnson)	Original	G0609	1	4.5	23.5	13.23	27.3	**8**
Life Sciences Workshop (Adam Suen)	Original	G0660	1	4.49	22.8	13.01	28.5	**8**
Animal Care Centre (Gordon Grey)	Original	G0014	1	4.22	19.8	13.27	28.2	**8**

The resulting test strips are shown in Figure 4, where lighter color represents lower aluminum contents. The colors are compared to a standard color chart (Figure 5) to quantify the aluminum concentration, presented in Table 2.

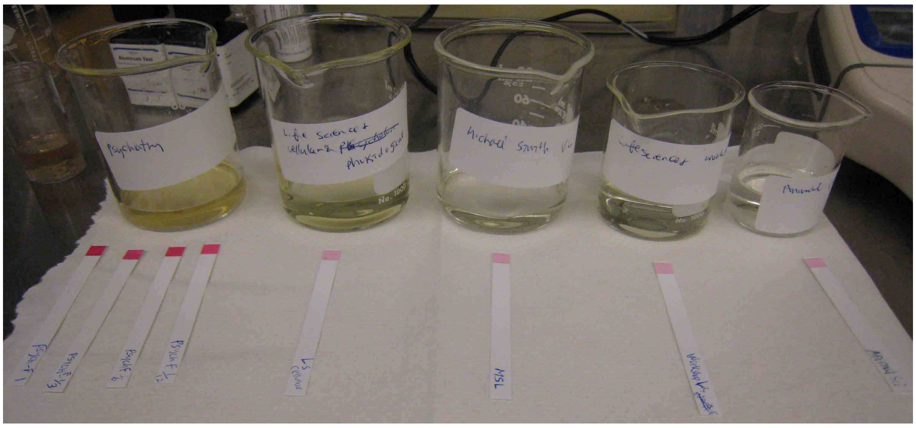

Figure 4. Aluminum Test Result

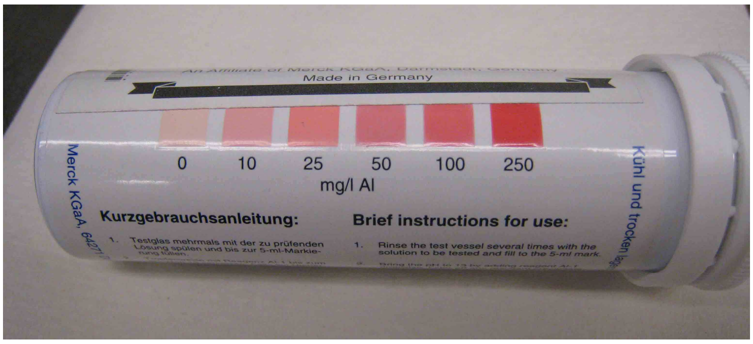

Figure 5. Color Zone Comparison Chart

It is determined that all sources contribute insignificant amount of aluminum, except for Detwiller Pavillon Psychiatry Centre, which had to be diluted by a factor of 12 to be within the measurable range for the aluminum strips. Based on the result, it is concluded that the Detwiller sample contains roughly 2400mg/ml of aluminum, which clearly indicates that Detwiller is the major contributor to the high aluminum content in UBC's photographic waste.

VI. Proposed Strategy

This project focuses on identifying the generators who contribute significantly to the elevated aluminum levels in UBC photographic waste, and implementing source reduction or waste treatment strategies to reduce aluminum levels to meet sewer discharge standards. After identification of the significant generators, the next step is to investigate the fixer processes and the potential for source reduction. In the fixing process, particularly for medical imaging, there are four steps: neutralization, clearing, preservation, and hardening. Several different aluminum compounds may be used for the final step, including aluminum chloride. It is possible that the elevated aluminum levels are a result of excess aluminum chloride or other chemicals. One strategy for source reduction is for generators to examine material selection and substitutions for aluminum-intensive steps of the fixer process.

With respect to aluminum removal, the ion exchange – pyrocatechol violet (PCV) complexation method and magnetically stabilized fluid bed are options. The PCV-ion exchanger method is based on the reactivity of monomeric aluminum with pyrocatechol violet solution. The sample solution is reacted with pyrocatechol violet solution at pH 6-6.2, and is passed through a strong cationic exchanger column. The aluminum binds to the column resins and is separated from the rest of the solution. Removal of aluminum ions can also be achieved by using magnetic adsorbent beads, specifically alizarin yellow-attached magnetic poly beads (Yuvuz, 2004). Despite the demonstrated efficiency of the above-mentioned methods, the methods require expensive absorbents and equipment, and the costs outweigh the benefits.

In terms of waste treatment strategies, residual aluminum levels in wastewater can be reduced by adjustment of pH to approximately 6.0, which is close to its minimum solubility (Faust and Aly 1998). This allows for the precipitation of aluminum, where particulate matter including $Al(OH)_3$ can be removed using filtration. Additional experimentation would be required to determine the optimal condition for filtration, including molecular weight cut-off for filtration membranes, trans-membrane pressure, and feed flow rate.

VII. Conclusion and Recommendations

This project was undertaken to apply green engineering tools to identify and reduce the impact of aluminum in UBC's photographic waste. Fixer waste from each waste source was collected to measure the aluminum content using Merckoquant® Aluminum Strips. From the testing, the major aluminum source was determined to be the Detwiller Pavilion Psychiatry Center, with approximately 2400mg/ml of aluminum in the fixer solution. It was proposed that personnel at the Detwiller Pavillon Psychiatry Center be consulted to investigate the source and eliminate the excess aluminum waste by means of source reduction. Treatment methods were also investigated, including precipitation and the PCV complexation-ion exchange method. Precipitation and filtration was determined to be the most suitable method due to the ease of scale-up.

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Acknowledgements

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Kelly Coulson, *Graduate Student, Chemical and Biological Engineering*

Appendix – Raw Data

Table A-1. Waste Fixer Generators on UBC Campus

Name	Department	Volume	Type
Adam Suem	LSI - Workshop	80	F
Victor Luk	MSB - Biotechnology	20	F
Wayne Vogl	Anatomy	60	F
Peter Houston	SUB - UBC Photo Society	60	F
Dr. S. Singh	Botany	40	F
Kathy Fu	Research	40	F
Nicole Voglmaier	BRC	40	F
Patrick Mcgeer	Detwiller - Psychiatry	20	F
James Johnson	LSI - Physiological Sciences	20	F
Susan Farmer	Station	20	F
Aimee Gerard	NeuroMed Technology	20	F

Effluent Standards

Schedule 1.2

[en. B.C. Reg. 132/92, s. 34; am. B.C. Reg. 319/2004, s. 2.]

Effluent Standards for Hazardous Waste Facilities

Column 1	Column 2	Column 3
Parameter	**Standard* for Discharges to the Environment or to Storm Sewers**	**Standard* for Discharges Directed to Municipal or Industrial Effluent Treatment Works**
Physical		
pH	6.5 to 8.5**	5.0 to 11.0**
Temperature	32° C	—
Total suspended solids	20	—
Toxicity (limit bioassay — 50% survival of Rainbow trout after 96 hours)	100% effluent	50% effluent
Inorganics		
Aluminum, dissolved	0.5	2.0
Ammonia, total (expressed as nitrogen)	2.0	—
Antimony, dissolved	0.25	0.5
Arsenic, dissolved	0.1	0.3
Barium, dissolved	1.0	2.5
Boron, dissolved	10.0	15.0
Cadmium, dissolved	0.05	0.1
Chromium, dissolved (hexavalent)	0.1	0.2
Chromium, total	0.5	1.0
Cobalt, dissolved	0.1	0.3
Copper, dissolved	0.1	0.3
Cyanide (weak acid dissociable)	0.1	0.2
Fluoride, dissolved	15	18
Lead, dissolved	0.1	0.3
Manganese, dissolved	0.5	1.0
Mercury, total	0.001	0.01
Molybdenum, dissolved	0.5	1.0
Nickel, dissolved	0.5	1.0
Selenium, dissolved	0.05	0.1
Tin, dissolved	0.5	1.0
Zinc, dissolved	0.2	0.5
Organics		
5 day Biochemical oxygen demand (BOD)	20	—
Dioxin TEQ	15 pg/L	15 pg/L
Oil	10	60
Phenol	0.2	0.5
Polychlorinated biphenyls, total	0.005	0.005
Total chlorinated phenol	0.006	0.05

Photographic Fixer – MSDS

Material Safety Data Sheet

SECTION I - Material Identity

Item Name	
Part Number/Trade Name	KODAK FLEXICOLOR FIXER AND REPLENISHER
National Stock Number	6750010371034
CAGE Code	19139
Part Number Indicator	A
MSDS Number	130830
HAZ Code	B

SECTION II - Manufacturer's Information

Manufacturer Name	EASTMAN KODAK COMPANY
Street	343 STATE STREET
City	ROCHESTER
State	NY
Country	US
Zip Code	14650
Emergency Phone	716-722-5151
Information Phone	716-722-5151

MSDS Preparer's Information

Date MSDS Prepared/Revised	21APR89
Date of Technical Review	04MAR92
Active Indicator	N

Item Manager	CX

Alternate Vendors

Vendor #5 CAGE	BGGTS

SECTION III - Physical/Chemical Characteristics

Specification Number	NONE
Specification Type/Grade/Class	N/R
Hazard Storage Compatibility Code	N1-L1
NRC License Number	N/R
Net Propellant Weight (Ammo)	NA
Appearance/Odor	CLEAR, SLIGHTLY YELLOW SOLUTION
Boiling Point	212F,100C
Melting Point	NOT GIVEN
Vapor Pressure	18 MMHG
Vapor Density	0.6
Specific Gravity	1.35
Decomposition Temperature	UNKNOWN
Evaporation Rate	NOT GIVEN
Solubility in Water	COMPLETE
Percent Volatiles by Volume	39 %
Chemical pH	6.2
Corrosion Rate	UNKNOWN
Container Pressure Code	4
Temperature Code	8
Product State Code	U

SECTION IV - Fire and Explosion Hazard Data

Flash Point Method	UNK
Lower Explosion Limit	NONFLAMMABLE
Upper Explosion Limit	NONFLAMMABLE
Extinguishing Media	USE AGENT APPROPRIATE FOR SURROUNDING FIRE
Special Fire Fighting Procedures	WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING
Unusual Fire/Explosion Hazards	FIRE OR EXCESSIVE HEAT MAY CAUSE PRODUCTION OF DECOMPOSITION PRODUCTS

SECTION V - Reactivity Data

Stability	YES
Stability Conditions to Avoid	HEAT, HIGH TEMPERATURES
Materials to Avoid	STRONG ACIDS AND BASES
Hazardous Decomposition Products	THERMAL DECOMPOSITION MAY PRODUCE AMMONIA AND OXIDES OF SULFUR AND NITROGEN
Hazardous Polymerization	NO
Polymerization Conditions to Avoid	NONE. WILL NOT OCCUR
LD50 - LD50 Mixture	NOT SPECIFIED BY MANUFACTURER

SECTION VI - Health Hazard Data

Route of Entry: Skin	NO
Route of Entry: Ingestion	YES
Route of Entry: Inhalation	NO
Health Hazards - Acute and Chronic	PRODUCT MAY BE IRRITATING TO EYES. IT IS A VERY LOW HAZARD FOR RECOMMENDED HANDLING
Carcinogenity: NTP	NO
Carcinogenity: IARC	NO
Carcinogenity: OSHA	NO
Explanation of Carcinogenity	PRODUCT CONTAINS NO MATERIALS CURRENTLY CLASSIFIED AS CARCINOGENIC BY NTP, IRAC OR OSHA
Symptoms of Overexposure	LOW INHALATION HAZARD FOR USUAL RECOMMENDED HANDLING. CAUSES EYE IRRITATION ON CONTACT. PROLONGED OR REPEATED CONTACT WITH THE SKIN MAY CAUSE IRRITATION. PRODUCT EXPECTED TO BE A LOW INGESTION HAZARD
Medical Cond. Aggrevated by Exposure	NONE SPECIFIED BY MANUFACTURER
Emergency/First Aid Procedures	EYES: IN CASE OF CONTACT, FLUSH WITH WATER FOR AT LEAST 15 MINUTES. SKIN: WASH WITH SOAP AND WATER. INHALATION: REMOVE TO FRESH AIR. INGESTION: IF SWALLOWED, DRINK 1-2 GLASSES OF WATER. SEEK MEDICAL ATTENTION IF SYMPTOMS PERSIST

SECTION VII - Precautions for Safe Handling and Use

Steps if Material Released/Spilled	LARGE SPILL: VENTILATE AREA OF SPILL. WEAR PROTECTIVE GLOVES & SAFETY GOGGLES. DIKE LIQUID SPILL WITH ABSORBENT. PUMP

	LIQUID INTO SALVAGE TANK. SMALL SPILL: FLUSH LIQUID TO AN ACID-FREE SEWER WITH LARGE AMOUNTS OF WATER
Neutralizing Agent	NONE SPECIFIED BY MANUFACTURER
Waste Disposal Method	KEEP IN COVERED DRUMS, PENDING DISPOSAL. HANDLE AND DISPOSE IN FULL COMPLIANCE WITH ALL APPLICABLE LOCAL, STATE AND FEDERAL REGULATIONS
Handling and Storage Precautions	RE IN COOL, DRY, WELL VENTILATED AREA. PROTECT FROM PHYSICAL DAMAGE. AVOID ANY PHYSICAL CONTACT. KEEP CONTAINERS TIGHTLY CLOSED. NO
Other Precautions	NONE SPECIFIED BY MANUFACTURER

SECTION VIII - Control Measures

Respiratory Protection	NONE NEEDED IN NORMAL CONDITIONS OF USE
Ventilation	GOOD GENERAL (MECHANICAL) VENTILATION SHOULD BE SUFFICIENT
Protective Gloves	IMPERVIOUS
Eye Protection	CHEMICAL/SAFETY GLASSESWITH SIDE SHIELDS
Other Protective Equipment	AS NECESSARY TO PREVENT PROLONGED OR REPEATED CONTACT
Work Hygenic Practices	USE NORMAL PRECAUTIONS APPLICABLE TO PHOTOGRAPHIC MATERIALS
Supplemental Health/Safety Data	SOLUTION # OF THE PRODUCT: 5542
Disposal Code	O

SECTION IX - Label Data

Protect Eye	YES
Protect Skin	NO
Protect Respiratory	NO
Chronic Indicator	UNKNOWN
Contact Code	SLIGHT
Fire Code	UNKNOWN
Health Code	UNKNOWN
React Code	UNKNOWN

SECTION X - Transportation Data

Container Quantity	2.5
Unit of Measure	LR

SECTION XI - Site Specific/Reporting Information

Volatile Organic Compounds (P/G)	0
Volatile Organic Compounds (G/L)	0

SECTION XII - Ingredients/Identity Information

Ingredient #	01
Ingredient Name	AMMONIUM THIOSULFATE
CAS Number	7783188
NIOSH Number	XN6465000
Proprietary	NO
Percent	50-55
OSHA PEL	NOT ESTABLISHED
ACGIH TLV	NOT ESTABLISHED
Ingredient #	02
Ingredient Name	WATER
CAS Number	7732185
NIOSH Number	ZC0110000
Proprietary	NO
Percent	35-40
OSHA PEL	NOT ESTABLISHED
ACGIH TLV	NOT ESTABLISHED
Ingredient #	03
Ingredient Name	AMMONIUM SULFITE
CAS Number	10196040
NIOSH Number	WT3505000
Proprietary	NO
Percent	1-5
OSHA PEL	NOT ESTABLISHED
ACGIH TLV	NOT ESTABLISHED
Recommended Limit	NOT ESTABLISHED
Ingredient #	04
Ingredient Name	SODIUM BISULFITE (SASA III)
CAS Number	7631905
NIOSH Number	VZ2000000
Proprietary	NO
Percent	<1.0
OSHA PEL	5 MG/M3
ACGIH TLV	5 MG/M3; 9192

Recommended Limit	NOT ESTABLISHED
Ingredient #	05
Ingredient Name	AMMONIUM ACETATE (SARA III)
CAS Number	631618
NIOSH Number	AF3675000
Proprietary	NO
Percent	<1.0
OSHA PEL	NOT ESTABLISHED
ACGIH TLV	NOT ESTABLISHED
Recommended Limit	NOT ESTABLISHED

Raw Developer Metals Assay

REPORTED TO: Bang Dang

REPORT DATE: February 29, 2008

GROUP NUMBER: 90226097

CANTEST

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		Raw Dev	
SAMPLE PREPARATION:		DISSOLVED	DETECTION LIMIT
CANTEST ID:		802260288	
Aluminum	Al	0.08	0.05
Antimony	Sb	0.06	0.05
Arsenic	As	<	0.03
Barium	Ba	0.001	0.001
Beryllium	Be	<	0.003
Boron	B	12.6	0.01
Cadmium	Cd	<	0.01
Calcium	Ca	0.22	0.05
Chromium	Cr	<	0.01
Cobalt	Co	<	0.02
Copper	Cu	<	0.02
Iron	Fe	0.01	0.01
Lead	Pb	<	0.03
Magnesium	Mg	<	0.05
Manganese	Mn	<	0.003
Molybdenum	Mo	<	0.02
Nickel	Ni	<	0.02
Phosphorus	P	3.1	0.15
Potassium	K	653	0.25
Silicon	Si	0.15	0.05
Silver	Ag	<	0.01
Sodium	Na	164	0.1
Strontium	Sr	<	0.001
Tin	Sn	<	0.03
Titanium	Ti	<	0.005
Vanadium	V	<	0.01
Zinc	Zn	0.006	0.005
Zirconium	Zr	<	0.02

Results expressed as milligrams per liter (mg/L)
< = Less than detection limit

Raw Fixer Metals Assay

REPORTED TO: Bang Dang

REPORT DATE: May 8, 2008

GROUP NUMBER: 90502127

CANTEST

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		Fix020508	
SAMPLE PREPARATION:		DISSOLVED	DETECTION LIMIT
CANTEST ID:		805020421	
Aluminum	Al	244	25
Antimony	Sb	25	25
Arsenic	As	<	15
Barium	Ba	<	0.5
Beryllium	Be	<	1.5
Boron	B	74	5
Cadmium	Cd	<	5
Calcium	Ca	30	25
Chromium	Cr	<	5
Cobalt	Co	<	10
Copper	Cu	<	10
Iron	Fe	231	5
Lead	Pb	<	15
Magnesium	Mg	<	25
Manganese	Mn	9	1.5
Molybdenum	Mo	<	10
Nickel	Ni	<	10
Phosphorus	P	<	75
Potassium	K	560	125
Silicon	Si	<	25
Silver	Ag	<	5
Sodium	Na	10400	50
Strontium	Sr	<	0.5
Tin	Sn	<	15
Titanium	Ti	<	2.5
Vanadium	V	6	5
Zinc	Zn	<	2.5
Zirconium	Zr	<	10

Results expressed as milligrams per liter (mg/L)
< = Less than detection limit

Fixer/Developer Mix Metals Assay

REPORTED TO: Bang Dang

REPORT DATE: March 4, 2008

GROUP NUMBER: 90226105

CANTEST

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		Fix DEV Mix	
SAMPLE PREPARATION:		DISSOLVED	DETECTION LIMIT
CANTEST ID:		802260320	
Aluminum	Al	4.23	0.05
Antimony	Sb	0.06	0.05
Arsenic	As	<	0.03
Barium	Ba	<	0.001
Beryllium	Be	<	0.003
Boron	B	3.83	0.01
Cadmium	Cd	<	0.01
Calcium	Ca	0.16	0.05
Chromium	Cr	0.02	0.01
Cobalt	Co	<	0.02
Copper	Cu	0.02	0.02
Iron	Fe	9.16	0.01
Lead	Pb	<	0.03
Magnesium	Mg	<	0.05
Manganese	Mn	0.15	0.003
Molybdenum	Mo	<	0.02
Nickel	Ni	<	0.02
Phosphorus	P	0.4	0.15
Potassium	K	239	0.25
Silicon	Si	0.06	0.05
Silver	Ag	<	0.01
Sodium	Na	139	0.1
Strontium	Sr	<	0.001
Tin	Sn	<	0.03
Titanium	Ti	<	0.005
Vanadium	V	<	0.01
Zinc	Zn	0.022	0.005
Zirconium	Zr	<	0.02

Results expressed as milligrams per liter (mg/L)
< = Less than detection limit

1/8 Fix/Dev Mix Metals Assay

REPORTED TO: Bang Dang

REPORT DATE: March 19, 2008

GROUP NUMBER: 90317110

CANTEST

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		1/8 Fix Dev	
SAMPLE PREPARATION:		DISSOLVED	
DATE SAMPLED:		Mar 17/08	DETECTION LIMIT
CANTEST ID:		803170290	
Aluminum	Al	6.88	0.05
Antimony	Sb	0.05	0.05
Arsenic	As	0.04	0.03
Barium	Ba	<	0.001
Beryllium	Be	<	0.003
Boron	B	0.40	0.01
Cadmium	Cd	<	0.01
Calcium	Ca	0.42	0.05
Chromium	Cr	<	0.01
Cobalt	Co	<	0.02
Copper	Cu	<	0.02
Iron	Fe	6.50	0.01
Lead	Pb	<	0.03
Magnesium	Mg	<	0.05
Manganese	Mn	0.065	0.003
Molybdenum	Mo	<	0.02
Nickel	Ni	<	0.02
Phosphorus	P	<	0.15
Potassium	K	6.6	0.25
Silicon	Si	0.13	0.05
Silver	Ag	6.03	0.01
Sodium	Na	57.0	0.1
Strontium	Sr	<	0.001
Tin	Sn	<	0.03
Titanium	Ti	<	0.005
Vanadium	V	<	0.01
Zinc	Zn	0.011	0.005
Zirconium	Zr	<	0.02

Results expressed as milligrams per liter (mg/L)
< = Less than detection limit

Treated Fixer Metals Assay

REPORTED TO: Bang Dang

REPORT DATE: February 29, 2008

GROUP NUMBER: 90226095

CANTEST

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		Treated Fix	
SAMPLE PREPARATION:		DISSOLVED	DETECTION LIMIT
CANTEST ID:		802260286	
Aluminum	Al	18.6	0.05
Antimony	Sb	<	0.05
Arsenic	As	0.03	0.03
Barium	Ba	<	0.001
Beryllium	Be	<	0.003
Boron	B	4.63	0.01
Cadmium	Cd	<	0.01
Calcium	Ca	0.14	0.05
Chromium	Cr	0.04	0.01
Cobalt	Co	<	0.02
Copper	Cu	<	0.02
Iron	Fe	56.9	0.01
Lead	Pb	<	0.03
Magnesium	Mg	<	0.05
Manganese	Mn	0.53	0.003
Molybdenum	Mo	<	0.02
Nickel	Ni	<	0.02
Phosphorus	P	<	0.15
Potassium	K	12.8	0.25
Silicon	Si	0.12	0.05
Silver	Ag	0.02	0.01
Sodium	Na	200	0.1
Strontium	Sr	<	0.001
Tin	Sn	<	0.03
Titanium	Ti	<	0.005
Vanadium	V	<	0.01
Zinc	Zn	0.016	0.005
Zirconium	Zr	<	0.02

Results expressed as milligrams per liter (mg/L)
< = Less than detection limit