

Screening Assessment

Poly(bios) Group

Chemical Abstracts Service Registry Numbers

1401-55-4

1415-93-6

56780-58-6

65497-29-2

65996-62-5

**Environment and Climate Change Canada
Health Canada**

November 2018

Cat. No.: En14-342/2018E-PDF

ISBN 978-0-660-28386-9

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Synopsis

Pursuant to sections 68 or 74 of the Canadian Environmental Protection Act, 1999 (CEPA), the Minister of Environment and the Minister of Health have conducted a screening assessment of five substances referred to collectively as the Poly(bios) Group. Substances in this group were identified as priorities for assessment as they met categorization criteria under subsection 73(1) of CEPA or were considered a priority on the basis of other human health concerns. The Chemical Abstracts Service Registry Numbers (CAS RN¹), their Domestic Substances List (DSL) names and their acronyms are listed in the table below.

Substances in the Poly(bios) Group

CAS RN	Domestic Substances List name	Acronyms
1401-55-4 ^a	Tannins	-
1415-93-6 ^a	Humic acids	-
65996-62-5	Starch, oxidized	-
56780-58-6 ^a	Starch, 2-hydroxy-3-(trimethylammonio)propyl ether, chloride	SEGAC
65497-29-2 ^a	Guar gum, 2-hydroxy-3-(trimethylammonio)propyl ether, chloride	GEGAC

^a This substance was not identified under subsection 73(1) of CEPA but was included in this assessment as it was considered a priority on the basis of other human health concerns.

These five substances were previously evaluated under the Second Phase of Polymer Rapid Screening, which identified tannins, humic acids and oxidized starch as having low potential to cause ecological harm, and SEGAC and GEGAC as having low potential to cause harm to human health. However, they were identified as requiring further assessment for potential human health or ecological risks on the basis of structural alerts and/or uses associated with significant consumer exposure. The present assessment further elaborates on the potential for tannins, humic acids, and oxidized starch to cause harm to human health, and for SEGAC and GEGAC to cause ecological harm, in order to reach an overall conclusion under section 64 of CEPA as to whether they pose a risk to the environment or human health.

Tannins occur naturally in the environment. In Canada, they are reported to be used in the food, pharmaceutical, cosmetic, fabric, and textile industries. It has been reported that volumes between 100-1000 kg of tannic acid (the most commonly used tannin) were either imported or manufactured in Canada in 2014. Tannins do not contain any reactive functional groups or other structural features associated with human health concerns. The toxicological information available indicates that they have a low hazard profile for human health. Tannins are naturally occurring in a number of botanical

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sources and tannic acid can be used as a food additive. Therefore, direct exposure is expected; however, indirect exposure through drinking water is negligible.

Humic acids occurs naturally in the environment. In Canada, it is reported to be used in cosmetics and natural health products. Import volumes of up to 100 000 kg of humic acids have been reported for the year 2014. Humic acids does not contain any reactive functional groups or other structural features associated with human health concerns. The toxicological information available indicates that it has a low hazard profile for human health. Humic substances are naturally occurring in the environment; however, both direct and indirect exposure to humic acids is expected to be negligible.

Oxidized starch does not occur naturally in the environment. In Canada, it is reported to be used in the paper and textile industries. It has been reported that greater than 10 million kilograms of oxidized starch were either imported or manufactured in Canada in 2014. The reactive aldehyde groups present in oxidized starch are found to be at very low amounts and do not present a human health hazard. No other toxicological concerns were identified therefore oxidized starch has a low hazard profile for human health. Oxidized starch is used as a food ingredient and, therefore, direct exposure from the diet is expected.

SEGAC is a cationic modified starch compound that does not occur naturally in the environment. According to available information, SEGAC, is used in the pulp and paper industries and between 100 000 and 1 000 000 kilograms were imported into Canada in 2014. On the basis of the use pattern, and exposure pattern, SEGAC is not expected to pose a risk to the environment.

GEGAC is manufactured by modifying guar gum with cationic functionality. It does not occur naturally in the environment. Up to 100 000 kilograms of GEGAC were imported into Canada in 2014 and reported to be used in personal care products². Considering the use patterns and hazard profile, GEGAC is not expected to pose a risk to the environment.

Considering all available lines of evidence presented in this screening assessment, there is low risk of harm to the environment from tannins, humic acids, oxidized starch, SEGAC, and GEGAC. It is concluded that tannins, humic acids, oxidized starch, SEGAC, and GEGAC do not meet the criteria under paragraphs 64(a) or (b) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the

² For the purpose of this document, a personal care product is defined as a product that is generally recognized by the public for use in personal cleansing or grooming. Depending on how the product is represented for sale and its composition, personal care products may fall into one of three regulatory categories in Canada: cosmetics, drugs or natural health products.

environment or their biological diversity or that constitute or may constitute a danger to the environment on which life depends.

On the basis of the information presented in this screening assessment, it is concluded that tannins, humic acids, oxidized starch, SEGAC, and GEGAC do not meet the criteria under paragraph 64(c) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

Therefore, it is concluded that tannins, humic acid, oxidized starch, SEGAC, and GEGAC do not meet any of the criteria set out in section 64 of CEPA.

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1. Introduction

Pursuant to sections 68 and 74 of the Canadian Environmental Protection Act, 1999 (CEPA) (Canada 1999), the Minister of Environment and the Minister of Health have conducted a screening assessment of five substances referred to collectively as the Poly(bios) Group to determine whether these substances present or may present a risk to the environment or to human health. The substances in this group were identified as priorities for assessment as they met categorization criteria under subsection 73(1) of CEPA or were considered a priority on the basis of other human health concerns (ECCC, HC [modified 2017]).

While the five substances considered in this assessment are collectively referred to as the Poly(bios) Group, they lack similarities that would support a group approach to exposure, hazard and risk characterization; thus, their exposure and hazard profiles were independently assessed for risk. The assessment of each substance forms its own chapter.

The substances considered in this assessment have been previously evaluated using a rapid screening approach. The approach and results of its application, are presented in the document “Second Phase of Polymer Rapid Screening: Results of the Screening Assessment” (ECCC, HC 2018). The ecological and human health rapid screening approaches are summarized in the Appendix of this screening assessment. Application of these approaches identified tannins, humic acid and oxidized starch as having low potential to cause ecological harm, and identified SEGAC and GEGAC as having low potential to cause harm to human health. These results, in conjunction with any other relevant information that became available after the publication of the report on the second phase of polymer rapid screening, are considered in support of the conclusions made under section 64 of CEPA in this screening assessment.

This screening assessment includes consideration of additional information on chemical properties, environmental fate, hazards, uses and exposures, including additional information submitted by stakeholders. Relevant data were identified up to September 2016. Empirical data from key studies as well as results from models were used to reach conclusions. When available and relevant, information presented in assessments from other jurisdictions was considered.

This screening assessment was prepared by staff in the CEPA Risk Assessment Program at Health Canada and Environment and Climate Change Canada and incorporates input from other programs within these departments.

This screening assessment focuses on information critical to determining whether substances meet the criteria as set out in section 64 of CEPA, by examining scientific

information and incorporating a weight of evidence approach and precaution³. The screening assessment presents the critical information and considerations upon which the conclusion is made.

2. Tannins

2.1 Substance identity

Tannins (CAS RN 1401-55-4) are primarily polyphenolic substances. Tannins are gallic acid derivatives found in nutgalls, bark and other plants parts (SciFinder). They are considered to be of unknown or variable composition, complex reaction products or biological materials (UVCBs⁴). Tannins may be divided into 2 groups: (a) condensed tannins (mostly derivatives of flavonols) and (b) hydrolysable tannins which are esters of a sugar (glucose) with one or more trihydroxybenzene-carboxylic acids (Merck Index 1989). The majority of the literature considers 'tannic acid' as a synonym for tannins (specifically hydrolyzed tannins). The CAS RN 72401-53-7 for tannic acid has also been indicated in some references as a synonym for tannins (EFSA 2014). Accordingly, the more defined substance, i.e. tannic acid, will be preferably used in this assessment report. The representative structure of tannic acid is presented in Figure 2-1. A list of additional chemical names (e.g., trade names) is available from the National Chemical Inventories (NCI 2015).

³A determination of whether one or more of the criteria of section 64 of CEPA are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment. For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and products used by consumers. A conclusion under CEPA is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the *Hazardous Products Regulations*, which are part of the regulatory framework for the Workplace Hazardous Materials Information System for products intended for workplace use. Similarly, a conclusion based on the criteria contained in section 64 of CEPA does not preclude actions being taken under other sections of CEPA or other acts.

⁴ UVCB is an acronym for Unknown or Variable composition Complex reaction products and Biological material. These materials are derived from natural sources or complex reactions and cannot be characterized in terms of constituent chemical compounds because their composition is too complex or variable. A UVCB is not an intentional mixture of discrete substances and is considered a single substance.

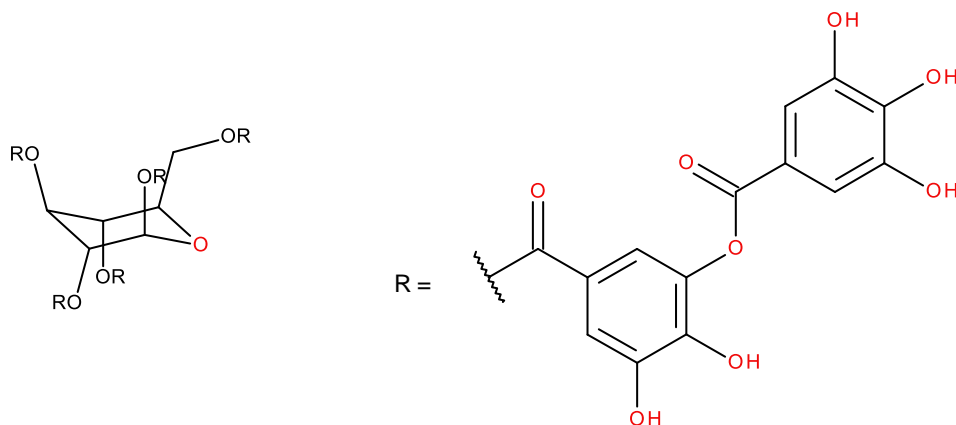


Figure 2-1. Representative structure of tannic acid

2.2 Physical and chemical properties

A summary of physical and chemical properties for tannic acid is presented in Table 2-1.

Table 2-1. Physical and chemical property values (at standard temperature) for tannic acid

Property	Tannic acid	Key reference(s)
Physical state	solid	Canada 2015, ECCC 2015
Mw= Weight-average molecular weight (Da)	1701.2	Merck Index 1989
Melting point (°C)	210-215 decomp.	Merck Index 1989
pH ^a	~ 3.5	Perez/Perez 2000,
Vapour pressure (Pa)	< 0.0001	Canada 2015, ECCC 2015
Water solubility	soluble	Merck Index 1989

^a Tannic acid is a weak organic acid (pH~ 3.5 for 1% solution) despite lacking the carboxylic acid functional group. This is due to having multiple phenolic groups (Perez and Perez 2000).

2.3 Sources and Uses

Tannic acid is available from a variety of botanical sources. It is obtained by solvent extraction of nutgalls or excrescences that form on the young twigs of *Quercus* species. Tannic acid is also obtained by solvent extraction of the seed pods of *Tara* (*Caesalpinia spinosa*) or the nutgalls of various sumac species (Burdock 2010, Smith and Hong-Shum 2003).

Tannic acid has been included in a voluntary survey (ECCC 2015) as well as a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015).

Table 2-2 below presents a summary of the total reported manufacture, total reported import and total use quantities for the substance in 2014. These sources indicate that the primary reported uses for tannic acid in Canada are in food, pharmaceutical, cosmetic, fabric, and textile industries.

Table 2-2. Summary of information on Canadian manufacturing, and import quantities of tannic acid in 2014 submitted pursuant to a voluntary survey and to a CEPA section 71 survey

Total manufacture ^a (kg)	Total imports ^a (kg)	Survey reference
0	100-1000	Canada 2015, ECCC 2015

^a Values reflect quantities reported in response to a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). See surveys for specific inclusions and exclusions (schedules 2 and 3).

Globally, tannic acid is used in the food industry as a food enhancer, clarifying agent, colour modifier, pH adjuster, boiler water additive; in the manufacturing industry it is used as a mordant in dyeing, printing fabrics, inks, tanning, coagulant, analytical reagent, photography; in the pharmaceutical industry it is used as an astringent, hemostatic agent; in the animal feeding industry it is used as a flavoring agent; and in the pesticide industry as a dispersing agent (Chung et al. 1998, EPA 2006).

A number of domestic government databases were searched to determine if tannic acid is registered and/or approved for uses in Canada. These uses for tannic acid are listed in Table 2-3.

Table 2-3. Additional uses in Canada for tannic acid

Use	Tannic acid
Food additive ^a	Yes
Food packaging materials ^b	No
Internal Drug Product Database as medicinal or non-medicinal ingredients in final Pharmaceutical, Disinfectant or Veterinary drug products in Canada ^c	Yes
Natural Health Products Ingredients Database ^d	Yes
Licensed Natural Health Products Database as medicinal or non-medicinal ingredients in natural health products in Canada ^e	Yes
List of Prohibited and Restricted Cosmetic Ingredients ^f	No
Notified to be present in cosmetics, on the basis of notifications submitted under the Cosmetic Regulations to Health Canada ^g	Yes
Formulant in pest control products registered in Canada ^h	No
Known toy use ⁱ	No

^a Health Canada (modified 2013)

^b Food Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^c DPD (modified 2015)

^d NHPID (modified 2016)

^e LNHPD (modified 2016)

^f Health Canada (modified 2015)

^g Consumer Product Safety Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^h PMRA (2010)

ⁱ Toy Industry Spreadsheet (2016)

2.4 Potential to cause ecological harm

Critical data and considerations used during the second phase of polymer rapid screening to evaluate the substance-specific potential to cause ecological harm are presented in ECCC (2016).

Tannins were identified as not containing any reactive functional groups associated with increased ecological concern. Therefore, this substance was characterized as having a low potential for ecological risk. It is unlikely that this substance results in concerns for organisms or the broader integrity of the environment in Canada.

2.5 Potential to cause harm to human health

2.5.1 Exposure assessment

2.5.1.1 Direct exposure

The majority of human exposure to tannic acid comes from its natural occurrence and its use as a food additive in numerous food and beverage products. The U.S. Food and Drug Administration (FDA) allow the use of tannic acid as a flavouring agent and adjuvant, and a processing aid at levels up to 400 ppm in various foods (FDA, CFR). By estimation, the individual consumption of tannic acid through food from its use as a food flavouring agent is 1.51 mg/kg/day or around 105 mg/day for a 70 kg-adult (Burdock 2010).

In Canada, tannic acid is permitted for use as a food additive in: chewing gum to reduce adhesion at a level of use in accordance with Good Manufacturing Practices; in cider, honey wine and wine as a fining agent at a maximum level of use of 200 ppm; and in beer as a fining agent at a maximum level of use of 10 ppm; as set out in the List of Permitted Food Additives with Other Generally Accepted Uses (Health Canada 2016/Food and Nutrition). On the basis of the limited foods to which the food additive tannic acid is permitted to be added and its purpose of use in wine and beer, exposure to tannic acid when used as a food additive is expected to be negligible.

Although tannic acid has been used in cosmetics, dermal absorption is not expected due to its high molecular weight. Exposure to tannic acid through inhalation is not expected to be a human health concern due to its low vapour pressure.

Tannic acid is listed in the Natural Health Products Ingredients Database (NHPID) with a medicinal role as classified as a natural health product substance falling under item 2 (an extract) of Schedule 1 to the Natural Health Products Regulations (NHPR), as well

as being listed, as Acidum tannicum and Tannicum acidum with a homeopathic role for use in homeopathic medicines at a minimum homeopathic potency of 3X⁵. Tannic acid is also listed in the NHPID with a non-medicinal role for use as clarifying agent, emulsifying agent, flavour enhancer, gelling agent, stabilizing agent, or thickening agent in natural health products. It is listed in the Licenced Natural Health Products Ingredients Database (LNHPD) as being present as such (a medicinal or non-medicinal ingredient) in a limited number of currently licensed natural health products in Canada. Tannic acid as an active drug ingredient is found in 29 products; 12 for human use (anti-diarrhea, anti-infective, keratolytic, astringent, antipruritic, anesthetic, and homeopathic) and 17 for veterinary use.

On the basis of notifications submitted under the Cosmetic Regulations to Health Canada, tannic acid is used in certain cosmetic products [59 cosmetics contain this substance at levels up to 30% (but mostly below 1%)] in Canada such as bath/fragrance product, cleanser, conditioner, hair color, lubricant, massage product, moisturizer, shaving product, shampoo, and hair/styling product (personal communication, emails from the Consumer Product Safety Directorate, Health Canada, to the Existing Substances Risk Assessment Bureau, Health Canada, December, 2016; unreferenced). As mentioned above, dermal absorption for the substance is not expected due to its large molecular weight.

2.5.1.2 Indirect exposure

In the event of an unforeseen environmental release of tannic acid, it is expected to become widely distributed in the aquatic environment on the basis of its high water solubility. However, tannic acid is a hydrolyzable tannin that yields mostly gallic acid and glucose as hydrolysis products when released to water. Consequently, the indirect exposure of the general population to tannic acid through environmental media such as drinking water is expected to be minimal.

2.5.2 Health effects assessment

During evaluation under the second phase of polymer rapid screening, tannins was identified as requiring further assessment as a result of possible subchronic toxicity or thyroid effects. The substance does not contain any reactive functional groups or structural features which are known to be associated with adverse human health effects.

The focus of the information provided is on tannic acid which has more information and is a representative for tannins.

⁵ 3X is an expression for concentration in homeopathic products, where the ratio between the substance and the solvent (primarily water) would be 1:1000 ratio.

Tannins are considered to be of low nutritive value and reduce the absorption of proteins; however, the toxicological information on tannic acid does not suggest any specific toxicity at dietary levels below 5% (Chung et al.1998). Tannic acid is poorly absorbed in the digestive tract (Nakamura et al., 2003) but can be degraded in the gut, by bacteria or enzymes, to gallic acid or ellagic acid, both of which are also naturally found in food. These degradation products can be absorbed in the digestive tract. In vitro studies carried out in ruminal fluid collected from cattle showed that tannic acid was converted to gallic acid, pyrogallol and resorcinol (Singh et al. 2001). Its metabolites in target species, experimental animals and humans are very similar and appear to be efficiently excreted (Singh et al. 2001).

Both gallic and ellagic acid have been associated with health benefits as they possess antioxidant activity (Chung et al.1998). Gallic acid did not show any subchronic toxicity in mice (Rajalakshmi et al., 2001) but did cause hematological and liver effects in rats, which is likely the subchronic toxicity identified during the polymer rapid screening process, triggering further assessment. In addition, these flavonoids (gallic acid, ellagic acid) may inhibit thyroid peroxidase and have anti-thyroid effects (de Souza Dos Santos et al., 2011); however no studies were found associating these effects with tannic acid. As such, the concerns on the basis of degradation products of tannic acid were not deemed relevant to tannic acid itself. Therefore, tannic acid is expected to have a low hazard.

Tannic acid is not classified as carcinogenic to humans by the International Agency for Research on Cancer (IARC) (group 3).

2.5.3 Characterization of risk to human health

In this assessment, the human health risks were established through consideration of both the hazard and the direct and indirect exposure of the substance for current uses identified from a mandatory survey issued pursuant to a CEPA section 71 notice.

The human health hazard associated with subchronic exposure to tannic acid is considered low. It is present at low concentrations in a limited number of food sources and is not well absorbed in the GI tract. Therefore, it is not anticipated to pose a human health risk through dietary exposure. Tannic acid is poorly absorbed through the dermal route. Taking into consideration the direct and indirect exposure, as well as low hazard, associated with tannic acid, the human health risk has also been determined to be low.

3. Humic Acid

3.1 Substance identity

The substance humic acid consists of a mixture of complex macromolecules resulting from the decomposition of organic matter, particularly dead plants (Merck index). It is found in soils, coals, peats, and water ecosystems. The composition of humic is variable

and may contain polyphenolics, heterocyclics, sugars, and amino acids/peptides with functional groups such as carboxyl, hydroxyl, ketone, and amine as well as others. The chemical (elemental) composition of humic acid varies considerably depending on its source, extraction method, and conditions. In other words, it is considered a UVCB. The CAS RN for humic acid is 1415-93-6. There is no defined structure for humic acid. Regardless of their origin, the building blocks of humic acid appear to be mostly small phenolic units. To represent a humic acid structure, these units are rearranged into a combination of structural moieties. Therefore, Figure 3-1 is a structural model showing molecular components thought to be present in natural humic substances (Tan 2014, Kosobucki and Buszewski 2014, Pena-Mendez et al. 2005). A list of additional chemical names (e.g., trade names) is available from the National Chemical Inventories (NCI 2015).

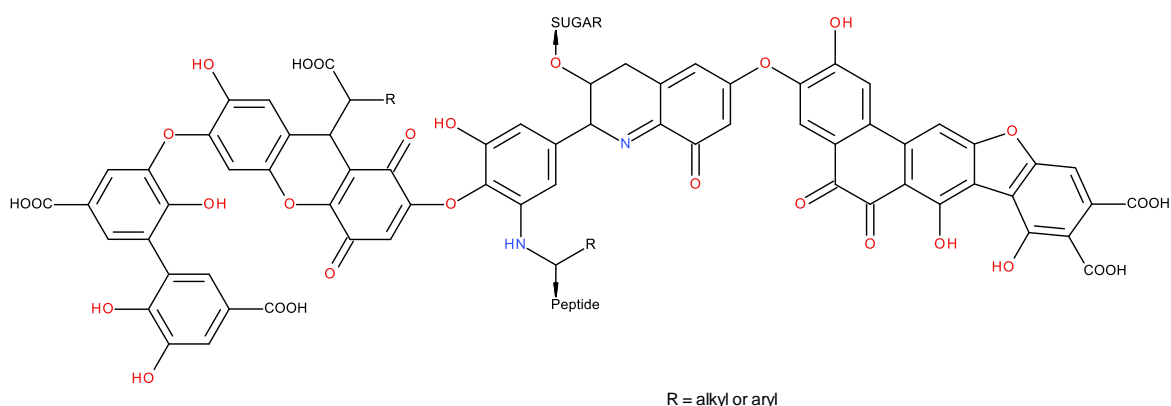


Figure 3-1. Representative structure of humic acid

3.2 Physical and chemical properties

A summary of physical and chemical properties for humic acid is presented in Table 3-1.

Table 3-1. Physical and chemical property values (at standard temperature) for humic acid

Property	Humic acid	Key reference(s)
Physical state	solid	Canada 2015, ECCC 2015
Mw= Weight-average molecular weight (Da)	~ 5 000-30 000	Tan 2014, Perminova 2003, Kosobucki/Buszewski 2014
Mn= Number-average molecular weight (Da)	~ 10 ³ -10 ⁴	Tan 2014
pH	3.5-4.0	Hewlett 2003
Vapour pressure (Pa)	negligible	Canada 2015, ECCC 2015
Water solubility	negligible to low	Tan 2014

Property	Humic acid	Key reference(s)
Octanol/water partition coefficient (log K _{ow}) ^a	-2.3 to -2.86	Badun 2004
Biodegradation	12.7% (1y) t _{1/2} ≈ 10 y	Qualls 2004
Density (g/cm ³)	1.6-1.8	Canada 2015, ECCC 2015

^a The values indicated for humic acid are, in fact, toluene/water partition coefficient (instead of octanol/water) as log K_w (Badun et al. 2004).

3.3 Sources and Uses

Soil contains 1-5% humic acids (humic acid and fulvic acid). Other main sources include peat (10-40%), manure (5-15%), and compost (2-5%). Leonardite, a coal originating from plant matter, may contain up to 80% humic acids (Davies 2001).

Humic acid has been included in a voluntary survey (ECCC 2015) as well as a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). Table 3-2 below presents a summary of the total reported manufacture and total reported import quantities for the substance in 2014.

Table 3-2. Summary of information on Canadian manufacturing, and import quantities of humic acid in 2014 submitted pursuant to a voluntary survey and to a CEPA section 71 survey

Total manufacture ^a (kg)	Total imports ^a (kg)	Survey reference
0	10 000-100 000	Canada 2015, ECCC 2015

^a Values reflect quantities reported in response to a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). See surveys for specific inclusions and exclusions (schedules 2 and 3).

The primary uses for humic acid in Canada, according to information reported in a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015), are in cosmetics as well as natural health products.

Globally, humic acid is used as a component in fertilizers. It has been used in industry (building, woodworking, ceramic, plastics, paper, etc.), in environmental chemistry (to remove toxic metals, anthropogenic organic chemicals and other pollutants from water), and in veterinary and human medicine (Pena-Mendez et al. 2005).

A number of domestic government databases were searched to determine if humic acid is registered and/or approved for uses in Canada. These uses for humic acid are listed in Table 3-3.

Table 3-3. Additional uses in Canada for humic acid

Use	Humic acid
Food additive ^a	No
Food packaging materials ^b	No
Internal Drug Product Database as medicinal or non-medicinal ingredients in final Pharmaceutical, Disinfectant or Veterinary drug products in Canada ^c	No
Natural Health Products Ingredients Database ^d	Yes
Licensed Natural Health Products Database as medicinal or non-medicinal ingredients in natural health products in Canada ^e	Yes
List of Prohibited and Restricted Cosmetic Ingredients ^f	No
Notified to be present in cosmetics, on the basis of notifications submitted under the Cosmetic Regulations to Health Canada ^g	Yes
Formulant in pest control products registered in Canada ^h	No
Known toy use ⁱ	No

^a Health Canada (modified 2013)

^b Food Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^c DPD (modified 2015)

^d NHPID (modified 2016)

^e LNHPD (modified 2016)

^f Health Canada (modified 2015)

^g Consumer Product Safety Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^h PMRA (2010)

ⁱ Toy Industry Spreadsheet (2016)

3.4 Potential to cause ecological harm

Critical data and considerations used during the second phase of polymer rapid screening to evaluate the substance-specific potential to cause ecological harm are presented in ECCC (2016).

Humic acid was identified as not containing any reactive functional groups associated with increased ecological concern. Therefore, this substance was characterized as having a low potential for ecological risk. It is unlikely that this substance results in concerns for organisms or the broader integrity of the environment in Canada.

3.5 Potential to cause harm to Human Health

3.5.1 Exposure Assessment

3.5.1.1 Direct Exposure

The majority of exposure to humic acid comes from its natural occurrence in soil. The mobility of chemicals in soil is assumed to be much less than the mobility of chemicals

in water and air (EPA 1992). For humic acid, dermal absorption is not expected due to its high molecular weight and expected very low octanol/water partition coefficient.

Inhalation exposure to humic acid is not expected to be a human health concern due to its negligible vapour pressure.

Humic acids is listed in the NHPID with a medicinal role as classified as a natural health product substance falling under item 2 (an extract) of Schedule 1 to the NHPR, with humic acids, potassium salts; humic acids, sodium salt; and peat as source ingredients. It is also listed in the NHPID with a non-medicinal role for topical use only as chelating agent or skin-conditioning agent in natural health products. It is listed in the LNHPD as being present as such (a medicinal or non-medicinal ingredient) in a limited number of currently licensed natural health products in Canada.

On the basis of notifications submitted under the Cosmetic Regulations to Health Canada, humic acid is used in certain cosmetic products (8 cosmetics contain this substance at levels up to 0.1%) in Canada such as cleanser, exfoliant, moisturizer, and makeup (personal communication, emails from the Consumer Product Safety Directorate, Health Canada, to the Existing Substances Risk Assessment Bureau, Health Canada, December, 2016; unreferenced). As mentioned above, dermal absorption for the substance is not expected due to its large molecular weight.

3.5.1.2 Indirect exposure

Humic acid has low water solubility. Humic substances (humic acid, fulvic acid, humates, humins, etc.) are present in natural waters up to 4 mg/L (Thurman 1985). Canadian municipalities supply approximately 86% of the Canadian population with drinking water obtained from surface water sources (Statistics Canada, 2015). The blackish to yellowish colour of surface water is predominantly due to organic substances of natural origin, specifically humic and fulvic acids (Health Canada 1979; Stevenson, 1982). There is no specific water quality test for humic acids. As such, there is no drinking water guideline for this parameter. Colour is a partial indicator (for presence of humic acid) but it is also associated with the presence of iron which is frequently present (Black and Christman, 1963) and thus confounds the exact colour source. In addition, natural organic matter (NOM) carbon is also sometimes a surrogate for humic acid. The regulatory agencies (i.e., provinces & territories) are aware of colour and organic carbon-related issues associated with water and monitor these through drinking water facilities (personal communication, email from Water and Air Quality Bureau/Water Quality and Science Division to New Substances Assessment and Control Bureau, Health Canada, dated December 6, 2016; unreferenced).

3.5.2 Health effects assessment

During evaluation under the second phase of polymer rapid screening, humic acid was identified as requiring further assessment as a result of a flag for potential carcinogenicity. However, humic acid was not carcinogenic in mice on the basis of data

available in the Carcinogenicity Potency Project (CPDB 2011). Claims for carcinogenicity likely arise from products generated as a result of the chlorination of humic acid which can contribute to the formation of trihalomethanes (THMs) and not from the substance itself (Meier et al, 1986, McDonald and Komulainen, 2005). Chlorinated by-products of humic acid are not considered with this evaluation.

Humic acid does not contain any reactive functional groups or structural features which are known to be associated with adverse human health effects, and has low acute oral toxicity as well as a low subchronic toxicity. It was not mutagenic in vitro (Bernacchi et al. 1996, AGDH 2010). Unmodified humic acid is expected to have a low hazard.

3.5.3 Characterization of risk to human health

In this assessment, the human health risks were established through consideration of both the hazard and the direct and indirect exposure of the substance for current uses identified from a mandatory survey issued pursuant to a CEPA section 71 notice.

The human health hazard associated with the carcinogenicity potential of humic acid is considered low for this substance. Taking into consideration the direct and indirect exposure, as well as low hazard associated with humic acid, the human health risk has also been determined to be low.

4. Oxidized Starch

4.1 Substance identity

Oxidized starch is considered a UVCB. The Chemical Abstracts Service Registry Number (CAS RN) for oxidized starch is 65996-62-5 and Figure 4-1 shows the synthesis and representative structure of this polymeric substance. A list of additional chemical names (e.g., trade names) is available from the National Chemical Inventories (NCI 2015). Oxidized starch stems from the partial modification of starch using various oxidizing agents, such as hypochlorite, hydrogen peroxide, persulfate, periodate, ozone as well as others. Under controlled conditions of temperature, pH, pressure and time, the oxidizing agent reacts with the starch to cleave the polymeric chains and/or cause oxidation of hydroxyl groups on the glucose units to carbonyl (aldehyde, ketone) or carboxyl groups. Depending on the type of oxidizing agent used, the resulting oxidized starch may contain different functional groups. For instance, oxidized starch for food use (referred to as E 1404) is mainly produced by the reaction of starch with sodium hypochlorite (Lewicka et al.2015). Importantly, oxidation only modifies up to 1.5% (w/w) of native starch. The resulting oxidized starch contains < 0.9% carboxyl group (COOH) and < 0.4% carbonyl group (C=O, ketone:aldehyde ≈ 2:1) (Lewicka et al. 2015, Horton 2004). In comparison to the native starch, the oxidized starch has better water solubility, lower viscosity, and lower retrogradation (rearrangement of polymeric chains) tendency (Sangseethong et al. 2006, Xie et al. 2005).

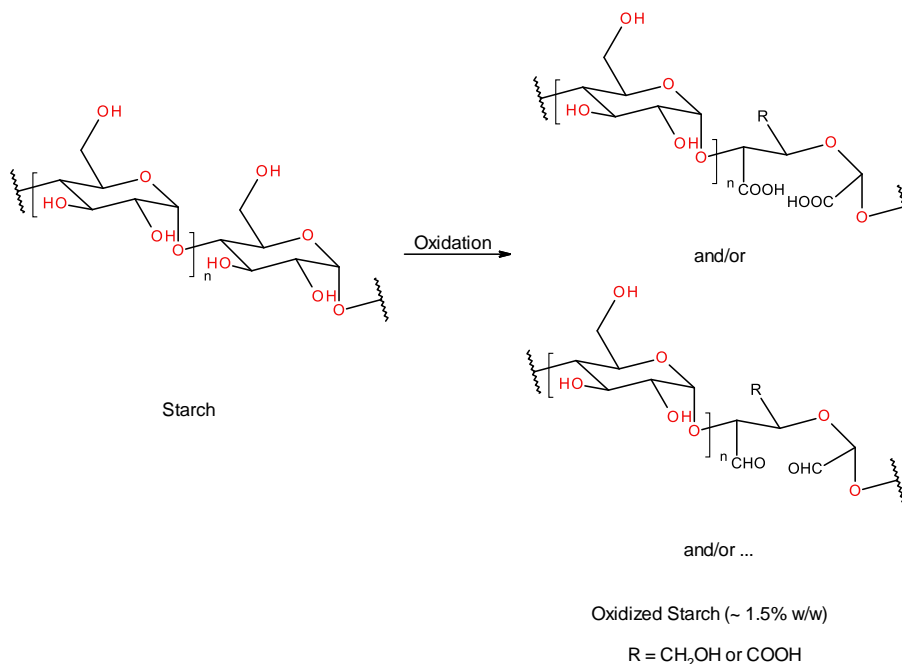


Figure 4-1. Synthesis and representative structure of oxidized starch

4.2 Physical and chemical properties

A summary of physical and chemical properties for oxidized starch is presented in Table 4-1.

Table 4-1. Physical and chemical property values (at standard temperature) for oxidized starch

Property	Oxidized starch	Key reference(s)
Physical state	solid	Canada 2015, ECCC 2015
Mw= Weight-average molecular weight (Da) ^a	~ 10 ⁶ -10 ⁸	Chan 2011, Berski 2011
Mn= Number-average molecular weight (Da) ^a	~ 10 ⁴ -10 ⁶	Chan 2011, Berski 2011
pH	4.0-6.2	Takizawa 2004
Vapour pressure (Pa)	negligible	Canada 2015, ECCC 2015
Water solubility	negligible to low	Merck Index
Density (g/cm ³)	1.5	Canada 2015, ECCC 2015

^a In one study, the weight average molecular weight (Mw) and number average molecular weight (Mn) for oxidized starch using ozone (as the oxidizing agent) have been reported to be ~ 3,300,000 and ~ 330,000 daltons, respectively (Chan et al. 2011). Another study, this time using sodium hypochlorite as the oxidizing agent, found the Mw and Mn values of ~ 44,000,000 and ~ 90,000 daltons, respectively (Berski et al. 2011).

4.3 Sources and uses

Although oxidized starch does not occur naturally in the environment, the native starch is widely distributed in nature, specifically in plants.

Oxidized starch has been included in a voluntary survey (ECCC 2015) as well as a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015).

Table 4-2 presents a summary of the total reported manufacture and total reported import quantities for the substance in 2014.

The primary use for oxidized starch in Canada, according to information reported in the above mentioned surveys is as a plating agent, adhesive, sealant, and in paper and textile industries. It is also used in the toy industry as a viscosity reducer. In Canada, modified starch (including oxidized starch) can be used as a food ingredient in food products as long as the starch has been prepared from permitted starch-modifying agents as listed in the List of Permitted Starch-Modifying Agents. It has also been identified as a component in the manufacture of certain food packaging materials (personal communication, emails from Food Directorate, Health Products and Food Branch, Health Canada, dated December, 2016; unreferenced).

Globally, the primary use of oxidized starch is as a food additive (emulsifier, binder, thickening agent, and stabilizer) (FAO-WHO). Oxidized starch is also used globally in paper and textile industries.

Table 4-2. Summary of information on Canadian manufacturing, and import quantities of oxidized starch in 2014 submitted pursuant to a voluntary survey and to a CEPA section 71 survey

Total manufacture ^a (kg)	Total imports ^a (kg)	Survey reference
10,000,000-100,000,000	100 000-1 000 000	Canada 2015, ECCC 2015

^a Values reflect quantities reported in response to a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). See surveys for specific inclusions and exclusions (schedules 2 and 3).

A number of domestic government databases were searched to determine if oxidized starch is registered and/or approved for uses in Canada. These uses for oxidized starch are listed in

Table 4-3.

Table 4-3. Additional uses in Canada for oxidized starch

Use	Oxidized starch
Food additive ^a	No
Food packaging materials ^b	Yes

Use	Oxidized starch
Internal Drug Product Database as medicinal or non-medicinal ingredients in final Pharmaceutical, Disinfectant or Veterinary drug products in Canada ^c	No
Natural Health Products Ingredients Database ^d	Yes (non-medicinal ingredient)
Licensed Natural Health Products Database as medicinal or non-medicinal ingredients in natural health products in Canada ^e	No
List of Prohibited and Restricted Cosmetic Ingredients ^f	No
Notified to be present in cosmetics, on the basis of notifications submitted under the Cosmetic Regulations to Health Canada ^g	No
Formulant in pest control products registered in Canada ^h	No
Known toy use ⁱ	Yes (viscosity reducer)

^a Health Canada (modified 2013)

^b Food Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^c DPD (modified 2015)

^d NHPID (modified 2016)

^e LNHPD (modified 2016)

^f Health Canada (modified 2015)

^g Consumer Product Safety Directorate, Health Canada, to the Risk Management Bureau, Health Canada; unreferenced

^h PMRA (2010)

ⁱ Toy Industry Spreadsheet (2016)

4.4 Potential to cause ecological harm

Critical data and considerations used during the second phase of polymer rapid screening to evaluate the substance-specific potential to cause ecological harm are presented in ECCC (2016).

Oxidized starch was not identified as containing any reactive functional groups associated with increased ecological concern. Therefore, this substance was characterized as having a low potential for ecological risk. It is unlikely that this substance results in concerns for organisms or the broader integrity of the environment in Canada.

4.5 Potential to cause harm to human health

4.5.1 Exposure assessment

4.5.1.1 Direct exposure

The industrial use of oxidized starch in food packaging (as component in paper and paperboard products), toys, papermaking, and textile industries is not expected to result

in direct consumer exposure to the substance since the substance forms a stable matrix from which it is not expected to be readily released. Therefore, oral (e.g. mouthing by children) and dermal exposure of the general population to oxidized starch is not expected when used in the food packaging, toys, paper and textile products.

In Canada, modified starch (including oxidized starch) can be used in food products as a food ingredient as long as the starch has been prepared using permitted starch-modifying agents (Health Canada 2016). Therefore, oral exposure to oxidized starch through food products is expected on the basis of the level of use.

Oxidized starch has been globally approved and used as a food additive in a variety of foods including beverage, dairy, baking, and other products at levels of use in accordance with Good Manufacturing Practices. The only restriction found for oxidized starch as food additive is the maximum level of 5% (i.e. safe limit of 50,000 mg/kg of food provided by the Codex Alimentarius Commission- International food standards) for 'Complementary foods for infants and young children' (FAO-WHO).

Although it is listed as a non-medicinal ingredient in the natural health products ingredients database, oxidized starch is currently not found in any licensed natural health products.

Inhalation exposure to oxidized starch is not expected to be a human health concern due to the inherent very low vapour pressure for these substances (on the basis of their very high molecular weight).

4.5.1.2 Indirect exposure

Products containing oxidized starch (such as food and paper) may be disposed of in landfills; however, leaching from landfills would not be expected on the basis of the substance's low water solubility. In addition, in the event of an unforeseen environmental release of oxidized starch, it is not expected to become widely distributed in the aquatic environment on the basis of its low water solubility.

4.5.2 Health effects assessment

During evaluation under the second phase of polymer rapid screening, oxidized starch was identified as requiring further assessment as a result of the presence of aldehyde reactive functional groups which are associated with adverse human health effects. The substance does not contain any other reactive functional groups or structural features which are known to be associated with adverse human health effects.

Starch is a naturally occurring substance with very low toxicity (Boyd and Liu, 1968), however, since starch can be modified through oxidation, an assessment of the health hazard of oxidized starch is warranted to ensure the chemical modification does not significantly increase the toxicity associated with the substance.

Aldehydes have long been known as genotoxic and cytotoxic molecules, and are implicated in the pathogenesis of various human diseases such as diabetes, atherosclerosis and neurological disorders (Xie et al., 2016). They are produced in cells as a consequence of lipid peroxidation and autoxidation or metabolic activation of precursors. In addition, exposure to anthropogenic aldehydes and intake of dietary aldehydes increases further the aldehyde burden in cells (O'Brien et al., 2005). The general mechanism of aldehyde toxicity involves adduct formation with biomolecules such as DNA and proteins, resulting in the inactivation of the function of these molecules (Xie et al., 2016).

The majority of the functional groups generated as a result of the oxidation process are carboxyls which are not known to be associated with adverse human health effects. A smaller quantity of carbonyl (ketone: aldehyde 2:1) groups are generated. Therefore, only a small proportion of the oxidized starch will contain reactive aldehyde groups (Lewicka et al. 2015, Horton 2004).

A USA Food and Drug select committee on Generally Recognized As Safe (GRAS) substances (US FDA, 2016) indicated that the digestibility and caloric value of starch oxidized with the maximum permitted level of sodium hypochlorite, as determined in rat feeding tests, were similar to those for unmodified starch (Til and Kuper, 1993). However, starch treated with about eight times the permitted level of hypochlorite caused diarrhea and marked growth depression and cercal enlargement in rats in 21-day feeding studies, demonstrating the adverse effects of starches containing high levels of oxidized groups. High dose groups fed 30% oxidized starch also noted treatment related changes in the kidney and urothelial epithelium associated with mineralization (Til and Kuper, 1993). No specific toxicity was noted in other organs or systems and the primary effects were limited to the gastrointestinal system. When oxidizing starch according to manufacturing guidelines and used at the permitted concentrations, the toxicological profile for oxidized starch is not expected to be significantly different than that of native starch.

In addition, the degradation product of the substance, which is primarily glucose, has low human health toxicity. Given the very low presence of aldehydes in oxidized starch (when the starch has been prepared from permitted starch-modifying agents as listed in the List of Permitted Starch-Modifying Agents), toxicity associated with oxidized starch is expected to be very low.

4.5.3 Characterization of risk to human health

In this assessment, the human health risks were established through consideration of both the hazard and the direct and indirect exposure of the substance for current uses identified from a mandatory survey issued pursuant to a CEPA section 71 notice.

The human health hazard associated with the presence of reactive aldehyde groups in oxidized starch is considered low owing to the negligible concentration of this reactive functional group. Consumption through food sources at permitted concentrations does

not significantly increase the body burden of aldehyde groups and is not anticipated to significantly increase the human health risk. Also, taking into consideration the direct dermal exposure to products intended for consumer use, the human health risk has been determined to be low for non-food related applications.

5. SEGAC

5.1 Substance identity

The substance, starch, 2-hydroxy-3-(trimethylammonio)propyl ether, chloride (CAS RN 56780-58-6), hereafter referred to as SEGAC, is represented by the structure shown in Figure 5-1. SEGAC may be obtained through a chemical reaction by the activation of a polysaccharide with an organic base, followed by etherification with quaternary ammonium compounds bearing glycidyl groups as cationizing agents (Sasano 1994).

SEGAC is a poly(saccharide) with an expected number average molecular weight (Mn) greater than 3 000 daltons and low oligomeric content (ECCC 2017). The monomers and reactants of SEGAC and their expected Mn or molecular weight (MW) are summarized in Table 5-1.

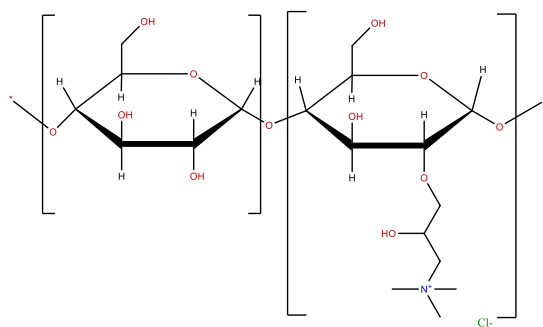


Figure 5-1. Representative structure of SEGAC

Table 5-1. Monomers and reactants of SEGAC

Monomer/reactant	CAS RN	Mn or MW ^a (daltons)	Source
Starch	9005-25-8	>3000 ^b	ECCC 2017
1-Propanaminium, 2,3-dihydroxy-N,N,N-trimethyl-	44814-66-6 ^c	134.20	NCI 2015

^a Number average molecular weight (Mn), Molecular weight (Mw).

^b MW obtained from New Chemicals Evaluation Section (NCES) database for a starch based substance.

^c CAS RN 44814-66-6 is structurally identical to CAS RN 34004-36-9, '1-Propanaminium, 2,3-dihydroxy-N,N,N-trimethyl-, chloride', but without chloride ion in the representative structure and CAS name.

The exact composition and the degree of substitution for this polymer were not provided through information submitted through a voluntary survey (ECCC 2015), or a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). However, the degree of substitution is known to vary depending on the needs for different applications, therefore representative information from various sources was considered for the purpose of this assessment.

5.2 Physical and chemical properties of SEGAC

Table 5-2 contains physical and chemical data obtained for SEGAC through surveys mentioned earlier. All information reflects summary data provided in Safety Data Sheets (SDS).

Table 5-2. Physical and chemical data of SEGAC

Property	Value	Source
Physical State	Powder ^a	SDS 2007
Physical State	Liquid ^{b,c}	SDS 2006; SDS 2014a
Water solubility	Insoluble @ 20 °C ^a	SDS 2007
Water solubility	Soluble up to 150 g/L @ 90 °C ^a	SDS 2007
Water solubility	Completely soluble in water ^{b, c}	SDS 2006; SDS 2014a
Density (g/cm ³)	0.55 kg/L ^a	SDS 2007
Density (g/cm ³)	1.1-1.2 g/mL ^c	SDS 2014a

^a The product was reported to contain 60-100% by weight SEGAC.

^b The product was reported to contain 10-30% by weight of SEGAC.

^c Reported physical and chemical information for Bufloc 5567 containing SEGAC. Concentration reported is proprietary.

The water solubility reported for SEGAC in various SDSs have shown significant variability. This variability could be attributed to the degree of substitution on the polymeric starch component. According to the Merck Index (1989), unmodified starch is not soluble in cold water; however, substitution with cationic segments purportedly will increase cold water solubility (Quab 2017). Insoluble SEGAC is therefore anticipated to have a low degree of substitution, whereas for water soluble SEGAC is it expected to be much higher. Furthermore, the solubility of cationic starch may also be dependent on the source or origin of the starch. For example, cationic potato starch having a similar degree of substitution as cationic wheat starch has significantly lower water solubility (Ziółkowska and Shyichuk 2011). For the purpose of this assessment, SEGAC is considered to be a water soluble amine functionalized polymeric starch.

Properties of SEGAC were not modelled using any predictive software, since it is expected to have a number average molecular weight of greater than 1000 daltons, which is out of the range where modelling software are considered reliable.

5.3 Sources and uses

SEGAC does not occur naturally in the environment. It is produced by the etherification of a starch substrate with quaternary ammonium compounds as described by Sasano (1994).

Table 5-3 presents a summary of the total reported manufacturing and reported import quantities for the SEGAC in 2014 (Canada 2015, ECCC 2015). According to information gathered through the surveys, import quantities in 2014 were reported to be less than 1 000 000 kg. SEGAC is only imported into Canada to be used primarily in the pulp and paper industry where it may be used in different stages of paper manufacturing. Minor uses of SEGAC have also been reported for hair and skin care products.

Table 5-3. Summary of Canadian manufacturing and import quantities of SEGAC in 2014 submitted pursuant to a voluntary survey and to a CEPA section 71 survey

Total manufacture^a (kg)	Total imports^a (kg)	Survey reference
0	100 000 – 1 000 000	Canada 2015, ECCC 2015

^a Values reflect quantities reported in response to a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). See survey[s] for specific inclusions and exclusions (schedules 2 and 3).

5.4 Releases to the environment

Cationic starch is used in paper manufacturing as a retention aid to enhance the sedimentation of pulp fibers (Ginebreda et al. 2011, OECD 2009). Furthermore, cationic polymers may also be added as wet or dry strength agents to enhance the strength of the paper (OECD 2009). Depending on when SEGAC is introduced into the paper manufacturing process, the release rate to effluent is between 5 and 10 % (OECD 2009). The majority of the substance will be retained on finished products and sludge generated within mill effluent (OECD 2009).

Small quantities (less than 100 kg per year) of SEGAC are also used in hair and skin care products in Canada. Considering the low volumes involved in products available to consumers, their overall ecological concern is expected to be significantly lower than environmental exposures for uses in pulp and paper applications. Therefore, quantitative estimation of the release of SEGAC was performed for pulp and paper applications only.

5.5 Environmental fate and behaviour

5.5.1 Environmental distribution

SEGAC is a cationic substituted polysaccharide, with molecular weight greater than 3000 daltons, and considered to be water soluble (available) for the purpose of this assessment. During industrial use of SEGAC, it is expected to be primarily adsorbed onto finished paper products and sludge as mentioned above. Less than 10 percent is expected to be released into the environment after wastewater treatment⁶ (WWT). Once released to the environment, SEGAC is not expected to volatilize into the air compartment as it has high molecular weight and a low expected vapour pressure. Considering the cationic nature of SEGAC, it is anticipated that it will adsorb onto suspended organic matter in rivers or lakes and settle out of the water column to sediments.

If released to soil, the resulting polymer would be expected to adsorb onto soil matter and have limited mobility in the soil compartment. Solubilization of the polymer into soil pore water is expected to be limited, as SEGAC is expected to strongly bind to soil particles via electrostatic interaction.

Considering the properties and use of SEGAC, if it released to the environment it is anticipated that the polymer will bind to organic matter. Thus, SEGAC is anticipated to be primarily retained in the soil and sediment compartments.

5.5.2 Environmental persistence

The biodegradation information gathered through surveys (ECCC 2015, Canada 2015) indicates that SEGAC is likely to be biodegradable in the environment. This is also supported by an OECD emission scenario document (2009), where cationic starch is considered biodegradable.

The biodegradation potential of SEGAC in sediments is not available; however, it is generally expected to be slower than biodegradation in soil or water, where aerobic conditions favour biodegradation. As such, it is anticipated that SEGAC will have lower biodegradation in sediments.

⁶ In this assessment, the term “wastewater treatment system” refers to a system that collects domestic, commercial and/or institutional household sewage and possibly industrial wastewater (following discharge to the sewer), typically for treatment and eventual discharge to the environment. Unless otherwise stated, the term wastewater treatment system makes no distinction of ownership or operator type (municipal, provincial, federal, indigenous, private, partnerships). Systems located at industrial operations and specifically designed to treat industrial effluents will be identified by the terms “on-site wastewater treatment systems” and/or “industrial wastewater treatment systems”.

According to the Merck Index (1989), pure starch is resistant to hydrolysis in cold water, as well as hydrolysis through naturally occurring enzymes. Thus, SEGAC is expected to have similar hydrolysis resistance.

On the basis of available information, SEGAC is expected to be biodegradable in the soil and water compartments, but stable in sediments. Considering the available information, the substance is expected to have a half-life of less than 6 months in water and soil and greater than 1 year in sediments.

5.5.3 Bioaccumulation potential

SEGAC is a cationic polymer, which is expected to strongly adsorb to anionic surfaces, such as fish gills, algal cells and negatively charged components of organic particles. This will limit the uptake of SEGAC, as well as passage of SEGAC through biological membranes, but sorption may lead to toxic reactions with dermal tissues. As such, bioaccumulation potential of SEGAC is expected to be limited. Furthermore, SEGAC has an expected molecular weight greater than 1000 daltons (i.e., large molecular dimensions) and no significant percentage of low molecular weight constituents. This will further reduce the uptake rate across biological membranes, and this is expected to result in a low bioconcentration potential (Arnot et al., 2009). Overall, SEGAC is expected to have a low bioaccumulation potential benchmarked against a halogenated organic molecule of smaller molecular dimensions and higher lipophilicity.

5.6 Potential to cause ecological harm

5.6.1 Ecological effects assessment

SEGAC is a cationic amine derivatized starch and, according to the US EPA (2010), substances containing cationic amine or potentially cationic amine functional groups may be associated with adverse effects to fish, invertebrates, and algae. Empirical ecotoxicity data for SEGAC were reported in response to a voluntary survey as well as a mandatory survey issued pursuant to a CEPA section 71 notice (see Table 5-4) (ECCC 2015; Canada 2015). The data extracted from SDS and summary information provided by stakeholders suggests that SEGAC could have low to moderate ecotoxicity for fish and low toxicity for Daphnia. Similar ecotoxicity trends can be seen from a data compilation for cationic polymers published by Boethling and Nabholz (1997). However, ecotoxicity data from Wang et al. (2016) indicates that cationic starch could have high ecotoxicological effects for Daphnia and moderate effects towards fish and algae (See Table 6-6). An analogue polymer with a high degree of structural similarity that was submitted to the New Substances Notification program also exhibited high toxicity towards algae. Available ecotoxicity data for SEGAC and various analogs are summarized in Table 5-5.

Table 5-4. Ecotoxicity data available for SEGAC

Common Name	Organism	Effect ^a	Result (mg/L)	Sources
Water flea	Daphnia magna	48h EC ₅₀	100 (WAF) ^b	Canada 2015 ^c
Water flea	Daphnia magna	48h EC ₅₀	> 100 ^d	ECCC 2015 ^c
Rainbow Trout	Oncorhynchus mykiss	96h LC ₅₀	> 100	Canada 2015 ^c
Rainbow Trout	Oncorhynchus mykiss	96h LC ₅₀	< 10 ^d	ECCC 2015 ^c

^a EC₅₀ is the Effect Concentration for 50 percent of the population; LC₅₀ is the Lethal Concentration for 50 percent of the population; IC₅₀ is the Inhibition Concentration for 50 percent of the population.

^b Water Accommodated Fraction (WAF). The effect concentrations were higher than the concentrations in the filtrate of a 100 mg/L loading rate. The product tested was 100% by weight SEGAC; test methods were not reported.

^c Data reported for SEGAC through a voluntary survey and mandatory survey issued pursuant to a CEPA section 71 notice.

^d To protect confidential business information, exact toxicity values are not reported.

Table 5-5. Ecotoxicity data available for other cationic starches

Common Name	Organism	Effect ^a	Result (mg/L)	Sources
Algae	NR	96h EC ₅₀	> 1000	Polymer 71 – Boethling and Nabholz 1997 ^b
Fish	NR	96h LC ₅₀	> 850	Polymer 71, 72, 73, 74 – Boethling and Nabholz 1997 ^b
Daphnid	NR	48h EC ₅₀	177	Polymer 72, 73, 74 – Boethling and Nabholz 1997 ^b
Fish	NR	96h LC ₅₀	0.37-1.18	Polymer 75 – Boethling and Nabholz 1997 ^b
Daphnid	NR	48h EC ₅₀	130	Polymer 76 – Boethling and Nabholz 1997 ^b
Green Algae	S. Carpicornutum	72h IC ₅₀	< 1 ^c	ECCC 2017

NR = Not Reported

^a EC₅₀ is the Effect Concentration for 50 percent of the population; LC₅₀ is the Lethal Concentration for 50 percent of the population; IC₅₀ is the Inhibition Concentration for 50 percent of the population.

^b Toxicity data reported by Boethling and Nabholz 1997 for 6 cationic starches with varying degree of percent amine nitrogen content, molecular weight, location of cation, and amine type (tertiary or quaternary). The specific species tested and the specific molecular structures were unknown.

^c Analogue identified through New Substances Notification Program.

The biodegradation of SEGAC may yield smaller cationic molecules and non-cationic molecules, the latter of which are not expected to be of ecological concern as starch is metabolized by different organisms. However, molecules with cationic functionality and free cationic moiety derived from the reactant, 1-Propanaminium, 2,3-dihydroxy-N,N,N-trimethyl- (CAS RN 44814-66-6), may present increased ecological hazard. However, ecological effects data for CAS RN 34004-36-9, which is structurally similar to CAS RN 44814-66-6, indicates low toxicity towards fish and daphnid (ECJRC 2008). Considering the low ecological hazard for free cationic moiety (CAS RN 34004-36-9), and degraded molecules with cationic functionalities, the ecological concern for the degradants is not expected to be significant, and is not considered further in this assessment.

SEGAC has an expected number average molecular weight greater than 1000 daltons and is therefore out of the range where modelling software are considered reliable. Thus, ecotoxicity modelling was not conducted. According to Boethling and Nabholz (1997), ecotoxicity for polycationics increases exponentially with increasing cationic charge and could explain the discrepancies in toxicity observed in Table 5-5 and Table 5-6. For example, higher toxicity is observed for substances with higher cationic charge density or percent amine-Nitrogen (%a-N). Furthermore, the solubility of the cationic starch may also explain toxicity differences for SEGAC. Ziółkowska and Shyichuk (2011) showed that two cationic starches with similar degrees of cationicity have significantly different water solubility. This was attributed to the source of starch that was used (potato starch versus wheat starch). If SEGAC is derived from potato starch, its water solubility is expected to be lower, which will reduce its bioavailability and hence lower potential ecological effects.

It is known that the ecotoxicity of polycationic polymers can be mitigated through the presence of organic matter present in the environment (Boethling and Nabholz, 1997). According to the authors, toxicity reduction is known to occur by the reaction of polycationics with organic carbon and/or the suspended solids in water to form neutral insoluble complexes (i.e., floc). As such, these authors and several others have proposed that ecotoxicity testing of polycationic polymers using clean laboratory water without the addition of organic carbon may not be representative of the substance's bioavailability in natural environments (Boethling and Nabholz 1997, Cary et al. 1987, Goodrich et al. 1991). Boethling and Nabholz (1997) have shown that the addition of approximately 10 mg/L of humic acid to laboratory ecotoxicity tests (to simulate environmental organic carbon levels) caused a 7- to 65-fold reduction in ecotoxicity, for polymers with %a-N less than 3.5 %. Cary et al. (1987) have reported toxicity reduction for four polycationic polymers, with mitigation factors ranging from 37 to 94 for *Daphnia magna*, and from 14 to 40 for fish, all on the basis of addition of 10 mg/L humic acid. Similarly, Goodrich et al. (1991) reported mitigation factors ranging from 7 to 16 for five polycationics tested using Rainbow trout and 5 mg/L humic acid. An even higher toxicity reduction was observed at 50 mg/L humic acid (33- to 75-fold toxicity reductions).

A more recent unpublished study on polycationic polymer mitigation demonstrated that even at low concentrations of humic acid (approximately 1.5 mg/L to 3 mg/L), toxicity towards *Daphnia magna* was reduced two fold (Salinas et al. 2016). A reduction in

toxicity was also observed by Wang et al. (2016) where cationic starch was premixed with soil (source of organic carbon) prior to aquatic toxicity testing. Table 5-6 summarizes the toxicity data from this study.

A toxicity mitigation factor determined through ecotoxicological testing can be used to correct for the expected reduction in toxicity in the environment due to the presence of organic matter (e.g., humic and fulvic acids). This is done by multiplying the ecological endpoints determined using clean laboratory water by the expected mitigation factor in order to adjust or reduce the values to reflect actual ecological effects expected under environmental conditions.

Table 5-6. Cationic starch ecotoxicity with mitigation by soil (Wang et al. 2016)

Common name	Organism	Effect ^a	Result (no soil; mg/L)	Result (with soil; mg/L)	Mitigation factor ^b
Algae	Chlorella Vulgaris	72h IC ₅₀	1.8	113.2	63
Water flea	Daphnia Magna	48h EC ₅₀	0.9	90.2	100
Worm	Limnodrilus hoffmeisteri	96h EC ₅₀	3.7	248.7	67
Carp	Cyprinus Carpio	96h LC ₅₀	1.4	173.1	124

^a EC₅₀ is the Effect Concentration for 50 percent of the population; LC₅₀ is the Lethal Concentration for 50 percent of the population; IC₅₀ is the Inhibition Concentration for 50 percent of the population.

^b Mitigation ratio, estimated on the basis of toxicity with and without soil.

As the %a-N could vary significantly for SEGAC, a mitigation factor of 7 was selected because SEGAC is anticipated to have low to moderate cationic charge density. For SEGAC with %a-N on the higher end of the charge density range, the mitigation is anticipated to be greater than 20 times. Therefore, a mitigation factor of 7 is considered to be a reasonable worst case. On the basis of toxicity data in Table 5-4, Table 5-5 and Table 5-6, SEGAC is anticipated to have moderate toxicity towards algae, low to moderate toxicity towards daphnid and fish after considering seven-fold mitigation.

No sediment ecotoxicity data were provided for SEGAG, or were available for other cationic starches. However, Wang et al. (2016) reported toxicity for worms exposed to solutions of cationic starch (see Table 5-6) where the cationic starch solution, without premixing with soil, was moderately toxic towards worms. Significant toxicity mitigation was observed for cationic starch premixed with soil. Although the test results are not for sediments or soil adsorbed with cationic starch, the results indicate that such polymers are expected to have moderate toxicity towards sediment dwelling species and lower sensitivity than with other aquatic species.

Overall, SEGAC is expected to show moderate to low toxicity to aquatic organisms, and low toxicity towards sediment dwelling species in natural environments. On the basis of

available data, the lowest mitigated ecotoxicity end point reported for SEGAC (O. mykiss: 96h LC₅₀ less than 10mg/L) was selected to be the critical toxicity value (CTV), and is used to estimate the aquatic Predicted No Effect Concentration (PNEC). A PNEC is not considered necessary for sediment species, as the toxicity is anticipated to be greater than 100 mg/L after mitigation.

The aquatic PNEC is derived from the critical toxicity value (CTV), which is divided by an assessment factor (AF) as shown:

$$\text{Aquatic PNEC (mg/L)} = \text{CTV} / \text{AF}$$

An AF of 100 is selected to estimate the aquatic PNEC. The AF selected represents 10 for extrapolation from acute to chronic toxicity, 5 for species sensitivity, and 2 for mode of action for cationic polymers. Considering the available ecotoxicity data for SEGAC (3 categories and over four species), a factor of 5 was selected to represent species sensitivity. As the ecotoxicity of cationic polymers depends strongly on the %a-N, and that the studies reviewed in this assessment lack details on the polymer and the %a-N, the factor of 2 was selected to represent the uncertainty of the %a-N for the polymers reviewed.

5.6.2 Ecological exposure assessment

SEGAC has reported use as a processing aid (wet strength agent) for the pulp and paper industry according to the data collected under voluntary and regulatory surveys (ECCC 2015, Canada 2015). The combined annual use quantity reported in the surveys was in the range of 100 000-1 000 000 kg in 2014. Most of the responses from the survey are from importers, and few to none were reported by the users of the polymers. Therefore, the number of paper mills that utilize SEGAC is unknown.

A generic paper mill scenario is used to calculate the exposure for SEGAC. This scenario represents the release and exposure conditions of Canadian paper mills, on the basis of information from approximately 60 mills derived from internal ECCC databases. These mills are equipped with on-site secondary treatment or equivalent and release treated effluent directly to natural receiving waters.

The predicted environmental concentration (PEC) of SEGAC in receiving water is estimated from the amount released to the on-site WWT facility, the effluent volume and the dilution factor of the receiving watercourse.

$$\text{PEC} = [10^9 \times Q \times E \times (1-R)] / [F \times D \times N]$$

Where:

PEC: predicted environmental concentration in receiving water near discharge point, µg/L

Q: Total quantity of SEGAC used per year, kg/y

E: emission factor to untreated wastewater, unitless
R: overall wastewater treatment removal, unitless
F: daily wastewater flow rate, L/d
D: receiving water dilution factor near discharge point, unitless
N: number of operation days per year, d/y
 10^9 : conversion factor from kg to μg , $\mu\text{g}/\text{kg}$

The total quantity (Q) used at a single facility is conservatively estimated to be 17 000 kg/y on the basis of the upper end of the total reported import quantity (1 000 000 kg/y) from the surveys and the number of paper mills (about 60 according to an internal database of Environment and Climate Change Canada).

Paper mills operate continuously throughout a year and the typical number of operation days (N) per year is 350 d/y.

According to the OECD emission scenario document for the Pulp, Paper, and Board Industry (2009), cationic starch can be used at two different stages of paper manufacturing. Firstly, it may be used as a coagulant to aid drainage and retention of paper fibers, or secondly as a wet or dry strength agent to strengthen paper. Depending on use, the fixation rate may vary from 90 to 95 percent. This is equivalent to an emission factor of between 5 and 10 percent to untreated wastewater. As a conservative assumption, an emission factor of 10 % is assumed for the purpose of this assessment.

SEGAC is a cationic starch with a molecular weight greater than 3000 daltons and is expected to have high affinity for organic matter, which tends to carry an anionic charge. SEGAC is therefore expected to be mostly removed from wastewater through solids removal. According to Boethling and Nabholz (1997), cationic polymers with molecular weight greater than 1000 daltons and with minimal oligomeric constituents (components with molecular weight less than 1000 daltons), are expected to have a removal rate of 90 percent during on-site WWT. For the purpose of this assessment, a removal rate of 90 percent is assumed.

A 10-fold dilution factor is used to estimate the level of exposure near the discharge point of each mill and this near-discharge-point exposure is taken as the aquatic PEC for SEGAC.

As the range of wastewater flow rate varies between facilities, it is given as a probabilistic distribution from 0.23 to 2 238 million L/d on the basis of operation data of Canadian paper mills (internal database of Environment and Climate Change Canada). This distribution then yields a probabilistic PEC distribution (

Table 5-7).

Table 5-7. Probabilistic PEC distribution: Wastewater flow rate and estimated PECs for paper mills in Canada

Percent of mills with given wastewater flowrate or less (%)	Wastewater flow rate (million L/d)	PEC (µg/L)
100	2 238	0.022
90	130	0.37
80	79	0.62
70	63	0.77
60	47	1.0
50	33	1.5
40	25	1.9
30	12	4.1
20	6.8	7.1
10	2.2	22
0	0.23	211

5.6.3 Characterization of ecological risk

The approach taken in this ecological risk assessment was to examine direct and supporting information and develop conclusions on the basis of a weight-of-evidence approach. Lines of evidence considered include information on sources and fate of the substance, persistence, bioaccumulation, estimated exposure to the substance, and ecological hazard properties. SEGAC is a cationic starch that is used in the pulp and paper industry for fiber retention and strength enhancement. On the basis of available information, between 100 000 kg and 1 000 000 kg of SEGAC was reported to be imported into Canada in 2014.

Water solubility data reported for SEGAC varies depending on the nature and type of product to which it is added. Some reported values indicate SEGAC is completely water soluble, while some others indicate low water solubility in cold water, but high water solubility at higher water temperature. The variability in water solubility could be attributed to two possible sources. First, solubility may increase with increasing cationic charge (Quab 2017). Second, the origin of the starch used in the synthetic process may also affect the overall water solubility of cationic starches (Ziółkowska and Shyichuk, 2011). On the basis of available information, SEGAC was considered fully water soluble for the purpose of this assessment.

When SEGAC is released into the environment, it is expected to be solubilized in water. Once there, partitioning into the air compartment is not expected due primarily to the high molecular weight and affinity for water. Furthermore, significant amounts of SEGAC are anticipated to adsorb onto organic matter and settle to sediments, with residual amounts remaining in the water column.

Biodegradation information for SEGAC suggests that it is a biodegradable polymer, whilst other information suggests it is not hydrolyzable. Degradants of SEGAC are not expected to pose an ecological risk and therefore were not considered further in this assessment.

Information in the form of BAF or BCF test data which could be used to assess the bioaccumulation potential of SEGAC were unavailable as is the case for most polymers, as they are generally unsuitable for such testing. However, on the basis of the high molecular weight of SEGAC, it is expected to have low bioconcentration potential.

In natural environments, the ecotoxicity of cationic polymers is expected to be mitigated in the presence of organic matter. On the basis of a conservative estimation for SEGAC, the reported ecotoxicity is expected to be mitigated by 7 times. According to the ecological hazard profile of SEGAC, this polymer could have low to moderate ecotoxicity towards fish and daphnid, and moderate ecotoxicity for algae after mitigation. The lowest reported mitigated toxicity for SEGAC was chosen to estimate the PNEC.

A series of risk quotients was estimated on the basis of the varying PECs from paper mills in Canada and a conservative PNEC, and are presented in Table 5-8.

Table 5-8. Probabilistic PEC distribution: Estimated risk quotients for SEGAC from paper mills in Canada

Percent of mills with given wastewater flow rate or less (%)	Wastewater flow rate (million L/d)	Risk quotient ^a (PEC/PNEC)
100	2 238	<1
90	130	<1
80	79	<1
70	63	<1
60	47	<1
50	33	<1
40	25	<1
30	12	<1
20	6.8	<1
10	2.2	<1
0	0.23	>1

^a To protect confidential business information provided, exact risk quotient values are not reported.

On the basis of Table 5-8, releases of SEGAC from all paper mills in Canada are not expected to result in any environmental concern, as calculated risk quotients are less than one. One exception is the site with the lowest wastewater flow rate at 0.23 million L/d. However, considering that conservative values, use quantity (17 000 kg/y) of SEGAC in particular, were used to estimate the PEC, it is considered that this exception site is overestimated for its potential risk. Overall, SEGAC is not expected to result in

ecological concern on the basis of available information and conservative estimation of the PEC and PNEC.

5.7 Potential to cause harm to human health

Classification of the hazard data and exposure profiles used to develop the potential for human health risks associated with SEGAC are presented in the document 'Supporting documentation: Final Risk Matrix Location of Polymers' (Health Canada, 2017).

Although exposure was established as high, the human health hazard for the substance was determined to be low for SEGAC. Therefore, taking into consideration the available data, it is unlikely that exposure to the substance will pose a human health risk.

6. GEGAC

6.1 Substance identity

The substance, Guar gum, 2-hydroxy-3-(trimethylammonio)propyl ether, chloride (CAS RN 65497-29-2) hereafter referred to as GEGAC, is represented by the structure shown in Figure 6-1. GEGAC is synthesized through a chemical reaction by activation of guar gum with an organic base, followed by etherification with quaternary ammonium compounds bearing glycidyl groups as cationizing agents (Sakakibara 2010, Sasano 1994).

GEGAC is a polysaccharide polymer with an expected number average molecular weight (Mn) greater than 220,000 daltons and low oligomeric content (Merck Index 1989). Its monomers, reactants, and their expected Mn or molecular weight (MW) are summarized in

Table 6-1.

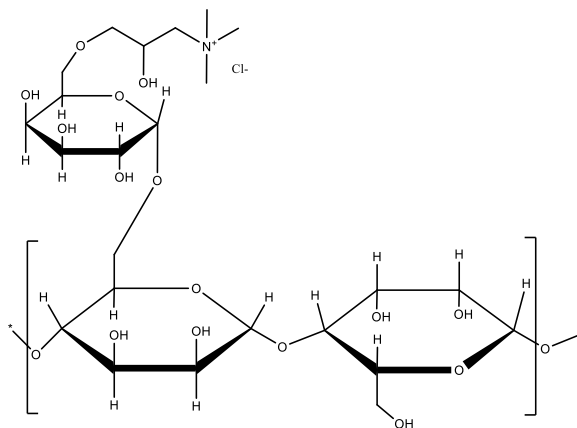


Figure 6-1. Representative structure of GEGAC (Barry et al., 2005)

Table 6-1. Monomers and reactants of GEGAC

Monomer/Reactant	CAS RN	Mn or Mw ^a (daltons)	Percent composition	Source
Guar gum	9000-30-0	220 000 ^b	20-90	ECCC 2015
1-Propanaminium, 2,3-dihydroxy-N,N,N- trimethyl-	44814-66- 6 ^c	134.20	10-80	ECCC 2015

^a Number average molecular weight (Mn), Molecular weight (Mw)

^b Merck Index 1989

^c CAS RN 44814-66-6 is structurally identical to CAS RN 34004-36-9, '1-Propanaminium, 2,3-dihydroxy-N,N,N-trimethyl-, chloride', but without chloride ion in the representative structure and CAS name.

6.2 Physical and chemical properties

Table 6-2 contains physical and chemical data obtained for GEGAC through a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). All information reflect summary data provided in Safety Data Sheets (SDS) and so could not be verified with respect to test methods employed, conditions used or the interpretation of the experimental data.

Table 6-2. Physical and chemical data for GEGAC

Property	Value	Source
Physical State	Powder ^a	SDS 2015
Water solubility (mg/L)	100 000 ^a	SDS 2015
Density (g/cm ³)	0.6 ^b	SDS 2014b

^a The product tested is N-Hance CG13 which contains 90 to 100% GEGAC by weight

^b The product tested is Jaguar C17 which contains more than 90% GEGAC by weight

The water solubility reported for GEGAC indicates that the polymer is highly water soluble. This is also supported by the fact that unmodified guar gum is completely soluble in cold and hot water (Merck Index 1989).

GEGAC was not modelled using any predictive software, since it is expected to have a number average molecular weight of greater much greater than 1000 daltons, which is out of the range where modelling software are considered reliable.

6.3 Sources and uses

GEGAC does not occur naturally in the environment. It is produced by the etherification of guar gum substrate with quaternary ammonium compounds as described in various patents (Sakakibara 2010; Sasano 1994).

Table 6-3 presents a summary of the total reported manufacture, and reported import quantities for the substance in 2014 (ECCC 2015, Canada 2015). On the basis of the surveys, the primary use for GEGAC in Canada is in products related to hair and skin care on the basis of the conditioning and protective properties of the substance. GEGAC also functions as a viscosity modifier in various applications, like shampoo (PDS 2017). No other uses were identified through the surveys. Furthermore, GEGAC is not manufactured in Canada on the basis of the responses to the surveys (ECCC 2015, Canada 2015).

Table 6-3. Summary of information on Canadian manufacturing, and import quantities of GEGAC in 2014 submitted pursuant to a voluntary survey and to a CEPA section 71 survey

Total manufacture^a (kg)	Total imports^a (kg)	Survey reference
0	10 000 -100 000	Canada 2015, ECCC 2015

^a Values reflect quantities reported in response to a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). See survey[s] for specific inclusions and exclusions (schedules 2 and 3).

Globally, GEGAC is also used in the cosmetic industry, paper industry, and in the textile industry (Quab 2017). However, uses in either the paper industry or textile industry were not reported in either survey. Therefore, uses in these two industries are considered to be minimal.

6.4 Releases to the environment

According to available information, between 10 000 kg and 100 000 kg of GEGAC was imported into Canada to be used in hair and skin care products. Depending on use and function, cationic guar gum is added to product formulations at concentrations ranging from 0.15 % to 1.5 % by weight of final formulations (PDS 2017, Jingkun 2017).

On the basis of the function of GEGAC in hair and skin care products, it is expected that the polymer would adsorb to the surface of negatively charged hair or skin. Some of the polymer would be released into wastewater during application, while the remaining portions would be washed off prior to the next application. Overall, 100 percent release of the polymer through hair and skin care products into wastewater system is expected. Wastewater containing hair and skin care products are expected to be treated through WWT systems and discharged into the environment.

There are no reported uses in Canada of GEGAC in either the paper industry or textile industry on the basis of government surveys. As such, it would be expected that if GEGAC is used in either industry, the quantity would be low as the reporting threshold for both surveys was greater than 100 kg per year. Therefore, quantitative estimation of the release of GEGAC through paper or textile industry was not performed.

6.5 Environmental fate and behaviour

6.5.1 Environmental distribution

GEGAC is a cationic substituted polysaccharide, with molecular weight greater than 220 000 daltons and is considered to be highly water soluble. On the basis of its use in hair and skin care products, 100 percent release of the polymer to WWT systems is expected. Considering the high molecular weight and cationic charge of GEGAC, significant removal through adsorption to sewage sludge is expected (Boethling and Nabholz, 1997). Less than 10 percent is expected to be released into the environment after WWT via effluent. Once release to the environment, GEGAC is not expected to volatilize into the air compartment as it has high molecular weight and low expected vapour pressure. GEGAC is anticipated to adsorb to suspended organic matter in rivers and lakes and settle out of the water column to sediments.

If released to soil, the resulting polymer would be expected to adsorb to soil matter and have limited mobility in the soil compartment. Solubilization of the polymer into soil pore water is expected to be limited as GEGAC is expected to bind to soil particles via electrostatic interaction.

6.5.2 Environmental persistence

Biodegradation data provided through voluntary and mandatory government surveys are summarized in Table 6-4.

Table 6-4. Ready biodegradation data for GEGAC

Result (%)	Test Method	Source
18-29 ^a	EEC C.6	Canada 2015
51 ^b	OECD 302	SDS 2014b
0 ^b	OECD 301	SDS 2014b
73.4 ^c	OECD 302B	SDS 2010
95 ^d	OECD 301D	SDS 2015

^a The product tested was Dehyquart Guar TC which contains 75 to 100% GEGAC by weight

^b The product tested was Jaguar C17 which contains more than 90% GEGAC by weight

^c The product tested was Activsoft which contains 60 to 100% GEGAC by weight

^d The product tested was N-Hance CG13 which contains 90% GEGAC by weight

GEGAC has a varied data set of biodegradability data ranging from 0 to 95 percent. The highest value of 95% was reported in the SDS of the product N-Hance CG13, which also contains fumaric acid (CAS RN 110-17-8). It is possible that this acid may be contributing to the higher biodegradability value. The overall trend indicates that the polymer is biodegradable.

Although there is no available information to assess the biodegradation potential of GEGAC in sediments, it is generally expected to be slower than in soil or water, where aerobic conditions favour biodegradation. As such, it is anticipated that GEGAC will have lower biodegradation in sediments.

Hydrolysis information for GEGAC was not provided. However, GEGAC is used in shampoo and other products where it would be formulated with water, thus, hydrolytic stability could be expected.

On the basis of available information, GEGAC is expected to be biodegradable in the soil and water compartments, but stable in sediments.

6.5.3 Bioaccumulation potential

GEGAC is a cationic polymer, which is expected to strongly adsorb to anionic surfaces, such as fish gills, algal cells and negatively charged components of organic particles. This will limit the uptake of GEGAC, as well as passage of GEGAC through biological membranes, but sorption may lead to toxic reactions with dermal tissues. As such, bioaccumulation potential of GEGAC is expected to be limited. Furthermore, GEGAC has an expected molecular weight greater than 1000 daltons (i.e., large molecular dimensions) and no significant percentage of low molecular weight constituents. This will further reduce the uptake rate across biological membranes, and this is expected to result in a low bioconcentration potential (Arnot et al., 2009). Overall, GEGAC is expected to have a low bioaccumulation potential benchmarked against a halogenated organic molecule of smaller molecular dimensions and higher lipophilicity.

6.6 Potential to cause ecological harm

6.6.1 Ecological effects assessment

- Empirical ecotoxicity data for GEGAC were reported in response to government surveys mentioned previously (ECCC 2015, Canada 2015). The results of ecological studies are summarized in
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Table 6-5. The data were extracted from SDS and Summary information provided by stakeholders and suggests that GEGAC could have low to moderate toxicity toward both daphnid and fish, and low toxicity toward algae. One exception is observed for rainbow trout reported in the SDS of the product “Jaguar C-17”, where high toxicity is reported. GEGAC is a cationic polymer, and therefore its ecotoxicity is expected to be primarily driven by cationic charge density (Boethling and Nabholz, 1997). This could be observed in the reported ecotoxicity for the products “N-Hance CG13” and “Jaguar C-17”, where according to the product data sheets, the former is considered to have medium %a-N, and the latter to have high %a-N (PDS 2017, PDS 2013). The toxicity difference could also be due to variations in inter-species sensitivity.

Table 6-5. Experimental ecotoxicity data for GEGAC

Common name	Organism	End point ^a	Value (mg/L)	Reference
Zebra fish	Brachydaniorerio	96h LC ₅₀	>100	Canada 2015
Zebra fish	Brachydanio rerio	96h LC ₅₀	<100	Canada 2015
Water flea	Daphnia magna	48h EC ₅₀	>100	Canada 2015
Carp	Cyprinus carpio	96h LC ₅₀	>100	SDS 2015
Water flea	Daphnia magna	48h EC ₅₀	54	SDS 2015
Blue-green algae	Aphanizomenon flos-aquae	72h NOEC	>100	SDS 2015
Water flea	Daphnia magna	48h EC ₅₀	100	SDS 2014b
Rainbow trout	Oncorhynchus ykiss	96h LC ₅₀	0.2 - 0.8	SDS 2014b

^a EC₅₀ is the Effect Concentration for 50 percent of the population; LC₅₀ is the Lethal Concentration for 50 percent of the population; NOEC is the No Observed Effect Concentration.

The biodegradation of GEGAC may yield smaller molecules of a cationic and non-cationic nature. Non-cationic molecules are not expected to be of ecological concern as starch is metabolized by different organisms. However, molecules with cationic functionality and free cationic moiety owing to the reactant, 1-Propanaminium, 2,3-dihydroxy-N,N,N-trimethyl- (CAS RN 44814-66-6), may present increased ecological hazard. Ecological effects data for CAS RN 34004-36-9, which is structurally similar to CAS RN 44814-66-6, indicate low toxicity toward fish and daphnid (ECJRC 2008). Considering the low ecological hazard of CAS RN 34004-36-9, low ecological hazard is expected for degraded molecules with cationic functionalities. Thus, ecological concern for the degradants is not expected to be significant, and is not considered further in this assessment.

GEGAC has an expected number average molecular weight much greater than 1000 daltons and is therefore out of the range where modelling software are considered reliable. Thus, ecotoxicity modelling was not conducted.

Cationic starch, such as SEGAC, is considered to be a suitable analogue for GEGAC even though the two polymers have compositional differences (see Table 5-4, Table 5-5, and Table 5-6). Although both polymers are polysaccharides, SEGAC is a starch based polymer while GEGAC is a guar gum based polymer. Guar gum is composed of a D-mannose repeating saccharide units with D-galactose bound to every other D-mannose unit, whereas starch is composed of two polymers: amylose and amylopectin (Merck Index, 1989). Amylose is a linear polymer composed of glucose repeating units, and amylopectin is a branched polymer composed of glucose repeating units (Merck Index 1989). SEGAC or other cationic starch based polymers are considered to be

suitable analogues considering that the hazard from GEGAC likely arises from the presence of the cationic functionality. Thus, the ecotoxicity observed for cationic starches is expected to be indicative of the potential toxicity of GEGAC. Section 6.6.1 above summarizes the ecotoxicity data available for various cationic starches. Comparing the ecotoxicity between cationic starch and GEGAC, it can be seen that there is no clear trend in ecotoxicity. However, ecotoxicity data reported for both types of polymers indicates that the ecological effects could vary significantly for the same species.

As mentioned in the Ecological Effects Assessment for SEGAC (Section 6.6.1), ecotoxicity of polycationic polymers are mitigated through the presence of organic matter present in natural environment. Considering that GEGAC is a polycationic polymer, similar mitigation of ecotoxicity would be expected. As the %a-N could vary significantly for GEGAC, a conservative mitigation factor of 7 was selected because that polymer is anticipated to have low to moderate cationic charge density. However, for GEGAC with a higher expected %a-N, the mitigation is anticipated to be more than 20 times. As there is insufficient information on the composition of GEGAC and on the %a-N, a mitigation factor of 7 is considered to be a reasonable worst case to account for mitigation of GEGAC with lower %a-N. On the basis of toxicity data in Table 6-5, GEGAC is anticipated to have low toxicity for daphnid and algae, and low to moderate toxicity towards fish after application of the mitigation factor.

No sediment ecotoxicity data were provided for GEGAC, or were available for other cationic guar gum. However, Wang et al. (2016) reported low to moderate toxicity for worms exposed to solutions of cationic starch (see Table 5-6). Considering that the ecological hazard of cationic starch and GEGAC arises from the presence of cationic functionality, GEGAC is expected to have similar toxicological effect towards sediment dwelling species.

Overall, GEGAC is expected to show moderate to low toxicity to aquatic organisms, and low toxicity towards to sediment dwelling species in natural environments. On the basis of the available data, the lowest ecotoxicity end point with mitigation for GEGAC was selected to be the critical toxicity value (CTV), and is used to estimate the aquatic Predicted No Effect Concentration (PNEC). A PNEC is not considered necessary for sediment species, as the toxicity value is anticipated to be greater than 100 mg/L after mitigation.

The aquatic PNEC is derived from the critical toxicity value (CTV; 0.2 mg/L *O. mykiss*, see Table 7.5), which is divided by an assessment factor (AF) as shown:

$$\text{Aquatic PNEC (mg/L)} = \text{CTV} / \text{AF}$$

$$\text{Aquatic PNEC (mg/L)} = (0.2 \text{ mg/L} \times 7) / 100$$

$$\text{Aquatic PNEC (mg/L)} = 0.014$$

An AF of 100 is selected to estimate aquatic PNEC. The AF selected represents 10 for extrapolation from acute to chronic toxicity, 5 for species sensitivity, and 2 for mode of action for cationic polymers. Considering the available ecotoxicity data for GEGAC and SEGAC (3 categories and over four species), a factor of 5 was selected to represent species sensitivity. As the ecotoxicity of cationic polymers depends strongly on the %a-N, and that the studies reviewed in this assessment lack details on the polymer and the %a-N, the factor of 2 was selected to represent the uncertainty of the %a-N for the polymers reviewed.

6.6.2 Ecological exposure assessment

GEGAC has reported use as a thickener and conditioning agent in different products available to consumers, including shampoo, and hair conditioners. The combined reported annual quantities are between 10 000 kg and 100 000 kg in 2014 (ECCC 2015, Canada 2015). All of the reported quantities were from importers of products containing the substances and not from formulators or users; thus the number of formulation sites that utilize GEGAC is unknown. Considering that there are a number of importers, it is likely that the total number of formulators would be greater than two. As a conservative assumption, the maximum quantities in the import quantity range are used to estimate the predicted environmental concentration (PEC). Furthermore, it is assumed that only two formulators will use GEGAC, and that the total volumes are equally distributed between the two facilities.

The PEC of GEGAC in the receiving water close to the discharge points of formulating facility is estimated from the amount released to the WWT system, the effluent volume, the daily flow rate of the receiving water, and using the following equation.

$$PEC = [10^6 \times Q \times E \times (1-R)] / [F \times N]$$

where

PEC: predicted environmental concentration in receiving water near discharge point, mg/L

Q: Total quantity of GEGAC used per year, kg/y

E: emission factor to untreated wastewater, unitless

R: overall wastewater treatment removal, unitless

F: daily flow rate, L/d

N: number of operation days per year, d/y

10⁶: conversion factor from kg to mg, mg/kg

Information regarding the number of operation days at a formulation facility is unknown. However, on the basis of OECD Emission Scenario Document for blending of fragrance oils into commercial and consumer products (2010), the maximum number of operations days per year that involves the use of GEGAC is assumed to be 250.

Information regarding the emission factor from formulators is unknown. For a conservative scenario, 10 percent emission of GEGAC is assumed, with two formulators, and a maximum quantity (Q) of 100 000 kg per year is used.

According to Boethling and Nabholz (1997), cationic polymers with molecular weight greater than 1000 daltons with minimal oligomeric (components with molecular weight less than 1000 daltons), are expected to adsorb on to organic matter and thus removed from wastewater. Median removal rate of solids from secondary WWT systems is approximately 95 percent (internal wastewater database). Considering that GEGAC is a high molecular weight cationic polysaccharide, similar high removal rates are expected. For the purpose of this assessment, a removal rate of 90 percent is assumed.

Wastewater will be discharged from formulation facility into WWT systems, where treated waste water will be discharged into various water courses. As the range of water courses varies significantly in size, a reasonable watercourse with a daily flow rate (F) of 159 million litres is assumed. The associated formulation PEC is then calculated from the equation above and is estimated to be 0.0126 mg/L.

Consumer release of GEGAC during its use in hair and skin care products is expected to occur throughout Canada. As such, the consumer PEC is estimated using the Consumer Release Aquatic Model (CRAM; Environment and Climate Change Canada Internal Model). CRAM is a Canadian population-based probabilistic model used to estimate environmental exposure resulting from down-the-drain release of chemicals present in products available to consumers. The estimation is on the basis of the worst case assumption that GEGAC is present in all shampoo and released throughout Canada. The conservative base case scenario obtained from CRAM produced PECs of 5.5×10^{-7} mg/L for the 10th percentile low flow events.

6.6.3 Characterization of ecological risk

The approach taken in this ecological risk assessment was to examine direct and supporting information and develop conclusions on the basis of a weight-of-evidence approach. Lines of evidence considered include information on sources and fate of the substance, persistence, bioaccumulation, estimated exposure to the substance, and ecological hazard properties. GEGAC is a cationic polysaccharide that is used in various hair and skin care products. On the basis of available information, between 10 000 kg and 100 000 kg of GEGAC was reported to be imported into Canada in 2014.

Water solubility information reported for GEGAC, indicates that it is completely water soluble. When GEGAC is released into the environment, it is expected to be solubilized in water. Due primarily to the high molecular weight and cationic charge, partitioning into the air compartment is not expected. Furthermore, significant amounts are anticipated to adsorb onto organic matter and settle to the sediments.

Biodegradation data for GEGAC suggest that it will be biodegradable in the environment, and other information suggests it is unlikely to be hydrolyzable.

Degradants of GEGAC are not expected to pose an ecological concern and were therefore, not considered further in this assessment.

Adequate data which could be used to assess the bioaccumulation potential of GEGAC were not available. However, on the basis of the high molecular weight of GEGAC, it is expected to have low bioconcentration potential.

Reported information on the current use patterns for GEGAC indicates that it is imported for use in hair and skin care products. It is expected that products containing GEGAC will be distributed to different formulators across Canada for use in various products (hair shampoos and conditioners for example). Release of GEGAC into WWT systems from consumer use is anticipated to occur on a daily basis. Conservative exposure estimation for the formulation of GEGAC generated the PEC shown in Table 6-6.

During the use of hair and skin care products, GEGAC is expected to be completely released into WWT systems. The conservative consumer PEC was estimated using CRAM and the estimated PEC is summarized in Table 6-6.

According to the ecological hazard profile of GEGAC, it generally has low to moderate toxicity towards fish and daphnid, and low toxicity towards algae. However, GEGAC could be highly toxic towards rainbow trout (SDS 2014b). The toxicity difference observed for carp and rainbow trout fish may be due to variations in species sensitivity or it could be attributed to the potential differences in cationic charge density. For the purpose of this assessment, the highest toxicity value (0.2 mg/L) was selected as the CTV.

In natural environments, the toxicity of cationic polymers is expected to be mitigated in the presence of organic matter (Boethling and Nabholz, 1997). On the basis of a conservative estimation, the selected CTV is expected to be mitigated by 7 times. The mitigated CTV for GEGAC was used to estimate the PNEC.

The risk quotient was estimated on the basis of the conservative PEC and PNEC. Table 6-6 summarizes the risk quotients calculated.

Table 6-6. Estimated risk quotient for release of GEGAC on the basis of formulation and consumer release scenarios

Scenario	PNEC (mg/L)	PEC (mg/L)	Risk quotient (PEC/PNEC)
Formulation	1.4×10^{-2}	1.3×10^{-2}	0.92
Consumer release with 10 th percentile flow event	1.4×10^{-2}	5.5×10^{-7}	3.9×10^{-5}

On the basis of Table 6-6, neither the formulation scenario nor the consumer use scenarios for GEGAC are expected to result in environmental concern (i.e., risk quotients are less than 1). The risk quotient for formulation is approaching 1. However,

considering that conservative values, such as the high emission factor, volumes, number of sites and flow rates, were used to estimate the PEC, it is anticipated that the risk quotient are an over estimation of the potential risk. For example, it is anticipated that there would be greater than two formulators in Canada that would use GEGAC, and that the emissions from formulators would be significantly less than 10 percent. Furthermore, the mitigation factor chosen is on the lower end, which would increase the hazard potential of GEGAC or lower the PNEC. Overall, GEGAC is not expected to result in ecological concern on the basis of available information and conservative estimation of PEC and PNEC values for several exposure scenarios.

6.7 Potential to cause harm to human health

Classification of the hazard data and exposure profiles used to develop the potential for human health risks associated with GEGAC are presented in the document 'Supporting documentation: Final Risk Matrix Location of Polymers' (Health Canada, 2017).

Although exposure was established as high, the human health hazard for the substance was determined to be low for GEGAC. Therefore, taking into consideration the available data, it is unlikely that exposure to the substance will pose a human health risk.

7. Uncertainties in evaluation of ecological risk

SEGAC and GEGAC are polymeric substances. It is recognized that a given CAS RN can describe polymers that have different Mn, composition, and %a-N; and hence, a different range of physical-chemical properties and hazard properties. However, considering that conservative assumptions were used to determine the hazard potential for SEGAC and GEGAC, changes in molecular weight, composition or %a-N are not expected to result in a significant increase in ecological effects.

8. Uncertainties in evaluation of risk to human health

Oxidized starch, tannins and humic acid are considered UVCBs. Consequently, there are uncertainties in the size and composition of the substances. There are some limitations with the available physical-chemical data, but given the sources, uses and known general properties of the substance, there is sufficient information to determine qualitative exposures. There is limited toxicological information on oxidized starch and there are uncertainties in the hazard associated with tannins and humic substances as there is data presenting opposing toxicological effects; some studies indicate beneficial properties to human health, other studies suggest potential health risks.

9. Conclusion

Considering all available lines of evidence presented in this screening assessment, there is low risk of harm to organisms and the broader integrity of the environment from

oxidized starch, tannins (tannic acid), humic acid, SEGAC, and GEGAC. It is concluded that oxidized starch, tannins (tannic acid), humic acid, SEGAC, and GEGAC do not meet the criteria under paragraphs 64(a) or (b) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity or that constitute or may constitute a danger to the environment on which life depends.

On the basis of the information presented in this screening assessment, it is concluded that oxidized starch, tannins (tannic acid), humic acid, SEGAC, and GEGAC do not meet the criteria under paragraph 64(c) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

Therefore, it is concluded that oxidized starch, tannins (tannic acid), humic acid, SEGAC, and GEGAC do not meet any of the criteria set out in section 64 of CEPA.

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Appendix - Assessment approaches applied during the second phase of polymer rapid screening

The approaches applied during the second phase of polymer rapid screening are outlined in this section. The detailed analyses, as well as the results of the second phase of polymer rapid screening for the individual substances, are presented in Chapter 3 to 7.

Characterization of ecological risk for tannins, humic acid and oxidized starch

The ecological risks of tannins, humic acid, and oxidized starch were characterized using the approach outlined in the report; “Second Phase of Polymer Rapid Screening: Results of the Screening Assessment” (ECCC, HC 2018). The approach consisted of multiple steps that addressed different factors related to the potential for a polymer to cause ecological harm. At each step in the rapid screening process, any substance that appeared to present a potential for harm was identified as requiring further assessment. The approach was intended to be pragmatic, protective of the environment, and fairly rapid, largely making use of available or easily obtainable data. This section summarizes the approach, which is described in detail in the report; “Second Phase of Rapid Polymer Screening, Results of the Screening Assessment” (ECCC, HC 2018).

The ecological component of the second phase of polymer rapid screening approach consisted of four main steps to identify polymers that warrant further evaluation of their potential to cause harm. The first step involved identifying polymers which are not likely to be of ecological concern on the basis of low reported import and manufacture quantities according to Phase Two of the Domestic Substances List Inventory Update (Canada 2012), a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). Polymers with import and/or manufacture volumes less than 1000 kg per year are not likely to be of ecological concern. This is consistent with the notifying trigger quantity of 1000 kg for polymers under section 7 of the New Substances Notification Regulations (Chemicals & Polymers) [NSNR (C&P)] (Canada 2005).

The second step involved determining whether the polymer will likely have water extractability greater than 2% by weight. Water extractability greater than 2% by weight indicates that the polymer may be more bioavailable to aquatic organisms. The increased potential for exposure to aquatic organisms may present higher ecological risk. Literature, online safety data sheet (SDS) databases, the internal New Substances database for polymers, data gathered through a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015), and other reliable sources and databases (e.g. QSAR toolbox, ECHA chemical database) were searched for water extractability and solubility information.

The third step in the ecological component involved identifying polymers with reactive functional groups (RFGs). RFGs are groups with chemical functionality that are

considered to be reactive and may have damaging effects on the biological community. These groups are well described in Schedule 7 of the NSNR (C&P) (Canada 2005) and polymers containing RFGs may be of increased ecological concern, and require further screening. The RFGs include, among others, potentially cationic or cationic functionalities, alkoxy silanes, and phenols with unsubstituted ortho or para positions. To determine the presence of RFGs, structural information was gathered through a voluntary (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). For polymers where no representative structures were provided, structural representations were derived from information available for similar polymers: 1) obtained from the internal New Substances program database; 2) from the Chemical Abstract Services (CAS) name; or 3) on the basis of professional knowledge on likely polymerization mechanisms.

The final step for ecological considerations involved applying environmental release scenarios to estimate environmental exposure. Two generic aquatic exposure scenarios were applied to identify potential concerns near the point of discharge of a polymer into the environment. These scenarios involved comparing conservative (i.e., ecologically protective) estimates of exposure in receiving waters [predicted environmental concentrations (PEC)] with an effects threshold [predicted no-effect concentration (PNEC)] in order to evaluate whether a polymer is likely to cause harm to the local aquatic environment. The approaches made use of quantity information from each reporting company gathered through Phase Two of the DSL Inventory Update (Canada, 2012), and import and/or manufacture volumes through a voluntary survey (ECCC 2015) and a mandatory survey issued pursuant to a CEPA section 71 notice (Canada 2015). The aquatic PNEC for each of the scenarios was derived from the critical toxicity value (CTV), which was divided by an assessment factor (AF) as shown:

$$\text{Aquatic PNEC (mg/L)} = \text{CTV} / \text{AF}$$

CTVs were on the basis of empirical or modelled data (where appropriate). Experimental ecotoxicity data were gathered through the voluntary survey, and a mandatory polymer survey issued pursuant to a CEPA section 71 notice literature information, as well as read-across data from polymers which have been assessed by the New Substances program. If the scenarios indicated a low likelihood of harm to aquatic organisms (i.e., ratio of PEC/PNEC is less than one), the polymer is anticipated to present low ecological concern.

It is recognized that conclusions resulting from the use of the second phase of polymer rapid screening have associated uncertainties, including commercial activity variations. However, the use of a wide range of information sources (relating to both exposure potential and hazard concerns identified for a polymer), as well as the use of conservative exposure scenarios increase confidence in the overall approach that the polymers identified as not requiring further assessment are unlikely to be of concern.

Information on the decision taken at each step for each polymer is presented in a document titled “Information on the Decision Taken at Each Step for Rapid Screening II of Polymers” (ECCC 2016).

On the basis of available information, tannins, humic acid, and oxidized starch were identified in “Second Phase of Polymer Rapid Screening: Results of the Screening Assessment” (ECCC, HC 2018), as being unlikely to cause ecological harm.

Characterization of risk to human health for SEGAC and GEGAC

The human health risks of SEGAC and GEGAC were characterized using the approach outlined in the report; “Second Phase of Polymer Rapid Screening: Results of the Screening Assessment” (ECCC, HC 2018). This process consisted of determining the location of each polymer in a health risk matrix, assigning a low, moderate or high level of potential concern for substances on the basis of their hazard and exposure profiles. The matrix has three exposure bands that represent different exposure potentials which increase from band 1 to 3 and three hazard bands representing different hazard potentials which increase from band A to C.

The first step involved identifying the degree of direct and indirect exposure for each polymer on the basis of its human exposure potential derived through its use pattern, import, manufacture or use quantity and water extractability. To determine if a polymer is used in or is present in a product available to Canadians, numerous additional sources of information related to both domestic and international use and product information were searched and consulted.

The highest exposure band (3) is designated for polymers which are expected to have high direct exposure resulting from their use in products available to consumers that are intended for consumption or application to the body, such as cosmetics, drugs and natural health products. **The middle exposure band (2)** is designated for polymers which are anticipated to have moderate direct or indirect exposure resulting from the use of polymers in household products that are not intended to be applied to the body or consumed, such as cleaning products, household paint and sealants. **The lowest exposure band (1)** is designated for polymers which are anticipated to have low direct or indirect exposure. This exposure band includes polymers which are used in the industrial sector to form manufactured articles and which are often contained within or reacted into a cured or hardened polymer matrix during industrial manufacturing.

The second step involved identifying the hazard potential, and corresponding hazard band, for each polymer on the basis of the presence of reactive functional groups (RFGs) and available toxicological data. Identification of a hazard band was performed independently of the identification of an exposure band. **The highest hazard band (C)** is associated with polymers which are known or suspected to have a RFG or metals of concern to human health. The highest hazard band is also assigned to polymers for which toxicological data on the polymer or a structurally-related polymer shows or suggests that the polymer may pose a human health risk. **The middle hazard band (B)**

is associated with polymers which do not contain any RFGs or metals of concern to human health but may contain other structural features such as ethylene glycol, aliphatic and aromatic amines or maleic acid anhydrides which may be associated with human health effects. **The lowest hazard band (A)** is associated with polymers which do not contain a RFG or other structural feature or metals which are known to be associated with human health concerns and available toxicological data indicates a low concern for human health.

The final step combined the exposure and hazard potentials to determine the overall risk potential as represented by the location in the risk matrix. Polymers which have a moderate-to-high exposure potential and the highest hazard potential (cells 2C or 3C) are identified as requiring further assessment to determine their risk to human health.

Polymers that are placed in all other cells of the risk matrix are considered unlikely to cause harm to human health at current levels of exposure. As a result, these polymers are not identified as requiring further human health assessment.

It is recognized that conclusions resulting from the use of this polymer rapid screening approach have associated uncertainties, including commercial activity variations and limited toxicological information. However, the use of a wide range of information sources (relating to both exposure potential and hazard concerns identified for a polymer), as well as the use of conservative exposure scenarios, increase confidence in the overall approach that the polymers identified as not requiring further assessment are unlikely to be of concern.

Information on the decision taken at each step for the substances in this assessment is presented in Health Canada (2017).

On the basis of available information, SEGAC and GEGAC are not anticipated to result in significant direct or indirect exposure or pose a health hazard as a result of exposure. It is therefore unlikely that SEGAC and GEGAC result in a human health risk for the general population.