



**ENVIRONMENT DIRECTORATE  
JOINT MEETING OF THE CHEMICALS COMMITTEE AND  
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY**

**Environmental Exposure Assessment**

**DRAFT EMISSION SCENARIO ON TEXTILE MANUFACTURING CARPET MILLS**

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This document includes a draft emission scenario document (ESD) on textile manufacturing wool mills, submitted by Canada. This document is intended to provide additional information about the published ESD on Textile Finishing Industry [ENV/JM/MONO(2004)12].

## **Emission Scenario Document for Carpet Dyeing and Finishing Mills**

Prepared for

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## **1 – INTRODUCTION**

The purpose of this emission scenario document (ESD) is to provide a realistic worst-case emission scenario for chemicals used at carpet dyeing and finishing mills. The information about the processes and chemicals used is derived from a field study, literature data, and several reports from the European Union and the United States. The emission estimation methods given in this ESD are based on those developed by the Organization for Economic Cooperation and Development with parameter defaults reflecting Canadian operations.

## **2 – CANADIAN CARPET WET PROCESSING SECTOR**

The textile industry can be divided into dry processing and wet processing from a standpoint of water usage (USEPA, 1996). The dry processing uses small amounts of water and contributes an insignificant load to wastewater generation. On the other hand, the wet processing involves many operations which consume large quantities of water and is, therefore, the primary source of the textile industry wastewater.

In Canada, the wet processing sector consisted of 145 mills divided into the following six types according to the Environment Canada's 1997/98 survey (Environment Canada, 1998):

- knit fabric dyeing and finishing mills
- woven fabric dyeing and finishing mills
- wool dyeing and finishing mills
- stock/yarn dyeing and finishing mills
- carpet dyeing and finishing mills
- non-woven fabric dyeing and finishing mills

The Canadian wet processing textile mills are concentrated in the provinces of Quebec and Ontario. As given in Table 1, 134 mills out of the total of 145 were located in the two provinces (Crechem Technologies Inc., 1998). The remaining 11 mills are located in New Brunswick, Nova Scotia, Prince Edward Island, and British Columbia.

Table 1 – Distribution of Canadian Wet Processing Textile Mills

Type	Knit	Woven	Stock/Yarn	Carpet	Wool	Non-woven	Unclassified	Total
Quebec	36	25	8	5	5	0	5	84
Ontario	24	9	5	2	0	7	3	50
New Brunswick	0	2	0	0	1	0	1	3
Nova Scotia	2	2	0	1	0	0	0	5
Prince Edward Island	0	0	0	0	1	0	0	1
Manitoba	0	0	0	0	0	0	0	0
Alberta	0	0	0	0	0	0	0	0
British Columbia	1	0	0	0	1	0	0	2
<b>Total</b>	<b>63</b>	<b>38</b>	<b>13</b>	<b>8</b>	<b>8</b>	<b>7</b>	<b>8</b>	<b>145</b>

Source: Crechem Technologies Inc., 1998

Carpet dyeing and finishing mills were a minor component of the Canadian wet processing sector. As given in Table 2, they accounted for 6% of the total mills, 13% of the fabric processed by the wet processing sector, and 11% of the wastewater generated (Crechem Technology Inc., 2000).

Table 2 – Woven Fabric Mills in Canadian Wet Processing Sector

	Number of Mills	Quantity of Fabric Processed	Quantity of Wastewater Generated
Carpet Mills	8	42.8 million kg/yr	10,900 m <sup>3</sup> /d
Industry Total	145	319.7 million kg/yr	103,700 m <sup>3</sup> /d
Industry Share	5.5%	13.4%	10.5%

Source: Crechem Technologies Inc., 2000.

### 3 – CARPET WET PROCESSING OPERATIONS

#### 3.1 – Process Description

Figure 1 shows a typical process for carpet dyeing and finishing mills. It starts with tuft yarns which are commonly synthetic fibres (nylon, acrylics and polyesters) (USEPA, 1978). The first step, i.e., tufting, is a dry operation and involves manufacturing pile fabrics by inserting yarn loops into a ground fabric (Joseph, 1981). The ground fabric may be woven or nonwoven (polypropylene).

If the tufted carpet is made from undyed yarns piece dyeing follows. (Corbman, 1975; Chen, 1989; USEPA, 1978). In case of pre-dyed yarns, dyeing is skipped. Piece dyeing is a dyeing method applied to the completed fabric (Joseph, 1981). It is performed with the carpet in a rope form in either atmospheric or pressure vessels. The carpet is connected end-to-end and rotated over a large drum through the dye liquor. After

dyeing the carpet is dried in a tunnel drier.

Upon drying the dyed and/or printed carpet is coated on the back with a plastic binder, latex foam, vinyl foam, or urethane foam (Corbman, 1975; Carr, 1995; Robinson, 1972). The usual method of applying back coatings is by pick-up from a lick roller. By that method the coating material contained in a trough is picked up by the revolving roller and transferred to the underside of the carpet. A spreading technique using a doctor blade may also be employed. The coated carpet is then dried in an oven.

A secondary backing may also be applied to the carpet and retards the rate of drying of a latex compound (Robinson, 1972). It is essential; therefore, for the bond strength to develop quickly, otherwise movement of the secondary backing relative to the carpet may cause delamination.

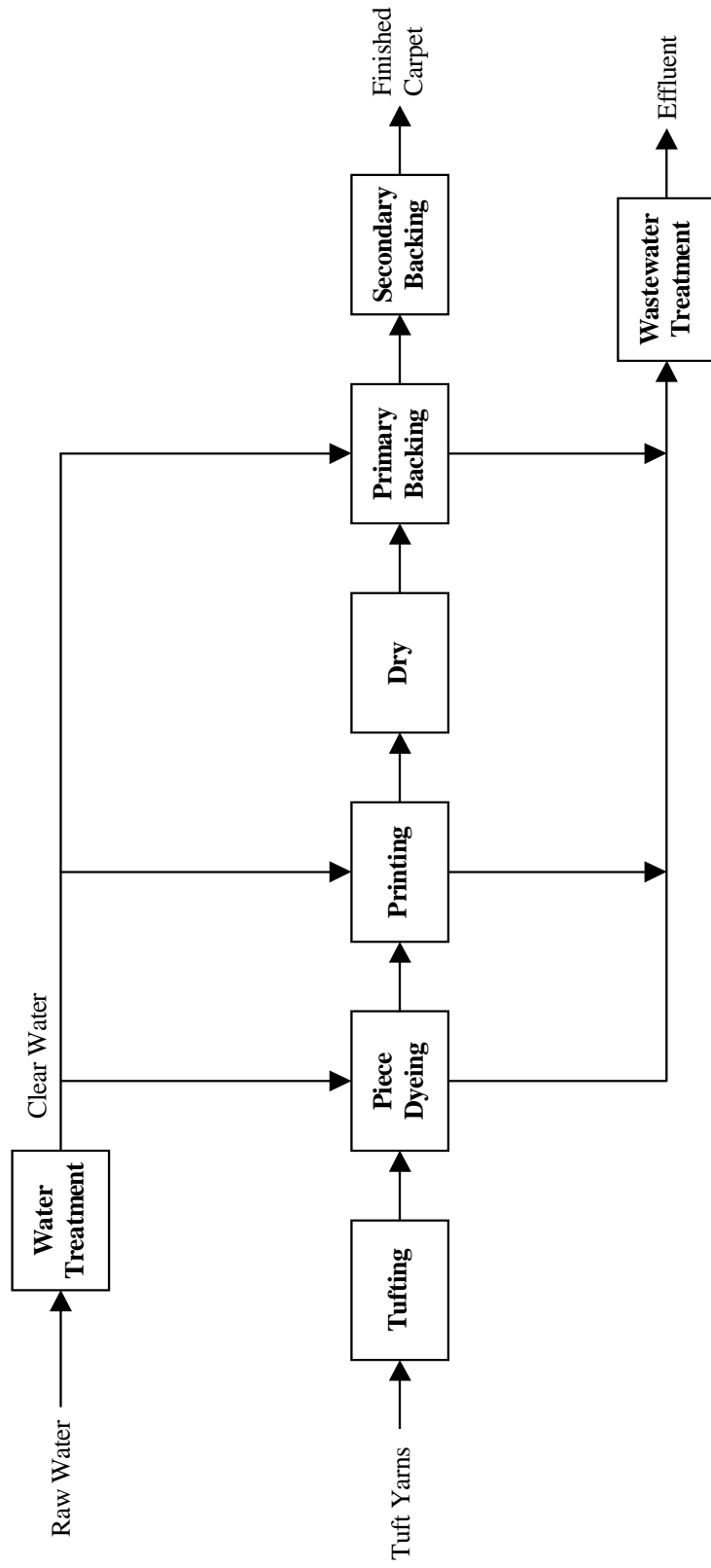


Figure 1 – Typical Process for Carpet Dyeing and Finishing Mills

### **3.2 – Chemical Use**

Chemicals used at carpet wet processing mills may be classified into the following categories (Crechem Technologies Inc., 2003):

- 1) Surfactants
- 2) Dyes and pigments
- 3) Dye carriers and auxiliaries
- 4) Solvents
- 5) Phosphates
- 6) Salts
- 7) Alkalis
- 8) Acids
- 9) Buffering agents
- 10) Thickeners
- 11) Chelating agents
- 12) Biocides
- 13) Cleaners
- 14) Chemicals for boiler and cooling water treatment
- 15) Chemicals for water treatment
- 16) Chemicals for wastewater treatment

#### ***3.2.1 – Chemicals Used in Dyeing***

Dyes, salts, dye carriers, and many auxiliaries are used in dyeing. Auxiliaries include buffering agents, acids/alkalis, dye bath lubricants, dispersing agents, chelating agents, anti-redeposition agents, etc. (USEPA, 1996, p.179-183).

Use of reductive agents is also found in dyeing (Smith, 1988). They help remove surface dye from fabric (after-clearing) and from dyeing machines. In addition, they function as antichlor agents to destroy residual chlorine from hypochlorite, chlorite bleaching or stripping prior to dyeing which uses potentially chlorine-sensitive dyes.

#### ***3.2.2 – Chemicals Used in Printing***

Pigments or dyes, and various auxiliaries are used in printing. Auxiliaries include thickeners, binders, reductants, etc. Thickeners are used in printing to ensure the printed design is precisely located with clean defined edges (Carr, 1995). Many polysaccharides derived from starch-containing plants, seaweeds yielding alginates, plant gums, and cellulose derivatives, particularly cellulose ethers, are used as thickeners in textile printing. They have been developed to substitute for kerosene (USEPA, 1996, p.198). Common binders are acrylic copolymers which allow for 100% fixation of prints. Reductants are used in discharge printing which involves destroying an existing dye in pre-dyed fabrics to replace it with another or to let the ground shade shine through (Cognis, Div. of Henkel

Canada, www.cognis.com).

#### 4 – RELEASE ESTIMATION

Environmental releases from carpet wet processing can be generally divided into: 1) wastewater; 2) air emissions; and 3) solid waste. The chemical nature of each group from dyeing and printing operations is summarized in Table 3 (USEPA, 1997, p.43).

Table 3 – Environmental Releases from Carpet Wet Processing

Process	Wastewater	Air Emissions	Solid Waste
Dyeing	metals; salt; surfactants; toxics; organic processing assistants; cationic materials; color; BOD; COD; sulphide; acidity/alkalinity; spent solvents	volatile organic compounds	little or no residual waste generated
Printing	suspended solids; urea; solvents; color; metals; heat; BOD; foam	solvents, acetic acid from drying and curing oven emissions; combustion gases; particulate matter	little or no residual waste generated

Source: USEPA, 1997, p.43

##### 4.1 – Wastewater

On average, Canadian carpet mills consumed 80.3 litres of water per kg of textile product and generated 1,361 m<sup>3</sup>/day of wastewater per mill (Environment Canada, 1999). In comparison, carpet mills in the U.S. consumed 47 litres/kg of water and generated 1,590 m<sup>3</sup>/day of wastewater per mill (USEPA, 1996, p.18). Effluents of carpet mills are similar in many ways to those of knit fabric mills (USEPA, 1978).

The quantity of chemicals released to wastewater depends upon their fixation rates. In typical dyeing operations, 50-100% of dyes are fixed on fibres and the remainder is discarded in the form of spent dyebaths and/or wastewater from subsequent textile washing (USEPA, 1997). Dyes commonly used for carpet dyeing include disperse, acid and basic (USEPA, 1996, p.36).

##### 4.2 – Solid Waste

Common types of solids waste include: 1) ash and sludge; 2) packaging materials; and 3)

processing waste (USEPA, 1996, p.21). Sources for ash and sludge are boilers and wastewater treatment. In the U.S., these sources generated approximately one-fourth of the total solid waste. Packaging materials include cardboard boxes, bale-wrapping film or fabric, baling wire, wooden crates, paper sacks, bags, and drums made of paperboard, plastic, or metal. Processing waste is waste textile such as trimmings and off-spec products.

### **4.3 – Air Emissions**

Sources for air emissions in carpet wet processing include dyeing and printing. In dyeing operations, specific sources are stacks from tenter frames and curing ovens used for drying operations (USEPA, 1998, p.II-42).

Printing operation is a source of solvent emissions. Solvent is emitted due to use of solvent-based print paste, but this has been replaced by polymeric thickeners (USEPA, 1998, p.II-47). Cleaning of machines and screens also results in solvent emissions.

## **5 – EMISSION SCENARIOS**

### **5.1 – Fate of Chemical Agents**

Described in Figure 2 is the fate of a chemical agent used at a facility. The agent is shipped to the facility using one or more types of containers. It is then unloaded or unpackaged and transferred to the production process. The agent leaves the facility via the following routes:

- Container residue that remains in containers after unloading or unpackaging and ends up in wastewater or is disposed of by other means.
- Process residue that remains in process vessels and transfer pipelines and also ends up in wastewater or is disposed of by other means.
- Liquid loss that enters wastewater streams during normal applications.
- Air emission that occurs if the agent contains volatile components.
- Reaction loss that occurs if the agent undergoes chemical reactions during its use.
- Product retention that accounts for a portion of the agent fixed onto finished products.

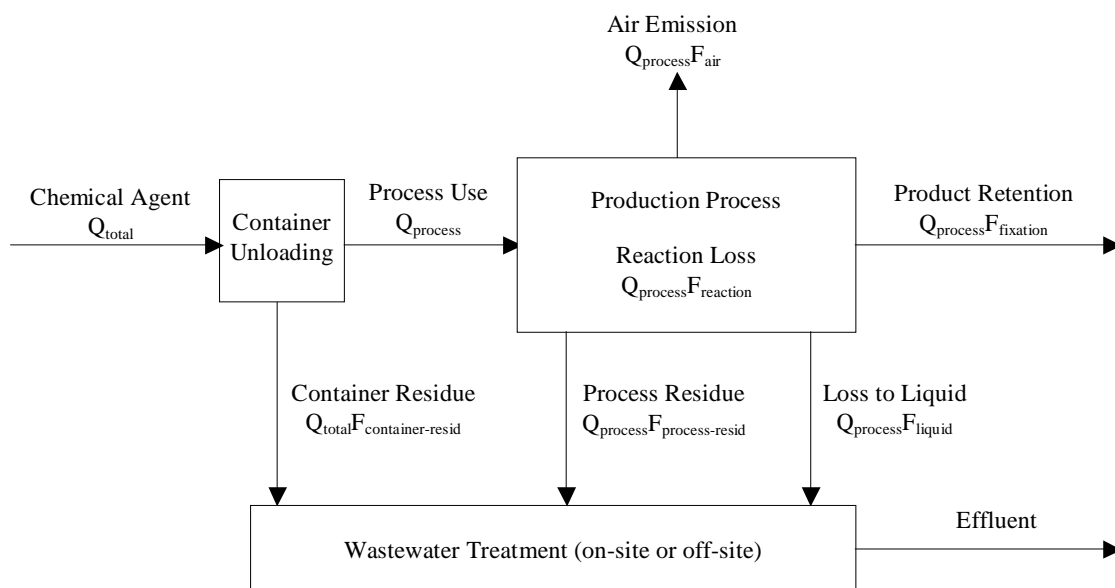


Figure 2 – Fate of a Chemical Agent Used at a Facility

Both dry and wet operations were performed at Canadian carpet mills according to a field study conducted for Health Canada (Crechem Technologies Inc., 2003). The dry operations identified in the study included twisting, heat setting, weaving, and tufting; the wet operations involved dyeing, finishing, and coating.

## 5.2 – General Approach to Aqueous Emission Estimation

A general approach to aqueous emission estimation was recommended by the Organization for Economic Cooperation and Development in 2000 in a publication entitled "Guidance Document on Emission Scenario Documents" (OECD, 2000). The approach is based on the fixation of chemical agents onto finished products and can be described by the following equation assuming no air emission and reaction loss:

$$E_{water} = \frac{Q_{product} Q_{agent} C_{substance} (1 - F_{fixation})}{T_{operation}}$$

The equation includes a set of input variables on the right and one output variable on the left. The definitions and value types of these variables are provided in Table 4.

Table 4 – Input and Output Variables of Aqueous Emission Estimation Equation

Variable		Symbol	Units	Value Type
Output	Aqueous emission of a substance in chemical agent	$E_{\text{water}}$	kg/d	Calculated
Input	Annual production	$Q_{\text{product}}$	tonne/yr	User input without default available
	Chemical agent use rate	$Q_{\text{agent}}$	kg/tonne	Provided with default which can be modified by users
	Substance concentration in chemical agent	$C_{\text{substance}}$	%	
	Fixation rate (fraction of chemical agent retained by product)	$F_{\text{fixation}}$	%	
	Annual operation days	$T_{\text{operation}}$	d/yr	

Source: OECD, 2000.

### 5.3 – Emission Estimation Calculations

#### 5.3.1 – Emission to Wastewater

The emission to wastewater from a carpet mill can be estimated according to a scheme described in Figure 2. The scheme is based on a spreadsheet formula used by the USEPA for exposure estimation. The emission consists of three portions: 1) liquid loss; 2) container residue; and 3) process residue. Liquid loss is incurred when a fraction of a chemical agent is not retained by finished products and enters wastewater, while container and process residues are common losses resulting from chemical handling and transferring. The following equation can be used for the aqueous emission estimation:

$$\begin{aligned}
 E_{\text{water}} &= \text{liquid loss} + \text{container residue} + \text{process residue} \\
 &= \frac{Q_{\text{total}} C_{\text{substance}}}{T_{\text{operation}}} (1 - F_{\text{container-resid}} - F_{\text{process-resid}}) (1 - F_{\text{air}} - F_{\text{reaction}} - F_{\text{fixation}}) + \\
 &\quad \frac{Q_{\text{total}} C_{\text{substance}}}{T_{\text{operation}}} F_{\text{container-resid}} + \frac{Q_{\text{total}} C_{\text{substance}}}{T_{\text{operation}}} F_{\text{process-resid}}
 \end{aligned}$$

where

- $E_{\text{water}}$ : daily aqueous emission of a substance in chemical agent, kg/d
- $Q_{\text{total}}$ : total chemical agent received by or shipped to a facility, kg/yr
- $C_{\text{substance}}$ : substance concentration in chemical agent, %
- $F_{\text{container-resid}}$ : container residue as percentage of total chemical agent received by or shipped to a facility, %
- $F_{\text{process-resid}}$ : process residue as percentage of total chemical agent received by or shipped to a facility, %
- $F_{\text{air}}$ : air emission as percentage of chemical agent used in production

	process, %
$F_{\text{reaction}}$ :	reaction loss as percentage of chemical agent used in production process, %
$F_{\text{fixation}}$ :	fixation rate, i.e., fraction of chemical agent retained by finished products, %
$T_{\text{operation}}$ :	annual operation days, d/yr

### 5.3.2 – Total Chemical Agent

The total amount of a chemical agent received by or shipped to a facility can be estimated from the use rate of the agent if it is not provided directly.

$$Q_{\text{total}} = \frac{Q_{\text{product}} Q_{\text{agent}}}{(1 - F_{\text{container-resid}} - F_{\text{process-resid}})}$$

where

$Q_{\text{total}}$ :	total chemical agent received by or shipped to a facility, kg/yr
$F_{\text{container-resid}}$ :	container residue as percentage of total chemical agent received by or shipped to a facility, %
$F_{\text{process-resid}}$ :	process residue as percentage of total chemical agent received by or shipped to a facility, %
$Q_{\text{product}}$ :	annual carpet production, tonne/yr
$Q_{\text{agent}}$ :	chemical agent use rate based on product mass, kg/tonne

### 5.3.3 – Air Emission

The fraction of a substance in a chemical agent emitted to the atmosphere is defined as

$$F_{\text{air}} = \frac{E_{\text{air}}}{Q_{\text{use}}} \times 100\%$$

where

$F_{\text{air}}$ :	fraction of a substance in a chemical agent released to air, %
$E_{\text{air}}$ :	quantity of a substance in a chemical agent released to air, kg/d
$Q_{\text{use}}$ :	quantity of a substance in a chemical agent used in production process, kg/d

The air emission of a target substance can be estimated from a reference substance based on vapour pressure if the two substances are involved in the same operations (USEPA, 2000).

$$F_{air} = F_{air-ref} \frac{P_{air}}{P_{air-ref}}$$

where

- $F_{air}$ : fraction of a target substance released to air, %
- $F_{air-ref}$ : fraction of a reference substance released to air, %
- $P_{air}$ : vapour pressure of a target substance, Pa
- $P_{air-ref}$ : vapour pressure of a reference substance, Pa

A reference substance should be volatile so that its air release reaches a sufficient quantity, while at the same time, it should be found in aqueous discharge to ensure reasonable partition between water and air. To simplify calculations it is necessary to assume that the reference substance is not retained in the finished products and is released to air and water only. Under these conditions, the air emission of the reference substance can be estimated by the equation.

$$F_{air-ref} = \frac{E_{air-ref}}{E_{air-ref} + E_{water-ref}}$$

where

- $E_{air-ref}$ : quantity of reference substance released to air, kg/d
- $E_{water-ref}$ : quantity of reference substance released to water, kg/d

### 5.3.4 – Reaction Loss

The loss due to chemical reactions is substance specific. In general, it is assumed at zero, i.e., the substance in question does not undergo chemical transformation. Some substances may, however, change chemically and need to be evaluated from the data available.

## 5.4 – Parameter Defaults

### 5.4.1 – Container Residue

Container residue results from chemical unloading and its quantity depends primarily upon the type of containers used. Listed in Table 5 are container residue defaults used by the USEPA for exposure estimation. Drums and totes (semi-bulk) are common container types used by the textile industry. It is recommended that a value of 3.0% instead of 4.0% be used to estimate liquid drum residue for Canadian facilities.

Table 5 – Container Residue Defaults

Container Type	Residue as % of Total Quantity Received	
	Dry	Liquid
Bag	0.1	0.2
Keg	0.3	0.6
Drum	1.0	4.0
Semi-bulk	0.1	0.5
Bulk	0.1	0.2

Source: USEPA spreadsheet exposure estimation, 2004

### 5.4.2 – Process Residue

Process residue results from the use of process vessels and transfer pipelines. Listed in Table 6 are process residue defaults used by the USEPA for exposure estimation.

Table 6 – Process Residue Defaults

Process Hardware	Residue as % of Total Quantity Received	
	Dry	Liquid
General	0.1	1.0
Batch vessel	0.2	1.0
Transfer pipeline	0.1	1.0

Source: USEPA Spreadsheet Exposure Estimation, 2004

### 5.4.3 – Air Emission

The fraction of a substance in a chemical agent released to air depends upon its volatility. Its default is zero assuming the substance is a non-volatile compound. The value for a volatile substance may be estimated using emission factors or engineering calculations.

#### 5.4.4 – Reaction Loss

The default for reaction loss is zero assuming no chemical reaction takes place as a chemical agent is used in production processes.

#### 5.4.5 – Annual Carpet Production

The annual carpet production varied widely from mill to mill. The figure ranged from 43 tonne/yr for a small mill with 30 employees to 16,000 tonne/yr for a large mill with 1,100 employees (Environment Canada, 1998). The average production was estimated at 5,350 tonne/yr.

#### 5.4.6 – Annual Operation Days

The default for annual operation days ( $T_{\text{operation}}$ ) is 250 d/yr based a field study conducted for Health Canada (Crechem Technologies Inc., 2003).

#### 5.4.7 – Use Rate, Active Substance Concentration and Fixation Rate

The use rate and fixation rate for chemical agents used at carpet mills were determined in a field study conducted for Health Canada (Crechem Technologies, 2003). These figures are presented in Table 7 and can be used as defaults. The active substance concentration was not determined in the study, but can be assumed to be 100% by default. It should be noted that the fixation rate for dyes is based on USEPA data (USEPA, 1997, p.35 and p.208).

Table 7 – Use Rate and Fixation Rate for Chemical Agents Used at Carpet Mills

Chemical Agent	Use Rate (kg/tonne)		Fixation Rate (%)	
	Default	Range	Default	Range
Lubricants	2.6	no data	0	0
Antifoams	1.0	no data	0	0
Antiprecipitants	0.56	no data	0	0
Levelers	6.3	no data	0	0
Acid dyes	1.2	no data	87 <sup>1</sup>	80-93 <sup>1</sup>
Basic dyes	0	0	98 <sup>1</sup>	97-98 <sup>1</sup>
Direct (cationic) dyes	0.12	0	83 <sup>1</sup>	70-95 <sup>1</sup>
Disperse dyes	0	0	86 <sup>1</sup>	80-92 <sup>1</sup>
Reactive dyes	0	0	65 <sup>1</sup>	50-80 <sup>1</sup>
Sulphur dyes	0	0	65 <sup>1</sup>	60-70 <sup>1</sup>
Vat dyes	0	0	88 <sup>1</sup>	80-95 <sup>1</sup>
Premetallized dyes	0.05	no data	97 <sup>1</sup>	95-98 <sup>1</sup>
Salts	0.67	no data	0	0
Acids	7.9	no data	0	0
Sequestering agents	3.9	no data	0	0
Detergents	0.16	no data	0	0

Source: Crechem Technologies Inc., 2003

<sup>1</sup>Data used by USEPA (1997, p.35 and p.208)

## **GLOSSARY**

Aging – a treatment method with which printed fabric is exposed to a hot moist atmosphere.

Backing – coating on the back of a carpet with a plastic binder, latex foam, vinyl foam, or urethane foam.

Chemical finishing – use of chemical agents to improve the appearance, texture and performance of fabric, same as wet finishing.

Dry finishing – use of mechanical means to cause physical changes to fabric.

Finishing – use of chemical or mechanical means to modify the property of fabric.

Steaming – a treatment method with which printed fabric is exposed to hot steam.

Tufting – a dry process to manufacture pile fabrics by inserting yarn loops into a ground fabric.

Wet finishing – use of a variety of agents in a solution to improve the appearance, texture, and performance of fabric.

## **ABBREVIATIONS**

ADMI – American Dye Manufacture Institute

BOD – Biochemical oxygen demand

COD – Chemical oxygen demand

ESD – Emission scenario document

OECD – Organization for Economic Cooperation and Development

TSS – Total suspended solids

UK – United Kingdom

USEPA – United States Environmental Protection Agency

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