UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

June 30, 2005

MEMORANDUM

SUBJECT: Ecological Hazard and Environmental Risk Assessment of Bromine and Sodium bromide for the Reregistration Eligibility Decision (RED) Document

Case No.: 4015-18801 **DP Barcode:** 315376

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Chemical Name	PC Code	CAS #	Common Name
Bromine	008701	7726-95-6	Bromine Gas (Br)
Sodium bromide	013907	7647-15-6	Bromide salt of sodium (NaBr)

Attached is the Ecological Hazard and Environmental Risk Assessment of Bromine and Sodium bromide for incorporation into the Reregistration Eligibility Decision (RED) document.

(1)

ECOLOGICAL HAZARD AND ENVIRONMENTAL RISK ASSESSMENT
Bromine and Sodium Bromide

CASE 4015-18801

PC Codes 008701 (Bromine) and 013907 (Sodium Bromide)

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2

Ecological Hazard and Environment Risk Assessment
Bromine and Sodium Bromide

Bromine (PC Code 008701) and Sodium bromide (PC Code 013907) are used for a variety of antimicrobial uses. Currently, all registered uses of bromine are indoor (food, non-food, medical, and residential). Bromine is used in water filters to purify drinking water. It also is used as a general disinfectant and sanitizer in indoor, non-food contact areas such as commercial establishments, hospitals and households, to control bacteria and fungi. In water and living organisms, bromine reacts with other compounds to form bromides. Sodium bromide is used as a water disinfectant, sanitizer, slimicide, bactericide, algicide, fungicide, and molluscicide control agent. Registered uses include aquatic non-food industrial (commercial and industrial recirculating water-cooling systems, wastewater treatment, industrial once-through water cooling systems, pulp and paper mill water systems) aquatic non-food residential (ornamental ponds/aquaria, swimming pool water systems, domestic/commercial nonpotable water), indoor food (food processing water systems), and indoor non-food (pasteurizer/warmer/cannery cooling water systems).

I. Ecological Toxicity Data

In addition to estimating risks to human health, the Agency also assesses risks to terrestrial animals, aquatic organisms, and plants. The toxicity endpoints presented below are based on the results of ecotoxicity studies submitted to EPA to meet the Agency=s data requirements for the uses of bromine and sodium bromide.

A. Toxicity to Terrestrial Animals

(1) Birds, Acute and Subacute

In order to establish the toxicity of bromine and sodium bromide to avian species for indoor and aquatic uses, the Agency requires an acute oral toxicity study using the technical grade active ingredient (TGAI). The preferred test species is either mallard duck (a waterfowl) or bobwhite quail (an upland game bird). The Agency has granted waivers for avian studies using bromine. Standard avian tests would not provide meaningful and useful toxicity data since bromine is a highly volatile, corrosive liquid chemical. The results of two acute oral toxicity studies, using sodium bromide, are provided in the following table (Table 1).

Table 1. Acute Oral Toxicity of Sodium Bromide to Birds

Species	Chemical, % Active Ingredient (a.i.)	Endpoint (mg/kg)	Toxicity Category	Satisfies Guidelines/ Comments	Reference (MRID No.)
Mallard duck (*Anas platyrhynchos)*	Sodium bromide, 97%	LD_{50}>2150	Practically non-toxic	Yes $ core study $ 21-day test duration	406699-01
Bobwhite quail (*Colinus virginianus)*	Sodium bromide, 99.23%	LD_{50}>2250	Practically non-toxic	Yes $ core study $ 14-day test duration	406708-11

The results indicate that sodium bromide is practically non-toxic to avian species on an acute oral basis. The studies fulfill guideline requirements (71-1/OPPTS 850.2100).

A subacute dietary study using the TGAI may be required on a case-by-case basis depending on the results of lower-tier ecological studies and pertinent environmental fate characteristics in order to establish the toxicity of a chemical to avian species. This testing was required for the aquatic uses of sodium bromide. Results of these studies are provided in Table 2.

Table 2. Subacute Dietary Toxicity of Sodium Bromide to Birds

Species	Chemical, % Active Ingredient (a.i.)	Endpoint (ppm)	Toxicity Category	Satisfies Guidelines/ Comments	Reference (MRID No.)
Mallard duck (*Anas platyrhynchos)*	Sodium bromide, 99.23%	LD_{50}>5633	Practically non-toxic	Yes $ core study $ 8-day test duration	406708-12
Bobwhite quail (*Colinus virginianus)*	Sodium bromide, 99.23%	LD_{50}>5633 NOEC = 1784	Practically non-toxic	Yes $ core study $ 8-day test duration	406708-13

The results indicate that sodium bromide is practically non-toxic to avian species on a subacute dietary basis. The studies fulfill guideline requirements (71-2/OPPTS 850.2200).

(2) Mammals, Acute, Subchronic, and Developmental Toxicity

Wild mammal testing is not routinely required by the Agency. In most cases, rat toxicity values obtained from studies conducted to support data requirements for human health risk assessments substitute for wild mammal testing. These toxicity values are reported below (Table 3). Further information on the mammalian toxicology of bromine and sodium bromide may be found in the Toxicology Chapter of this RED document.

Table 3. Acute, Subchronic and Developmental Toxicity of Bromine and Sodium Bromide to Mammals (excerpted from Toxicology Chapter)

Guideline No.	Study Type	MRID No.	Results	Tox. Cat.
'81-1 (OPPTS870.1100)	Acute Oral Sodium Bromide 99.23%	40670804	LD_{50} 4.5 g/kg Male LD_{50} 3.9 g/kg Female LD_{50} 4.2 g/kg combined	III
'81-2 (OPPTS 870.1200	Acute Dermal Sodium Bromide 46%	46083032	LD_{50} >2.0 g/kg	III
'81-3	Acute Inhalation	study not available		
'81-4 (OPPTS 870.2400)	Primary Eye Irritation sodium bromide 46%	46083033 40670806	mild conjuctival irritation found in 6/6 animals, which persisted for 72 hr in 1/6 animals. No effects at 96 hr.	III
'81-5 (OPPTS 870.2500)	Primary Dermal Irritation sodium bromide 46%	46083034	very mild erythema on 1/6 animals, cleared by 24 hr. No irritation fount at other times. P.I.I. = 1.0	IV
'81-6 (OPPTS 870.2600	Dermal Sensitization	study not available		
'81-8 (OPPTS 870.6200)	Acute and Subchronic Neurotoxicity	study not available		
'82-1 (OPPTS 870.3100)	Oral Subchronic Bromine 38%	418336-01	NOAEL=20 mg/kg/day LOAEL=200mg/kg/day	
'83-3 (OPPTS 870.3700)	Developmental Toxicity sodium bromide 99.84%	557946-01	Maternal Toxicity: NOEL=100mg/kg/day LOAEL=300mg/kg/day Developmental Toxicity: NOAEL=100mg/kg/day LOAEL=300mg/kg/day	

B. Toxicity to Aquatic Animals

The Agency requested that aquatic toxicity studies be conducted with hypobromous acid since, under typical use conditions, hypobromous acid is formed and is essentially the active ingredient which is introduced into the aquatic environment from the microbicide use of sodium bromide. Because hypobromous acid is formed from both bromine chloride and sodium bromide when added to water, studies using technical bromine chloride (100% a.i.) can be used to support the data requirements for aquatic organism testing.

(1) Freshwater Fish, Acute

In order to establish the acute toxicity of bromine and sodium bromide to freshwater fish, the Agency requires freshwater fish toxicity studies using the TGAI. The preferred test species are rainbow trout (a coldwater fish) and bluegill sunfish (a warmwater fish). Results of freshwater fish acute studies, submitted for bromine and sodium bromide, are presented in Table 4.

Table 4. Acute Toxicity of Bromine and Sodium Bromide to Freshwater Fish

Species	Chemical, % Active Ingredient (a.i.)	Endpoints (ppm)	Toxicity Category	Satisfies Guidelines/ Comments	Reference (MRID No.)

Bluegill sunfish *(Lepomis macrochirus)*	Sodium bromide, 99.23%	LC_{50}> 1000
		NOEC = 1000
			Practically non-toxic	No
				$ supplemental study
				$ 96-hr test duration
				$ static system
				$ although study scientifically sound, aquatic studies with hypobromus acid required
					406708-14

Bluegill sunfish *(Lepomis macrochirus)*	Bromine chloride, 100%	LC_{50} = 0.52 as bromine
		NOEC = 0.30 as bromine
			Highly toxic	Yes
				$ core study
				$ 96-hr test duration
				$ static system
					406699-03

Rainbow trout *(Salmo gairdneri)*	Sodium bromide, 99.23%	LC_{50} >1000	Practically non-toxic	No
				$ supplemental study
				$ 96-hr test duration
				$ static system
				$ although study scientifically sound, aquatic studies with hypobromous acid required
					406708-15

Rainbow trout *(Salmo gairdneri)*	Bromine chloride, 100%	LC_{50} = 0.31 as bromine
		NOEC = 0.10 as bromine
			Highly toxic	Yes
				$ core study
				$ 96-hr test duration
				$ static system
					406699-02

The results from the two core studies (MRIDs 406699-03 and 406699-02) indicate that bromine chloride, measured as bromine, is highly toxic to freshwater fish (both coldwater and warmwater) on an acute basis. These studies fulfill guideline requirements (72-1/OPPTS

7

850.1075). The remaining two studies (MRIDs 406708-14 and 406708-15) are scientifically sound, but do not fulfill guideline requirements that require aquatic testing with hypobromous acid.

(2) Freshwater Invertebrates, Acute

The Agency requires a freshwater aquatic invertebrate study using the TGAI to establish the acute toxicity to freshwater invertebrates. The preferred test species is *Daphnia magna*. Results of the two studies, submitted for bromine and sodium bromide, are provided in the following table (Table 5).

Table 5. Acute Toxicity of Bromine and Sodium Bromide to Freshwater Invertebrates

Species	Chemical, % Active Ingredient (a.i.)	Endpoints (ppm)	Toxicity Category	Satisfies Guidelines/ Comments	Reference (MRID No.)

Waterflea *(Daphnia magna)*	Bromine chloride, 99%	LC_{50} = 1.07 as bromine	Highly toxic	Yes
				$ core study
				$ 48-hr test duration
				$ static test system
					406699-04

Waterflea *(Daphnia magna)*	Sodium bromide, 99.23%	LC_{50} >1000
		NOEC = 1000
			Practically non-toxic	No
				$ supplemental study
				$ 48-hr test duration
				$ static test system
				$ although study scientifically sound, aquatic studies with hypobromous acid required
					406708-16

Results of the core study (MRID 406699-04) indicate that bromine chloride, measured as bromine, is highly toxic to freshwater invertebrates. The guideline requirement has been fulfilled (72-2, OPPTS 850.1010) by this study.

8

(3) Estuarine and Marine Organisms, Acute

Acute toxicity testing with estuarine and marine organisms using the TGAI is required when the end-use product is intended for direct application to the marine/estuarine environment or effluent containing the active ingredient is expected to reach this environment. The preferred fish test species is sheepshead minnow. The preferred invertebrate test species are mysid shrimp and eastern oysters. This testing is required for sodium bromide based on the chemical=s use in pulp and paper mills, once-through cooling towers, oil recovery drilling muds/packer fluids, and secondary oil recovery injection waters. It is not required for bromine, as all of the currently registered uses are indoor applications for which there are no effluents. In the submitted studies, sodium bromide was combined with sodium hypochlorite to produce hypobromous acid. Results of the three toxicity studies are presented in Table 6.

Table 6. Acute Toxicity of Sodium Bromide to Estuarine and Marine Organisms

Species	Chemical, % Active Ingredient (a.i.)	Endpoints (ppm)	Toxicity Category	Satisfies Guidelines/ Comments	Reference (MRID No.)

Sheepshead minnow *(Cyprinodon variegatus)*	Sodium bromide, 46%	LC_{50} = 0.19 as bromine
		NOEC = 0.11
			Highly toxic	Yes
				$ core study
				$ 96-hr test duration
				$ flow-through system
					407010-03

Mysid shrimp *(Mysidopsis bahia)*	Sodium bromide, 46%	LC_{50} = 0.18 as bromine
		NOEC < 0.037
			Highly toxic	Yes
				$ core study
				$ 96-hr test duration
				$ flow-through system
					407010-01

Eastern oyster *(Crassostrea virginica)*	Sodium bromide, 46%	EC_{50} = 0.47 as bromine
		NOEC < 0.068
			Highly toxic	Yes
				$ core study
				$ 96-hr test duration
				$ shell deposition
				$ flow-through system
					407010-02

NOTE: Sodium bromide was combined with sodium hypochlorite (9.4%) to produce hypobromous acid.

9

The results indicate that sodium bromide, measured as bromine, is highly toxic to estuarine/marine organisms on an acute basis. The studies fulfill guideline requirements (72-3/OPPTS 850.1035, 850.1055, and 850.1075).

(4) Aquatic Organisms, Chronic

Chronic toxicity testing (Fish early life stage, 72-4a/OPPTS 850.1400 and aquatic invertebrate life cycle, 72-4b/OPPTS 850.1300) is required for pesticides when certain conditions of use and environmental fate apply. This testing is not required for bromine and sodium bromide. All of the currently registered uses of bromine are indoor applications for which there are no effluents. Chronic testing of sodium bromide is not required based on results of the residue monitoring studies that indicate that residues of sodium bromide (hypobromous acid) are short-lived and are highly toxic on an acute basis. In addition, the environmental fate assessment (see Environmental Fate Assessment Summary, Section IIA) prepared for bromine/sodium bromide shows that sodium bromide (hypobromous acid) is likely to degrade quickly in soil and water with ultimate biodegradation completed within a few weeks. Therefore, standard chronic toxicity tests would not provide meaningful and useful toxicity data and are waived.

(5) Actual Aquatic Field Residue Monitoring

Aquatic residues monitoring studies in freshwater and estuarine/marine are required by the Agency to determine the actual residues of sodium bromide, based on its industrial use in once-through cooling systems. Two studies were submitted to meet the requirements.

The first study (MRID 407570-01) was an EPA-sponsored study conducted at an electric power plant discharging to an estuarine/marine environment. A once-through cooling system is employed at the plant. This study was designed to examine bromine chloride as a potential substitute for chlorine when used in condenser cooling systems. Two 15-day trials were made using continuous dose rates of BrCl and Cl_2. Application rates were 510 and 135 ppb BrCl.

The results of this study indicate that the highest discharge residue (104 ppb, measured at the point of discharge) of bromine, as hypobromous acid, from an initial continuous application of 510 ppb, exceeds the level of concern (LOC-1/2 LC_{50}), based on the submitted studies, for the mysid shrimp, 90 ppb, and the sheepshead minnow, 95 ppb.

The second study (MRID 410641-01) was conducted at a wastewater treatment plant which discharges into a freshwater stream. The facility uses aeration followed by disinfection, and in this study, chlorine in the absence of bromide, and chlorine with bromide (from sodium bromide in both cases) were used in the disinfection.

The results of this study indicate that the highest bromine or hypobromous acid concentration (1081.6 ppb) in the effluent exceeds the LOCs for all freshwater aquatic species at

the point of discharge. Residue concentrations as high as 135.2 ppb were detected 80 meters downstream. Residues were no longer detectable between 80 and 130 meters downstream. By 130, 180, and 500 meters downstream, however, all effluent concentrations are below the LOCs for freshwater aquatic species.

The freshwater residue monitoring study is scientifically sound but does not fulfill all data requirements (supplemental study). However, when considered in conjunction with the EPA-sponsored study of 1977, both studies provide enough data on decline, dispersion, and persistence of hypobromous acid (or bromine) from sodium bromide when used with chlorine, or from bromine chlorine to fulfill all data requirements (72-7/OPPTS 850.1950).

C. Toxicity to Non-target Plants

Non-target plant toxicity testing is required for pesticides when certain conditions of use and environmental fate apply. The following testing is required for bromine and sodium bromide to support the once-through cooling tower use.

123-1/850.4225	Seedling emergence dose-response in rice	TEP
123-2/850.4400	Aquatic vascular plant dose-response toxicity – *Lemna* sp.	TGAI or TEP
123-2/850.5400	Acute algal dose-response toxicity – 4 species	TGAI or TEP

II. Risk Assessment and Characterization

Risk assessment integrates the results of the exposure and ecotoxicity data to evaluate the likelihood of adverse ecological effects. One method of integrating the results of exposure and ecotoxicity data is called the quotient method. For this method, risk quotients (RQs) are calculated by dividing exposure estimates by ecotoxicity values, both acute and chronic:

RQ = EXPOSURE/TOXICITY

RQs are then compared to OPP=s levels of concern (LOCs). These LOCs are criteria used by OPP to indicate potential risk to nontarget organisms and the need to consider regulatory action. The criteria indicate that a pesticide used as directed has the potential to cause adverse effects on nontarget organisms. LOCs currently address the following risk presumption categories: (1) **acute high** - potential for acute risk is high, and regulatory action may be warranted in addition to restricted use classification; (2) **acute restricted use** - the potential for acute risk is high, but this may be mitigated through restricted use classification; (3) **acute endangered species** - the potential for acute risk to endangered species is high, and regulatory action may be warranted; and (4) **chronic risk** - the potential for chronic risk is high, and regulatory action may be warranted. Currently, AD does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to mammalian or avian species.

11

The ecotoxicity test values (i.e., measurement endpoints) used in the acute and chronic risk quotients are derived from the results of required studies. Examples of ecotoxicity values derived from the results of short-term laboratory studies that assess acute effects are: (1) LC_{50} (fish and birds); (2) LD_{50} (birds and mammals); (3) EC_{50} (aquatic plants and aquatic invertebrates); and (4) EC_{25} (terrestrial plants). Examples of toxicity test effect levels derived from the results of long-term laboratory studies that assess chronic effects are: (1) LOEC (birds, fish, and aquatic invertebrates); (2) NOEC (birds, fish and aquatic invertebrates); and (3) MATC (Maximum Allowable Toxic Concentration) (fish and aquatic invertebrates). For birds and mammals, the NOEC value is used as the ecotoxicity test value in assessing chronic effects. Other values may be used when justified. Generally, the MATC (defined as the geometric mean of the NOEC and LOEC) is used as the ecotoxicity test value in assessing chronic effects to fish and aquatic invertebrates. However, the NOEC is used if the measurement endpoint is production of offspring or survival.

Risk presumptions, along with the corresponding RQs and LOCs are tabulated below.

Risk Presumptions for Terrestrial Animals

Risk Presumption	RQ	LOC
Birds and Wild Mammals		
Acute High Risk	EEC[1]/LC_{50} or LD_{50}/sqft[2] or LD_{50}/day[3]	0.5
Acute Restricted Use	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day (or LD_{50} < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.1
Chronic Risk	EEC/NOEC	1

[1] Abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

[2] $\frac{mg/ft^2}{LD_{50} * wt. of bird}$ [3] $\frac{mg\ of\ toxicant\ consumed/day}{LD_{50} * wt. of bird}$

Risk Presumptions for Aquatic Animals

Risk Presumption	RQ	LOC
Acute High Risk	EEC[1]/LC_{50} or EC_{50}	0.5
Acute Restricted Use	EEC/LC_{50} or EC_{50}	0.1
Acute Endangered Species	EEC/LC_{50} or EC_{50}	0.05
Chronic Risk	EEC/MATC or NOEC	1

[1] EEC = (ppm or ppb) in water

Risk Presumptions for Plants

Risk Presumption	RQ	LOC
Terrestrial and Semi-Aquatic Plants		
Acute High Risk	EEC[1]/EC_{25}	1
Acute Endangered Species	EEC/EC_{50} or NOEC	1
Aquatic Plants		
Acute High Risk	EEC[2]/EC_{50}	1
Acute Endangered Species	EEC/EC_{05} or NOEC	1

[1] EEC = lab ai/A
[2] EEC = (ppb/ppm) in water

A. Environmental Fate Assessment Summary (excerpted from the Environmental Fate Science Chapter of this RED document)

In 1993, the Agency issued a RED on Bromine (EPA document: EPA-738-F-93-023) in which it was stated: "The current use patterns of pesticide products containing bromine do not result in environmental exposure. Therefore, the RED includes no discussion of bromine's environmental fate." In the present RED environmental fate of both bromine and sodium bromide are being assessed together.

Bromine as bromide is found in seawater at 65 ppm level while in the earth's crust it is detected at 2.5 ppm level. (The elements by J. Emsley 1989, Oxford University press, pp 34-35), Its major antimicrobials use is as a disinfectant and all the registered uses are indoor.

Pure bromine exists as a liquid. In aqueous solution, it reacts with water instantaneously forming hydrobromic (HBr) acid and hypobromous acid (HOBr). The chemistry of bromine in water is, therefore, that of hydrobromic and hypobromous acids of bromide (Br^-) and hypobromide (OBr^-) species.

In the atmosphere it is moderately persistent and in water it can react with a number of cations ions to form bromides and or hypobromides. In can be moderately persistent in soils, although no experimental Kd are available to quantitatively assess binding with soils.

Henry Law Constant (HLC) for bromine is quite low (2.5×10^{-2} atm-m^3/mol) so it less likely to volatilize from aqueous medium to the air.

EPI Suite estimates that it is likely to biodegrade fast as is non-linear biodegradation.

Ultimate biodegradation in soils/water can probably take place within a few weeks.

Estimated Log K_{ow} value of 1.03 indicates that bromine is not likely to bioaccumulate in aquatic organisms.

In aqueous medium, the chemistry and fate of sodium bromide is going to be the same as bromide ion. When used, as a solid, its vapor pressure is very low (1.77×10^{-17} mm Hg) and is not likely to volatilize into the air when in aqueous medium.

EPI Suite estimated that it is likely to biodegrade fast in soil and water. Ultimate biodegradation can take place in few weeks.

Estimated Log K_{ow} of 0.63 is a strong indicator of little probability of bioaccumulation with aquatic organisms.

B. Environmental Exposure and Ecological Risk Assessment

Freshwater and estuarine/marine aquatic organisms could potentially be exposed to sodium bromide discharged into the aquatic environment. The Agency conducted modeling in 1993 and 2005 to estimate the exposure and environment risk resulting from such discharges.

(1) 1993 Tier Ic EEC Modeling

In 1993, the Agency conducted Tier Ic EEC modeling (preliminary or lower tier exposure assessment) for hypobromous acid. (Hypobromous acid is formed when sodium bromide is added to water and is the actual toxic agent). Tier Ic EEC modeling determines the maximum concentration likely to occur immediately downstream from an industrial (point source) discharge site. EECs were evaluated for both Ahigh exposure@ cases and Atypical@ sites. The calculated Ahigh exposure@ EEC, i.e., cases of extreme exposure, for hypobromous acid as bromine for all sites tested was 450 ppb (0.45 ppm). This result is comparable with the previously mentioned residue monitoring studies, which showed high concentrations of hypobromous acid as far downstream as 80 meters. The EECs for typical sites ranged from 0.38 ppb to 0.75 ppb (0.00038 to 0.00075 ppm).

RQ values are calculated using the predicted surface water EECs and measured endpoints derived from the results of required studies. The resultant RQs are then compared to the LOCs. The results are presented in the following tables for freshwater organisms (Table 7) and estuarine/marine organisms (Table 8).

Table 7. Acute Risk Quotients for Freshwater Organisms

Species	High Exposure			Typical Exposure		
	LC_{50} (ppm)	EEC (ppm)	RQ (EEC/LC_{50})	LC_{50} (ppm)	EEC (ppm)	RQ (EEC/LC_{50})
Rainbow Trout *(Salmo gairdner)*	0.31	0.45	1.45(a)	0.31	0.00038 to 0.00075	0.00122 to 0.00242
Bluegill Sunfish *(Lepomis macrochirus)*	0.52	0.45	0.87(a)	0.52	0.00038 to 0.00075	0.000731 to 0.00144
Waterflea *(Daphnia magna)*	1.07	0.45	0.42(b)	1.07	0.00038 to 0.00075	0.000355 to 0.000701

a = high risk, restricted use and endangered species LOCs have been exceeded.
b = restricted use and endangered species LOCs have been exceeded.
c = endangered species LOC has been exceeded.
d = none of the LOCs have been exceeded.

Table 8. Acute Risk Quotients for Estuarine/Marine Organisms

Species	High Exposure			Typical Exposure		
	LC_{50} (ppm)	EEC (ppm)	RQ (EEC/LC_{50})	LC_{50} (ppm)	EEC (ppm)	RQ (EEC/LC_{50})
Sheepshead minnow *(Cyprinodon variegatus)*	0.19	0.45	2.37(a)	0.19	0.00038 to 0.00075	0.00200 to 0.00395
Mysid shrimp *(Mysidopsis bahia)*	0.18	0.45	2.50(a)	0.18	0.00038 to 0.00075	0.00210 to 0.00417
Easter oyster *(Crassostrea virginica)*	0.47	0.45	0.96(a)	0.47	0.00038 to 0.00075	0.000809 to 0.001600

a = high risk, restricted use and endangered species LOCs have been exceeded.
b = restricted use and endangered species LOCs have been exceeded.
c = endangered species LOC has been exceeded.
d = none of the LOCs have been exceeded.

The results for high exposure sites indicate that the RQs exceed all of the LOCs for freshwater fish (rainbow trout and bluegill sunfish) and for estuarine/marine organisms (sheepshead minnow, mysid shrimp, and eastern oyster), but not for the freshwater invertebrate *Daphnia magna*. Therefore, the Agency presumes high risk to freshwater fish and estuarine/marine organisms at the point of discharge and downstream to 80 meters. However, the results for Atypical@ sites show that the RQs are well below all of the LOCs for both freshwater and estuarine/marine organisms. This would indicate that hypobromous acid can be used at typical sites most of the time, without producing effluents above LOCs. Since the discharge of hypobromous acid is limited by the NPDES permit program, the Agency will be able to control the discharge of hypobromous acid on a site-by-site basis so that toxic levels are avoided.

(2) 2005 Probabilistic Dilution Modeling

The PDM4 Model was used to estimate exposure from once-through cooling tower uses. The details of this model are found in the Environmental Modeling Chapter of this document. A high-flow power plant (1000 $\pm$ 10 million gallons per day) was used as the scenario providing the maximum concentrations of bromide in the receiving water, e.g., the Aworst case@ scenario. It was assumed that the chemical was being applied at the highest listed rate shown on any of the sodium bromide product labels, and that all bromide was converted to available bromine. Actual concentrations in receiving waters are likely lower, and will likely not show the increasing trend indicated in Table 9, due to higher flow rates, lower conversion rate to available bromine, and possible degradation/dissipation of available bromine by mechanisms other than hydrolysis. A summary of concentrations over time is provided in Table 9. The concentrations selected for analysis were the measured endpoints derived from the results of the required studies (see Section I.B.)

The probability associated with exceedence once per year is 1/365 = 0.274%. Therefore, in any given year, the two-day peak concentration of bromide in rivers receiving the discharge of once-through cooling waters is expected to be less than 0.11 ppm. In any given year, the four-day peak concentration is expected to be less than 0.037 ppm.

Table 9. Percent Probability of Exceedence of Bromine in Rivers Receiving Discharge from Low-Flow Power Plants Using Once-Through Cooling Systems

Concentrations (ppm as bromine)	Probability Of Continuous Exceedence Over:	
	2 Days	4 Days
0.037	2.62	0.0689
0.068	0.787	0.00619
0.1	0.314	0.000983
0.11	0.246	0.000605
0.18	0.0645	0.0000416
0.19	0.0552	0.0000305
0.3	0.0144	0.00000207
0.31	0.0130	0.00000169
0.47	0.00362	0.000000131
0.52	0.00262	0.0000000687
1.07	0.000213	0.000000000454

C. Endangered Species Considerations

The Agency has developed the Endangered Species Protection Program to identify pesticides whose use may cause adverse impacts on endangered and threatened species and to implement mitigation measures that address these impacts. The Endangered Species Act requires federal agencies to ensure that their actions are not likely to adversely affect individuals of listed species or adversely modify designated critical habitat. To analyze the potential of registered pesticide uses to affect any particular species, EPA puts basic toxicity and exposure data developed for risk assessments into context for individual listed species and their locations by evaluating important ecological parameters, pesticide use information, the geographic relationship between specific pesticide uses and species locations, and biological requirements and behavioral aspects of the particular species. A determination that there is a likelihood of potential impact to a listed species may result in limitations on use of the pesticide, other measures to mitigate any potential impact, or consultations with the Fish and Wildlife Service and/or the National Marine Fisheries Service as necessary.

The PDM4 Model was used to estimate exposure from once-through cooling tower uses (see Environmental Modeling Chapter of this document). The endangered species risk assessment for a typical use of bromine and bromine chloride (hypobromus acid) did not result in any LOC exceedences for terrestrial or aquatic animals. Therefore, bromine and sodium bromide are not expected to adversely affect endangered/threatened terrestrial or aquatic animal species or critical habitat (NLAA) under typical use conditions. A risk assessment was not conducted for non-target plants due to the absence of toxicity data.

A high-flow power plant (1000 $\pm$ 10 million gallons per day) that discharges into a low-flow surface stream was modeled as a "worst case" scenario in order to predict a maximum concentration of bromide in receiving water. The model assumed the chemical was applied at the highest registered label dosage and that all bromide was converted to available bromine. The probability of a high exposure scenario is extremely low, however, the results indicate that LOCs are exceeded for aquatic animals: freshwater fish (rainbow trout and bluegill sunfish) and for estuarine/marine organisms (sheepshead minnow, mysid shrimp, and eastern oyster), except for the freshwater invertebrate *Daphnia magna*. Therefore, the Agency presumes high risk to freshwater fish and estuarine/marine organisms at the point of discharge from a high-flow plant and downstream to 80 meters.

This modeling would indicate that hypobromous acid can be used at typical sites most of the time, without producing effluents above LOCs. Since the discharge of hypobromous acid is limited by the NPDES permit program, the Agency will be able to control the discharge of hypobromous acid on a site-by-site basis so that toxic levels are avoided. Other options include a reduction of the maximum label dosage and/or reduced hypobromous acid use by high-flow plants during periods of low water flow.

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Sign-off Date : 07/14/05
DP Barcode No. : D315376