Copy No._______

Defence Research and Development Canada | Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

Bilge Water Characterization of CF Ships

Gary Fisher

Philippe Nault

Defence R&D Canada – Atlantic

Technical Memorandum

DRDC Atlantic TM 2005-249

August 2006

Canada

This page intentionally left blank.

Bilge Water Characterization of CF Ships

Gary Fisher

Philippe Nault

Defence R&D Canada – Atlantic

Technical Memorandum

DRDC Atlantic TM 2005-249

August 2006

Author

Gary Fisher

Gary Fisher

Approved by

Calvin Hyatt

Calvin Hyatt

Head Emerging Materials Section

Approved for release by

Cheryl L Munroe, A/Chair

pp Kirk Foster

DRP Chair

The information contained herein has been derived and determined through best practice and adherence to the highest levels of ethical, scientific, and engineering investigative principles. The reported results, their interpretation, and any opinions expressed therein, remain those of the authors and do not represent, or otherwise reflect, any official opinion or position of DND or the Government of Canada.

Abstract

Liquid collected in the bilge spaces of four different classes of CF ships were sampled and analyzed for pH and the content of hydrocarbons and various metals. The results were compared to acceptable water quality criteria for waste disposal via municipal sewer. Significant failure rates (> 10%) were observed for pH, hydrocarbon content and concentrations of copper and zinc. These results are comparable to previous studies of bilge water content on Canadian and American military vessels.

Résumé

Le liquide accumulé dans le fond de cale de quatre classes différentes de navire des FC a été échantillonné et analysé pour en déterminer le pH et la teneur en hydrocarbures et en métaux divers. Les résultats étaient comparés aux critères de qualité appliqués à l'élimination des déchets par voie d'égouts municipaux. D'importants taux de défaillance (> 10 %) ont été constatés au niveau du pH et des concentrations de cuivre et de zinc. Ces résultats sont comparables à ceux des études effectuées antérieurement sur le contenu de l'eau de cale de navires militaires canadiens et américains.

This page intentionally left blank.

Executive summary

Background: The bilge spaces of vessels have always been used to collect waste water, oils, detergents and other liquids generated during shipboard machinery operation and maintenance. Historically, when the level of fluid in the space was sufficient it was jettisoned by onboard bilge pumps. It is now recognized that introduction of such wastes into marine or inland waters presents a significant environmental problem. Modern vessel fleets, including the CF, therefore utilize numerous methods to both reduce the volume and hazardous content of generated bilge water and to eliminate its entry into waterways.

Despite these efforts bilge water can enter the environment through either inadvertent releases or through catastrophic events such as hull ruptures or ship loss. The environmental damage caused by such releases and the subsequent clean-up and remediation of the affected ecosystems depends on the composition of the released waste. Knowledge of bilge water composition at the instance of release is not practical as it will vary depending on operations, ship class and the efficiency of ship husbandry for the affected crew. DND therefore commissioned a characterization study to determine the composition of bilge waters from various operational ships.

Principal Results: Twenty-three (23) bilge spaces taken from 6 ships representing 4 ship classes were studied. Their composition was compared to municipal legislation governing disposal of wastewater via municipal sewer. The results indicate that hydrocarbon and zinc content exceeds municipal sewer disposal regulations in at least 50% of bilge spaces. Hydrocarbons in bilge spaces likely arise from lubricants leaks and accidental releases and machinery maintenance and cleaning operations. Zinc content may be related to the use of sacrificial zinc anodes, degradation of galvanized steel or paint coatings on the bilge spaces. Zinc metal is the coating placed on steel during the process of galvanization and zinc primers are often used as base coats for paint coverings over steel.

A significant percentage of bilge spaces also failed copper content and pH. Copper alloys would be expected to be used in many marine vessel spaces that are anticipated to encounter seawater. In all of pH failures the obtained value was acidic. This may be due to improper disposal of acidic cleaning agents.

Significance of Results: Knowledge of bilge water composition can facilitate assessment of environmental damage and subsequent mitigation efforts. As the bilge space samples were collected at the end of an operational period they represent a “worst-case scenario” snapshot of bilge water composition. The data may then be used to assess the extent of damage and plan appropriate clean-up actions in the event of accidental or catastrophic bilge water releases.

Fisher, Gary & Nault, SLt. 2006. Bilge Characterization of CF Ships. DRDC Atlantic TM 2005-249. Defence Research & Development Canada – Atlantic.

Sommaire

Contexte : Le fond de cale d'un navire a toujours servi à recueillir des eaux usées, des huiles, des détergents et d'autres liquides provenant de l'exploitation et de l'entretien des machines à bord du navire. D'habitude, lorsque le fluide dans la cale atteint un certain niveau, on le jette à la mer à l'aide de pompes de cale embarquées. Il est convenu maintenant que l'infiltration de déchets de ce genre dans les eaux de mer ou les eaux intérieures pose un sérieux problème environnemental. Aussi les flottes de navires modernes, y compris celles des FC, adoptent-elles de nombreuses méthodes pour réduire le volume et le contenu nocif de l'eau de cale et empêcher en même temps l'infiltration de celle-ci dans les voies d'eaux.

Malgré ces efforts, l'eau de cale peut s'infiltrer dans l'environnement soit par rejets accidentels soit à cause d'événements catastrophiques comme les ruptures de coque ou la perte de navire. Les dommages causés à l'environnement par ce genre de rejets ainsi que le nettoyage et le redressement de l'écosystème altéré dépendent de la composition des déchets rejetés. Toutefois, la connaissance de la composition de l'eau de cale au moment du rejet est inutile, car cette composition varie selon les opérations, la classe du navire et l'efficacité des travaux d'entretien et de propreté. Le MDN a par conséquent commandé une étude de caractérisation afin de déterminer la composition des eaux de cale de différents navires opérationnels.

Résultats principaux : Vingt-trois (23) fonds de cale provenant de six navires représentant quatre classes de navire sont étudiés. Leur composition est comparée aux critères des règlements et arrêtés municipaux régissant l'élimination des déchets par voie d'égouts municipaux. Les résultats indiquent que pour au moins 50 % des fonds de cale, la teneur en hydrocarbures et en zinc dépasse celle recommandée par les règlements municipaux sur élimination des déchets. Les hydrocarbures des fonds de cale proviennent probablement de fuites de lubrifiants, de rejets accidentels ainsi que des activités d'entretien et de nettoyage des machines. La teneur en zinc peut être liée à l'utilisation d'anodes sacrificielles en zinc, à la dégradation de l'enduit d'acier galvanisé ou des peintures tapissant les fonds de cale. Le métal de zinc est l'enduit qui sert à recouvrir l'acier lors de la galvanisation, et des apprêts de zinc sont utilisés comme couches de fond pour les peintures appliquées sur acier.

Un pourcentage élevé de fonds de cale ont aussi failli quant à la teneur en cuivre et au pH. Le fond de cale de nombreux navires prévus pour être en contact avec l'eau de mer contiendraient sans doute des alliages de cuivre. Concernant le pH, les valeurs obtenues indiquent que l'eau est acide, ce qui probablement est dû à la mauvaise élimination des produits de nettoyage acides.

Importance des résultats : La connaissance de la composition de l'eau de cale peut faciliter l'évaluation des dommages causés à l'environnement et les efforts pour réduire ces derniers plus tard. Comme les échantillons de fonds de cale étaient prélevés à la fin d'une période opérationnelle, ils représentent le pire des scénarios en ce qui concerne la composition de l'eau de cale. Les données peuvent donc servir à évaluer la

gravité des dommages et à planifier des opérations de nettoyage appropriées en cas de rejets accidentels ou catastrophiques d’eau de cale.

Fisher, Gary & Nault, SLt. 2006. Bilge Characterization of CF Ships. DRDC Atlantic TM 2005-249. Defence Research & Development Canada – Atlantic.

Table of contents

List of tables

This page intentionally left blank.

1. Introduction

The bilge spaces of vessels have always been used to collect waste water, oils, detergents and other liquids generated during shipboard machinery operation and maintenance. Historically, when the level of fluid in the space was sufficient it was jettisoned by onboard bilge pumps. It is now recognized that introduction of such wastes into marine or inland waters presents a significant environmental problem. Modern vessel fleets, including the CF, therefore utilize numerous methods to both reduce the volume and hazardous content of generated bilge water and to eliminate its entry into waterways.

Despite these efforts bilge water can enter the environment through either inadvertent releases or through catastrophic events such as hull ruptures or ship loss. The environmental damage caused by such releases and the subsequent clean-up and remediation of the affected ecosystems depends on the composition of the released waste. Knowledge of bilge water composition at the instance of release is not practical as it will vary depending on operations, ship class and the efficiency of ship husbandry for the affected crew.

DND therefore commissioned a characterization study to determine the composition of bilge waters from various operational ships. The intent was to determine the composition of the waters at the end of an operational period as this would likely represent a “worst-case scenario”. The data could then be used to assess the extent of damage and plan appropriate clean-up actions in the event of accidental or catastrophic bilge water releases.

In the 1990s the US DOD and EPA conducted numerous studies to characterize bilge water from military vessels as part of Phase I of the Uniform National Discharge Standards (UNDS) [1-3]. While bilge water composition was found to vary somewhat according to ship class, the results showed that bilge water typically contained hydrocarbons, various metals and some organic compounds. One detailed study of bilge water effluent from an aircraft carrier [4] indicated that the concentration of Total Petroleum Hydrocarbons, copper, iron, nickel and zinc exceed American Federal Acute Water Quality Criteria on a more than infrequent basis. Other parameters, such as measures of reactivity (BOD and COD) and concentrations of various inorganic and organic species, were consistently below federal guidelines.

Similar results were obtained in an examination of bilge water from CF ships, completed in 1999 [5]. The only parameters that exceeded applicable water quality guidelines were metallic elements (cadmium and zinc in this study) and total hydrocarbons. Therefore this study focused on measuring concentrations of metallic constituents and total hydrocarbons.

2. Procedures and Equipment

CF ships recently returned from operational duty were identified by Formation Safety and Environment (FSE) and their bilge spaces sampled using commercial drum samplers. Drum samplers enable depth profiling of a liquid and therefore a representative sample of both the aqueous and non-aqueous portions of the bilge could be included in a single sample.

Each sample was separated into aqueous and non-aqueous components and the volume of each component measured. Other than this determination of the percentage of hydrocarbon present in the bilge space, no further analysis of the non-aqueous component was conducted.

The pH of the aqueous component was measured using an Accumet AP85 meter. Approximately 1 mL of nitric acid was added to the aqueous component and metal content determined using an Agilent 7500ce inductively coupled plasma – mass spectrometer (ICP-MS). Instrument parameters are detailed in Table 1. A 1 part per billion (ppb) solution of yttrium was used as an internal standard to correct for instrument response fluctuations.

Table 1. *ICP-MS instrument parameters*

PARAMETER	VALUE
Plasma gas flow	15 L/min
Carrier gas flow	0.8 (0.9*) L/min
Make-up gas flow	0.24 (0.17*) L/min
Reaction gas flow	2.4 mL/min
RF power	1500 W
Sampling depth	8.5 mm
Cones	platinum
* - condition when reaction cell utilized	

ICP-MS is, compared to other spectroscopic techniques, relatively free of spectral or background interferences. However, metastable polyatomic species can form in the plasma, particularly in samples that have high dissolved solids content. Some of these species have the same mass as analyte elements. For example, $^{40}Ar^{16}O$ has an atomic mass of 56 atomic mass units (amu) which is the same mass as the major isotope of iron (^{56}Fe). Such interferences can be handled by either selecting a different isotope of the analyte (^{57}Fe, for example) or by elimination of the polyatomic species before it enters the mass spectrometer. In this work, elimination of polyatomic species was accomplished by introduction of either H_2 or He gas into a small reaction chamber situated between the cones and mass spectrometer. H_2 destroys some polyatomics via chemical reaction while He provides a kinetic barrier that suppresses the introduction of large radii polyatomics into the mass spectrometer relative to the amount of small radii monoatomic species. Table 2 identifies the isotopes that were analyzed in this work and, where appropriate, details which reaction gas was used for suppression of polyatomic interference.

Table 2. *Isotopes analyzed*

ELEMENT	ISOTOPE	REACTION GAS	POLYATOMIC INTERFERENCE
Aluminum	^{27}Al	None	
Antimony	^{121}Sb	None	
Arsenic	^{75}As	Helium	$^{40}Ar^{35}Cl$
Beryllium	^{9}Be	None	
Bismuth	^{209}Bi	None	
Boron	^{11}B	None	
Cadmium	^{111}Cd	None	
Caesium	^{133}Cs	None	
Chromium	^{53}Cr	None	
Cobalt	^{59}Co	None	
Copper	^{63}Cu	None	
Gallium	^{69}Ga	None	
Indium	^{115}In	None	
Iron	^{56}Fe	Hydrogen	$^{40}Ar^{16}O$
Lead	^{208}Pb	None	
Lithium	^{7}Li	None	
Manganese	^{55}Mn	None	
Molybdenum	^{95}Mo	None	
Nickel	^{60}Ni	None	
Selenium	^{82}Se	Hydrogen	$^{41}Ar_2$
Silver	^{107}Ag	None	
Strontium	^{88}Sr	None	
Thallium	^{205}Tl	None	
Tin	^{118}Sn	None	
Titanium	^{47}Ti	None	
Uranium	^{238}U	None	
Vanadium	^{51}V	Helium	$^{35}Cl^{16}O$
Zinc	^{66}Zn	None	

3. Results and Discussion

The results will be presented by CF Ship Class. Some elements (Cs, Ga, In, Tl and U) were not detected in any of the bilge samples. Due to space constraints, these elements were not included in the discussion below. Detection limits for these elements would be less than 0.1 ppb.

Regulatory limits on the concentration of species in bilge water are governed by the International Convention for the Prevention of Pollution from Ships (MARPOL) established by the International Maritime Organization (IMO) in 1973. The MARPOL regulations have since been frequently modified and these modifications are reflected in the *Canada Shipping Act* [6]. Current MARPOL regulations restrict discharge of classes of species either by geographic area or in terms of the species concentration as measured in the ship's wake when travelling at a specified velocity. For example, MARPOL regulations restrict the amount of a Category B noxious species that may be discharged from a Ship to the amount necessary to ensure that the concentration of the species remains below 1 part per million (ppm) when measured in the wake astern of the ship while travelling at a speed of at least 7 knots. Such regulatory limits do not facilitate comparison of static bilge water species concentrations, as determined in this study.

Current bilge water disposal practice involves contractor pumping of bilge spaces and subsequent treatment of the effluent to ensure compatibility with limitations imposed by the wastewater disposal By-Law of the Halifax Regional Municipality [7]. These limits are utilized in the discussion below. Species concentrations that exceed the municipal limits are shown in bold text in the appropriate Table.

For comparison purposes, three other regulatory limits are shown in the Tables. These are the Canadian Council of Ministers of the Environment (CCME) guidelines for Marine Aquatic Life (MAL) and Fresh Water Aquatic Life (FWAL) [8] and the limits for non-potable ground water established under the Environmental Protection Act of the Province of Ontario [9]. While none of these regulatory guidelines are strictly valid for bilge water in a marine setting, they are illustrative.

In the following sections bilge spaces are identified by acronyms. Explanation of these acronyms can be found in the List of Abbreviations on page 25.

3.1 Halifax Class

Bilge spaces from three Halifax Class ships, HMCS VILLE DE QUEBEC, HMCS MONTREAL and HMCS TORONTO, were sampled. Table 3 shows the percentage hydrocarbon content of these respective bilges. On the day of sampling, the Oily Water bilge space on HMCS MONTREAL and HMCS TORONTO was either dry or contained insufficient fluid to permit sampling.

Table 3. *Hydrocarbon content of Halifax Class bilge waters.*

SHIP	CONCENTRATION (%)			
	FAMR	**AAMR**	**FER**	**OILY WATER**
HMCS VILLE DE QUEBEC	5.9	51	8.1	88
HMCS MONTREAL	0.6	47	2.5	NS
HMCS TORONTO	50	100	16	NS

The limit on Total Oil and Grease (mineral/synthetic) permitted by HRM for discharge to a wastewater facility is 15 ppm [7]. The bilge space that had the lowest concentration of hydrocarbon (FAMR on HMCS MONTREAL) contained 0.6%, or 6000 ppm. Thus, all of the bilge spaces on Halifax Class ships contained a higher concentration of hydrocarbon than would be permitted for disposal via a municipal sewer.

The pH and concentration of metallic elements found in the aqueous portions of the bilge waters from these ships are shown in Tables 4-6 inclusive, along with the various regulatory limits. Values that exceed the municipal wastewater disposal limits are highlighted in bold text. Note that values for the AAMR bilge space on HMCS TORONTO are not shown, as no water was found in this space.

The results indicate that the FAMR bilge spaces on both HMCS MONTREAL and HMCS TORONTO and the FER space on HMCS MONTREAL contained metallic species concentrations above the municipal limit. Further, the pH of the water in the FAMR on HMCS TORONTO was well below the acceptable range. No exceedances were observed in the HMCS VILLE DE Quebec spaces.

The elevated metal concentrations were for copper, nickel and zinc. All three of these elements are commonly used in marine machinery equipment. Their presence may be indicative of recent cleaning operations involving such equipment.

The pH of the FAMR space on HMCS TORONTO was found to be 2.45. Such a pH can only have been caused by ingress of an acidic species into the space. Most cleaning chemicals used onboard the ships (Reverse Osmosis Device {ROD} cleaning chemicals, engine washes, general detergents, etc.) are alkaline or neutral and, thus, could not be responsible for the observed acidic value. However, some cleaning chemicals, such as toilet bowl cleaners or wax strippers, are acidic and may be the culprit.

Table 4. *HMCS VILLE DE QUEBEC bilge waters.*

PARAMETER	CONCENTRATION (PPB)							
	REGULATORY LIMITS				MEASURED			
	HRM	MAL	FWAL	O REG	FAMR	AAMR	FER	OILY WATER
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	6.75	6.72	7.48	5.85
Aluminum	50,000	-	100	-	150	2900	210	240
Antimony	5000	-	-	16,000	2.1	3.8	7.7	2.1
Arsenic	1000	12.5	5.0	480	< 0.1	23	4.4	9.1
Beryllium	5000	-	-	53	130	110	160	77
Boron	-	-	-	50,000	1900	5000	2500	3000
Cadmium	1000	0.12	0.017	11	12	25	5.1	10
Chromium	2000	56[a]	8.9[a]	2000	52	180	97	73
Cobalt	5000	-	-	100	1.6	2.3	7.4	3.7
Copper	1000	-	4.0	23	560	680	550	380
Iron	50,000	-	300	-	6900	5400	2400	8800
Lead	1000	-	7	32	520	25	44	170
Lithium	-	-	-	-	56	160	79	94
Manganese	5000	-	-	-	320	460	620	450
Molybdenum	5000	-	73	7300	29	11	7.1	4.6
Nickel	2000	-	150	1600	54	78	350	330
Selenium	1000	-	1.0	50	83	300	130	140
Silver	2000	-	0.1	1.2	< 0.1	< 0.1	< 0.1	< 0.1
Strontium	-	-	-	-	1600	4500	2000	2700
Tin	5000	-	-	-	< 0.1	< 0.1	< 0.1	< 0.1
Titanium	5000	-	-	-	< 0.1	7.6	< 0.1	< 0.1
Vanadium	5000	-	-	200	11	50	22	19
Zinc	2000	-	30	1100	1100	890	970	980

Table 5. *HMCS MONTREAL bilge waters.*

PARAMETER	CONCENTRATION (PPB)						
	REGULATORY LIMITS				MEASURED		
	HRM	**MAL**	**FWAL**	**O REG**	**FAMR**	**AAMR**	**FER**
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	5.93	9.04	6.90
Aluminum	50,000	-	100	-	138	110	780
Antimony	5000	-	-	16,000	4.0	4.2	7.3
Arsenic	1000	12.5	5.0	480	0.7	14	1.9
Beryllium	5000	-	-	53	32	64	120
Boron	-	-	-	50,000	1500	3200	2200
Cadmium	1000	0.12	0.017	11	60	< 0.1	98
Chromium	2000	56[a]	8.9[a]	2000	45	110	86
Cobalt	5000	-	-	100	15	2.4	32
Copper	1000	-	4.0	23	**2200**	630	**1600**
Iron	50,000	-	300	-	14,000	4900	13,000
Lead	1000	-	7	32	83	8.9	72
Lithium	-	-	-	-	62	150	64
Manganese	5000	-	-	-	3000	82	2800
Molybdenum	5000	-	73	7300	7.0	17	7.3
Nickel	2000	-	150	1600	**3500**	250	1300
Selenium	1000	-	1.0	50	89	200	84
Silver	2000	-	0.1	1.2	< 0.1	< 0.1	< 0.1
Strontium	-	-	-	-	1900	3200	1800
Tin	5000	-	-	-	13	< 0.1	< 0.1
Titanium	5000	-	-	-	< 0.1	1.6	< 0.1
Vanadium	5000	-	-	200	8.7	30	14
Zinc	2000	-	30	1100	4300	640	**7800**

Table 6. *HMCS TORONTO bilge waters.*

PARAMETER	CONCENTRATION (PPB)					
	REGULATORY LIMITS			MEASURED		
	HRM	MAL	FWAL	O REG	FAMR	FER
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	**2.45**	6.52
Aluminum	50,000	-	100	-	710	300
Antimony	5000	-	-	16,000	2.6	1.9
Arsenic	1000	12.5	5.0	480	14	3.2
Beryllium	5000	-	-	53	89	140
Boron	-	-	-	50,000	4200	1900
Cadmium	1000	0.12	0.017	11	5.3	< 0.1
Chromium	2000	56[a]	8.9[a]	2000	140	65
Cobalt	5000	-	-	100	5.5	4.6
Copper	1000	-	4.0	23	**3500**	330
Iron	50,000	-	300	-	15,000	2800
Lead	1000	-	7	32	58	20
Lithium	-	-	-	-	130	60
Manganese	5000	-	-	-	1000	570
Molybdenum	5000	-	73	7300	9.1	9.0
Nickel	2000	-	150	1600	1100	170
Selenium	1000	-	1.0	50	200	100
Silver	2000	-	0.1	1.2	< 0.1	6.4
Strontium	-	-	-	-	3900	1400
Tin	5000	-	-	-	< 0.1	< 0.1
Titanium	5000	-	-	-	2.5	< 0.1
Vanadium	5000	-	-	200	33	17
Zinc	2000	-	30	1100	**7200**	820

3.2 Protecteur Class

Three bilge spaces on HMCS PRESERVER, starboard ATR, after ER and bow thrusters compartments, were sampled. Negligible amounts of hydrocarbons were found in any of the spaces. The pH and elemental content of the three samples are shown in Table 7.

The bow thruster sample was found to contain copper in a concentration above the municipal limit and the after ER space contained excess amounts of copper, lead and zinc. Once again, copper and zinc are metals used in many marine industrial components.

The excessive concentration of lead however, requires more explanation. While not above the legal limit, it should be noted that the after ER bilge water also contains a significant concentration (520 ppb) of tin. Tin and lead are used together in many solders. Improper disposal of soldering wastes could have attributed to these results. Another possibility includes lead-tin-antimony alloys that are often used as bearings, colloquially referred to as “white metal bearings”. The results indicate that the antimony concentration in this space was an order of magnitude higher than seen in other spaces on the ship.

Table 7. *HMCS PRESERVER bilge waters.*

PARAMETER	CONCENTRATION (PPB)						
	REGULATORY LIMITS				MEASURED		
	HRM	MAL	FWAL	O REG	STBD ATR	BOW THRTR	AFT ER
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	5.74	6.67	5.94
Aluminum	50,000	-	100	-	278	120	130
Antimony	5000	-	-	16,000	2.4	3.8	18
Arsenic	1000	12.5	5.0	480	< 0.1	8.3	< 0.1
Beryllium	5000	-	-	53	160	82	< 0.1
Boron	-	-	-	50,000	3300	3000	540
Cadmium	1000	0.12	0.017	11	2.4	7.6	28
Chromium	2000	56[a]	8.9[a]	2000	26	75	20
Cobalt	5000	-	-	100	2.6	7.8	5.6
Copper	1000	-	4.0	23	660	**1200**	**1900**
Iron	50,000	-	300	-	3300	3100	2500
Lead	1000	-	7	32	16	80	**1700**
Lithium	-	-	-	-	32	120	11
Manganese	5000	-	-	-	510	820	160
Molybdenum	5000	-	73	7300	3.8	36	9.4
Nickel	2000	-	150	1600	57	280	29
Selenium	1000	-	1.0	50	28	150	< 0.1
Silver	2000	-	0.1	1.2	< 0.1	10	< 0.1
Strontium	-	-	-	-	580	3300	8.2
Tin	5000	-	-	-	< 0.1	< 0.1	520
Titanium	5000	-	-	-	< 0.1	< 0.1	< 0.1
Vanadium	5000	-	-	200	3.9	19	0.7
Zinc	2000	-	30	1100	1600	1500	**7200**

3.3 Victoria Class

Four bilge spaces (ATP, mast well, auxiliary machinery space, and engine room) were sampled on HMCS WINDSOR. The percentage of hydrocarbon found in each sample is shown in Table 8. Only the AMS space had a hydrocarbon content below the acceptable limit for disposal via municipal sewer (15 ppm).

The pH and elemental concentrations of the aqueous phases of the bilge samples are shown in Table 9. The ATP and engine room spaces contain significant concentrations of zinc. While the ATP sample also marginally failed copper content (1100 ppb), the general lack of elevated concentrations of other common metals suggests a unique source of zinc. One possibility is the use of sacrificial zinc anodes in the spaces to prevent corrosion damage.

Table 8. *Hydrocarbon content of HMCS WINDSOR bilge waters.*

SHIP	CONCENTRATION (%)			
	ATP	MAST WELL	AMS	ER
HMCS WINDSOR	19	1.6	0	62

3.4 Kingston Class

Six bilge spaces on HMCS MONCTON were sampled. The spaces sampled were the FAMR, AMMR, FMMR port, FMMR starboard, the Z-drive compartment and the black water compartment. Negligible amounts of hydrocarbon were found in all spaces except the Z-drive, which contained 7% hydrocarbon.

The pH and metal content of the aqueous phases of the samples are detailed in Table 10. All of the spaces contained a concentration of zinc at or in excess of the municipal limit. The zinc concentration in four of the spaces (forward, port and starboard machinery rooms and the Z-drive) is suggestive of the use of zinc anodes for corrosion protection.

Two of the spaces (port and starboard machinery room) contained elevated copper while the Z-drive contained manganese at the municipal limit. Three of the spaces (aft, port and starboard machinery rooms) also exhibited a pH less than the acceptable municipal range.

Table 9. *HMCS WINDSOR bilge waters.*

PARAMETER	CONCENTRATION (PPB)							
	REGULATORY LIMITS				MEASURED			
	HRM	MAL	FWAL	O REG	ATP	MAST WELL	AMS	ER
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	6.36	6.73	6.43	**5.38**
Aluminum	50,000	-	100	-	170	380	94	160
Antimony	5000	-	-	16,000	49	< 0.1	< 0.1	32
Arsenic	1000	12.5	5.0	480	22	31	8.0	16
Beryllium	5000	-	-	53	110	89	100	130
Boron	-	-	-	50,000	4400	5400	2600	4300
Cadmium	1000	0.12	0.017	11	< 0.1	< 0.1	< 0.1	< 0.1
Chromium	2000	56[a]	8.9[a]	2000	140	230	80	150
Cobalt	5000	-	-	100	12	2.1	1.7	21
Copper	1000	-	4.0	23	**1100**	660	660	540
Iron	50,000	-	300	-	13,000	3200	3800	4600
Lead	1000	-	7	32	6.5	7.4	32	5.7
Lithium	-	-	-	-	330	210	94	150
Manganese	5000	-	-	-	630	440	73	330
Molybdenum	5000	-	73	7300	17	2.7	5.3	40
Nickel	2000	-	150	1600	260	56	57	430
Selenium	1000	-	1.0	50	240	370	150	240
Silver	2000	-	0.1	1.2	< 0.1	< 0.1	< 0.1	< 0.1
Strontium	-	-	-	-	4400	7300	3300	4500
Tin	5000	-	-	-	< 0.1	< 0.1	< 0.1	< 0.1
Titanium	5000	-	-	-	47	9.0	< 0.1	< 0.1
Vanadium	5000	-	-	200	42	58	23	34
Zinc	2000	-	30	1100	**38,000**	610	1500	**12,000**

Table 10. *HMCS MONCTON bilge waters.*

PARAMETER	CONCENTRATION (PPB)									
	REGULATORY LIMITS				MEASURED					
	HRM	MAL	FWAL	O REG	FAMR	AMMR	FMMR PORT	FMMR STBD	Z DRIVE	BWC
pH	5.5 – 9.5	7.0 – 8.7	6.5 – 9.0	-	6.29	**5.38**	**5.11**	**4.55**	5.75	5.59
Aluminum	50,000	-	100	-	74	360	450	150	97	170
Antimony	5000	-	-	16,000	3.5	3.3	1.0	1.0	< 0.1	0.7
Arsenic	1000	12.5	5.0	480	< 0.1	2.9	21	2.4	< 0.1	< 0.1
Beryllium	5000	-	-	53	150	150	100	160	95	100
Boron	-	-	-	50,000	1400	1800	3800	1400	1400	660
Cadmium	1000	0.12	0.017	11	< 0.1	10	34	180	< 0.1	16
Chromium	2000	56[a]	8.9[a]	2000	18	55	130	39	23	13
Cobalt	5000	-	-	100	5.4	20	7.9	8.6	9.7	1.2
Copper	1000	-	4.0	23	180	900	**1500**	**1800**	190	410
Iron	50,000	-	300	-	9400	45,000	18,000	31,000	12,000	1200
Lead	1000	-	7	32	98	20	9.1	16	12	23
Lithium	-	-	-	-	39	80	180	97	180	22
Manganese	5000	-	-	-	960	3200	2100	2600	**5000**	370
Molybdenum	5000	-	73	7300	10	6.6	13	7.6	4.0	5.6
Nickel	2000	-	150	1600	41	610	480	460	64	79
Selenium	1000	-	1.0	50	7.8	88	240	64	51	7.1
Silver	2000	-	0.1	1.2	4.0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Strontium	-	-	-	-	300	1800	4700	1400	960	190
Tin	5000	-	-	-	54	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Titanium	5000	-	-	-	< 0.1	< 0.1	9.9	< 0.1	< 0.1	< 0.1
Vanadium	5000	-	-	200	< 0.1	13	39	20	4.3	< 0.1
Zinc	2000	-	30	1100	**14,000**	**2000**	**38,000**	**15,000**	**54,000**	**2000**

4. Conclusions

Twenty-three (23) bilge spaces taken from 6 ships representing 4 ship classes were studied. Their composition was compared to municipal legislation governing disposal of wastewater via municipal sewer. The results indicate that hydrocarbon and zinc content exceeds municipal sewer disposal regulations in at least 50% of bilge spaces. Hydrocarbons in bilge spaces likely arise from lubricants leaks and accidental releases and machinery maintenance and cleaning operations. Zinc content may be related to the use of sacrificial zinc anodes, degradation of galvanized steel or paint coatings on the bilge spaces. Zinc metal is the coating placed on steel during the process of galvanization and zinc primers are often used as base coats for paint coverings over steel.

A significant percentage of bilge spaces also failed copper content and pH. Copper alloys would be expected to be used in many marine vessel spaces that are anticipated to encounter seawater. In all of pH failures the obtained value was acidic. This may be due to improper disposal of acidic cleaning agents.

Table 11. *Summary of exceedances*

PARAMETER	2006 STUDY		1999 STUDY	
	# OF FAILS	% FAILS	# OF FAILS	% FAILS
Hydrocarbon	15	65	29	73
pH	5	22	1	2.5
Zinc	11	48	12	30
Copper	9	39	2	5
Manganese	1	4	0	0
Nickel	1	4	0	0
Lead	1	4	2	5

A similar study was conducted in 1999 on 40 bilge spaces. The results of the 2006 study are summarized in Table 11 and compared to the 1999 study. It is interesting to note that the most significant failures in 1999 (hydrocarbon and zinc content) were also the largest culprits in the current study. These results also mirror the results from studies of bilge water from American military vessels [1-4].

The percentage of “failures” due to pH and copper content has increased since the last study. This may not be a matter of major concern however. Perhaps due to increased perception of the importance of environmental concerns, liaison with CF Ship crew was more efficient in this study. In 1999 it was often the case that bilge spaces had been pumped before DRDC Atlantic staff could arrive to sample. It is suspected that the bilge water composition in such cases was not truly reflective of conditions. Such concerns were not encountered in this study. The 2006 results may therefore be a more accurate indication of bilge water quality throughout the CF fleet.

5. References

1. David Taylor Naval Ships Research and Development Center, Bilgewater Characterization and Generation Surveys Aboard DD-963 Class Ships, DTNSRDC/SME-81/09, April 1981

2. Naval Surface Warfare Center Carderock Division, The Characterization of Bilgewater Aboard U.S. Navy Ships, CDNSWC/SME-CR-10-91, October 1992.

3. Naval Surface Warfare Center Carderock Division, In-Port Oily Wastewater Generation on USS ARLEIGH BURKE (DDG 51), NSWCCD-TR-63-97/37, November 1996.

4. Nature of Discharge Report, Surface Vessel Bilgewater/OIL Water Separator (OWS) Discharge, http://www.epa.gov/owow/oceans/regulatory/unds/surfacebilge/index.html, April 2006.

5. Fisher, G.C., Hiltz, J.A. et al, "Bilge Water Survey CF Ships January to March 1999", Defence Research Establishment Atlantic Technical Memorandum 1999-102, July 1999.

6. Canada Shipping Act, "Dangerous Chemicals and Noxious Liquid Substances Regulations", SOR/93-4

7. Halifax Regional Municipality By-Law W-101 "Respecting Discharge into Public Sewers", 20 June 2001.

8. Canadian Water Quality Guidelines for the Protection of Aquatic Life, Canadian Council of Ministers of the Environment, 2005.

9. Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the *Environmental Protection Act*, Province of Ontario, 9 March 2004.

List of symbols/abbreviations/acronyms/initialisms

AAMR	After auxiliary machinery room
AMMR	After main machinery room
amu	atomic mass units
AMS	Auxiliary machinery space
ATP	Air turbine pump
ATR	Auxiliary turbine room
CF	Canadian Forces
DND	Department of National Defence
ER	Engine room
FAMR	Forward auxiliary machinery room
FER	Forward engine room
FMMR	Forward main machinery room
FSE	Formation Safety and Environment
FWAL	Fresh Water Aquatic Limits
HRM	Halifax Regional Municipality
ICP-MS	inductively coupled plasma – mass spectroscopy
L/min	litres per minute
MAL	Marine Aquatic Limits
mL	millilitres
mm	millimetre
OREG	Province of Ontario ground water limits
ppb	parts per billion

ppm	parts per million
STBD	Starboard
THRTR	thruster
W	watts

Distribution list

Internal Distribution by DRDC Atlantic

5 DRDC Atlantic Library

1 Gary Fisher, DRDC Atlantic

External Distribution by DRDKIM 2-2-3

1 DRDKIM 2-2-3

1 Formation Safety and Environment
Formation Halifax
PO Box 99000 Stn. Forces
Halifax, NS B3K 5X5
Attention: SO EIM

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) DRDC Atlantic	2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable). UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title).

Bilge Water Characterization of CF Ships

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

Fisher, Gary C. and Nault, Philippe SLt.

5. DATE OF PUBLICATION (month and year of publication of document) August 2006	6a. NO. OF PAGES (total containing information Include Annexes, Appendices, etc). 28 (approx.)	6b. NO. OF REFS (total cited in document) 9

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered).

Technical Memorandum

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include address).

Defence R&D Canada – Atlantic
PO Box 1012
Dartmouth, NS, Canada B2Y 3Z7

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant). 20ck11	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written).
10a ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC Atlantic TM 2005-249	10b OTHER DOCUMENT NOs. (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Defence departments and defence contractors; further distribution only as approved
( ) Defence departments and Canadian defence contractors; further distribution only as approved
( ) Government departments and agencies; further distribution only as approved
( ) Defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected).

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

Liquid collected in the bilge spaces of four different classes of CF ships were sampled and analyzed for pH and the content of hydrocarbons and various metals. The results were compared to acceptable water quality criteria for waste disposal via municipal sewer. Significant failure rates (> 10%) were observed for pH, hydrocarbon content and concentrations of copper and zinc. These results are comparable to previous studies of bilge water content on Canadian and American military vessels.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title).

Bilge water, characterization, ICP-MS, inductively coupled plasma – mass spectroscopy

This page intentionally left blank.

Defence R&D Canada

Canada's leader in defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca