Australian Government
Department of Health and Aged Care
Australian Industrial Chemicals Introduction Scheme

Fluorescent Brightener 71 and related chemicals

Evaluation statement

25 September 2023

Draft

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AICIS evaluation statement

Subject of the evaluation

Fluorescent Brightener 71 and related chemicals

Chemicals in this evaluation

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Benzenesulfonic acid, 2,2′-(1,2-ethenediyl)bis[5-[[4-[bis(2-hydroxyethyl)amino]-6-[(4-sulfophenyl)amino]-1,3,5-triazin-2-yl]amino]-, sodium salt (1:4)	16470-24-9
Benzenesulfonic acid, 2,2'-(1,2-ethenediyl)bis[5-[[4-[bis(2-hydroxyethyl)amino]-6-(phenylamino)-1,3,5-triazin-2-yl]amino]-, disodium salt	4193-55-9

Reason for the evaluation

Evaluation Selection Analysis indicated a potential environmental risk.

Parameters of evaluation

This evaluation considers the environmental risks associated with the industrial uses of Fluorescent Brightener 71 (FB-71) (CAS RN 16090-02-1), Fluorescent Brightener 220 (FB-220) (CAS RN 16470-24-9) and Fluorescent Brightener 28 (FB-28) (CAS RN 4193-55-9).

Chemicals in this group have been assessed for environmental risk according to the following parameters:

- Australian introduction volumes of 100–1000 t/year.
- Industrial uses listed in the ‘Summary of use’ section.
- Expected emission to sewage treatment plants (STPs) following consumer and commercial use.
- Expected emission to surface water following industrial use.

These chemicals have been assessed as a group because they are structurally similar and have similar use patterns.

Summary of evaluation

Summary of introduction, use and end use

Chemicals in this group are used as optical brightening agents in the following products according to Australian and international use data:

- laundry and dishwashing products
- fabric, textile and leather products
- paper products
- paint and coating products.

Available information indicates that chemicals in this group are used in high volumes in Australia and worldwide.

Environment

Summary of environmental hazard characteristics

Based on the information presented in this evaluation and according to the environmental hazard thresholds stated in the Australian Environmental Criteria for Persistent, Bioaccumulative and/or Toxic Chemicals (DCCEEW n.d.), the chemicals are:

- Persistent (P)
- Not bioaccumulative (Not B)
- Not toxic (Not T).

Environmental hazard classification

The chemicals FB-220 and FB-28 do not satisfy the criteria for classification for environmental hazards according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). All experimental toxicity endpoints exceed minimum effect levels for classification (UNECE 2017). This evaluation does not consider classification of physical and health hazards.

FB-71 satisfies the criteria for classification as follows:

Environmental Hazard	Hazard Category	Hazard Statement
Hazardous to the aquatic environment (acute / short-term)	Aquatic Acute 2	H401: Toxic to aquatic life

Summary of environmental risk

Chemicals in this evaluation are present in a range of household and commercial products. These chemicals are expected to be released to wastewater through the use of the products. The main sources of emissions are expected to be from their use in laundry detergents and from paper and textile processing. The environmental releases are expected to affect surface waters, sediments and soils.

Chemicals in this group are not bioaccumulative (Not B) and not toxic (Not T). They are persistent in sediment and soil (P). FB-220 and FB-28 are also persistent in water. Based on standard exposure modelling supported by international monitoring data, chemicals in this group are not expected to pose a significant risk to the Australian environment as RQs in water and soil fall well below the level of concern (RQ <1). Although the risk to sediment-dwelling organisms cannot be ruled out (RQs in this compartment were not determined), international monitoring data indicate declining site specific sediment concentrations of fluorescent brightening agents (FBA) may reduce the risk.

Conclusions

The conclusions of this evaluation are based on the information described in this evaluation statement.

The Executive Director proposes to be satisfied that the identified environment risks can be managed within existing risk management frameworks. This is provided that all requirements are met under environmental, workplace health and safety and poisons legislation as adopted by the relevant state or territory.

Note: Obligations to report additional information about hazards under Section 100 of the *Industrial Chemicals Act 2019* apply.

Supporting information

Rationale

This evaluation considers the environmental risks associated with the industrial use of Fluorescent Brightener 71 (FB-71), Fluorescent Brightener 28 (FB-28) and Fluorescent Brightener 220 (FB-220). Chemicals in this group have similar structures, physico-chemical properties, industrial uses and environmental hazards. Therefore, these chemicals are suitable for group assessment.

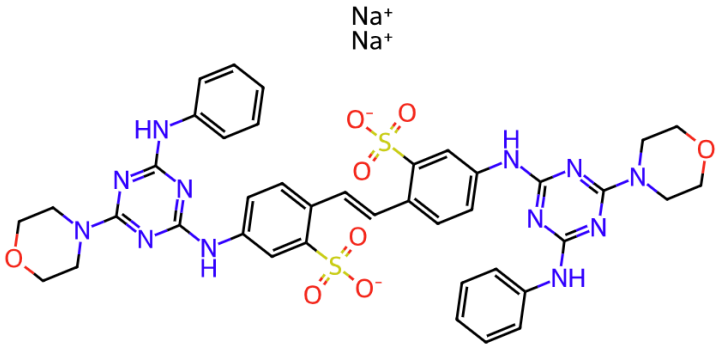
The evaluation selection analysis (ESA) for chemicals in this group highlighted a high volume of use globally and potential persistence and ecotoxicity, which indicate a high concern for the environment.

Chemical identity

Chemicals in this group are characterised by a stilbenedisulfonic acid joined to substituted triazinyl groups via amine linkages. They are formally salts of sodium, but commercial products include aqueous slurries or powders that may contain added salts, dispersants and dedusting agents (OECD 2001; 2005a; 2005b). The stereochemistry of the internal alkene is not specified in the chemical names of this group. However, the cis-stilbene configuration is not fluorescent and commercial forms are therefore available in the trans-stilbene configuration. These configurations are denoted the *(Z)*- and (*E*)-isomers, respectively.

Chemical name	Benzenesulfonic acid, 2,2'-(1,2-ethenediyl)bis[5-[[4-(4-morpholinyl)-6-(phenylamino)-1,3,5-triazin-2-yl]amino]-, disodium salt
CAS RN	16090-02-1
Synonyms	Fluorescent Brightener 71 (FB-71) Fluorescent Brightener 260 FWA 1 Benzenesulfonic acid, 2,2′-(1,2-ethenediyl)bis[5-[[4-(4-morpholinyl)-6-(phenylamino)-1,3,5-triazin-2-yl]amino]-, disodium salt Disodium 4,4′-bis(2-anilino-4-morpholino-1,3,5-triazin-6-ylamino)-2,2′-stilbenedisulfonate
Molecular formula	C40H38N12O8S2.2Na
Molecular weight (g/mol)	924.91 g/mol
SMILES (canonical)	[Na].[Na].O=S(=O)(O)C1=CC(=CC=C1C=CC2=CC=C(C=C2S(=O)(=O)O)NC3=NC(=NC(=N3)N4CCOCC4)NC=5C=CC=CC5)NC6=NC(=NC(=N6)N7CCOCC7)NC=8C=CC=CC8

Structural formula



Chemical name	Benzenesulfonic acid, 2,2′-(1,2-ethenediyl)bis[5-[[4-[bis(2-hydroxyethyl)amino]-6-[(4-sulfophenyl)amino]-1,3,5-triazin-2-yl]amino]-, sodium salt (1:4)
CAS RN	16470-24-9
Synonyms	Fluorescent Brightener 220 (FB-220) C.I. 40623 Benzenesulfonic acid, 2,2′-(1,2-ethenediyl)bis[5-[[4-[bis(2-hydroxyethyl)amino]-6-[(4-sulfophenyl)amino]-1,3,5-triazin-2-yl]amino]-, tetrasodium salt Tetrasodium 4,4'-bis[[4-[bis(2-hydroxyethyl)amino]-6-(4-sulfonatoanilino)-1,3,5-triazin-2-yl]amino]-2,2’-stilbenedisulfonate
Molecular formula	C40H40N12O16S4.4Na
Molecular weight (g/mol)	1168 g/mol
SMILES (canonical)	[Na].[Na].[Na].[Na].O=S(=O)(O)C1=CC=C(C=C1)NC=2N=C(N=C(N2)N(CCO)CCO)NC3=CC=C(C=CC4=CC=C(C=C4S(=O)(=O)O)NC5=NC(=NC(=N5)N(CCO)CCO)NC6=CC=C(C=C6)S(=O)(=O)O)C(=C3)S(=O)(=O)O

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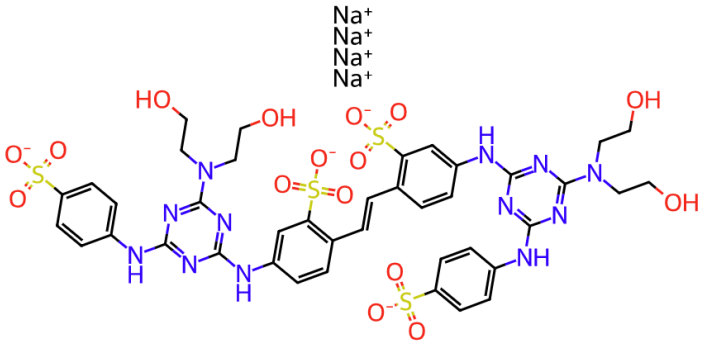

Chemical name	Benzenesulfonic acid, 2,2'-(1,2-ethenediyl)bis[5-[[4-[bis(2-hydroxyethyl)amino]-6-(phenylamino)-1,3,5-triazin-2-yl]amino]-, disodium salt
CAS RN	4193-55-9
Synonyms	Fluorescent Brightener 28 (FB-28) Fluorescent Brightener 113 Disodium 4,4'-bis[6-anilino-[4-[bis(2-hydroxyethyl)amino]-1,3,5-triazin-2-yl]amino]-2,2’-stilbenedisulfonate
Molecular formula	C40H38N12O8S2.2Na
Molecular weight (g/mol)	924.91 g/mol
SMILES (canonical)	[Na].[Na].O=S(=O)(O)C1=CC(=CC=C1C=CC2=CC=C(C=C2S(=O)(=O)O)NC3=NC(=NC(=N3)N(CCO)CCO)NC=4C=CC=CC4)NC5=NC(=NC(=N5)N(CCO)CCO)NC=6C=CC=CC6

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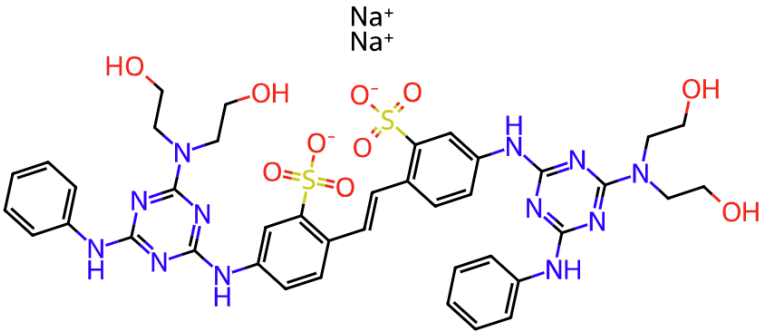

Relevant physical and chemical properties

Physical and chemical property data were retrieved from the registration dossiers for FB-71, FB-220 and FB-28 under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation in the European Union (EU) (REACH n.d.-a; n.d.-b; n.d.-c).

Chemical	FB-71	FB-220	FB-28
Physical form	Solid	Solid	Solid
Melting point	Decomposes at 300°C (exp.)	Decomposes at 360°C (exp.)	Decomposes at 300°C (exp.)
Water solubility	1.9 g/L at 20°C (exp.)	650 g/L at 20°C (exp.)	48.2 g/L at 20°C (exp.)
Ionisable in the environment?	Yes	Yes	Yes
log K_{ow}	-1.58 (exp.)	-3.9 (exp.)	-3.5 (calc.)

Experimentally derived dissociation constants (pKa) were not identified for chemicals in this group. Based on data submitted to the former National Industrial Chemicals Notification and Assessment Scheme (NICNAS) for an analogous chemical, the sulfonate groups will have pKa values of around 2 while the secondary and aromatic ring nitrogens will have pKa values of around 5–6 (NICNAS 1995).

Introduction and use

Australia

Based on information reported to NICNAS under previous mandatory and/or voluntary calls for information, chemicals in this group are imported into Australia in volumes of between 100–1000 t/year.

No Australian uses were identified for chemicals in this group. However, FB-71 is reportedly used in laundry detergents (Kramer 1992).

International

Chemicals in this group are used in significant volumes worldwide (OECD n.d.). Global production volumes were estimated at 10,000–50,000 t/year of FB-71, 35,000 t/year of FB-220 and 5,000–10,000 t/year of FB-28 between 1999 and 2005 (OECD 2001; 2005a; 2005b). Current use volumes in specific international jurisdictions are 1–1,000,000 t/year per chemical:

Chemical	Europe (2023)	USA (2016–2019)	Japan
FB-71	1000–10,000	454–4540	101 (2014) 117 (2013)
FB-220	10,000–100,000	4540–22,700	1000–2000 (2021) 10,000–20,000 (2020)
FB-28	100,000–1,000,000	454–9070	1–1000 (2014–2021)

All units are in t/year. European volumes were retrieved from the REACH registration dossiers (REACH n.d.-a; n.d.-b; n.d.-c). Volumes from the United States of America (USA) were retrieved from the 2020 Chemical Data Reporting (CDR) database (US EPA 2020). Volumes for Japan were retrieved from the Japan CHEmicals Collaborative Knowledge database (J-CHECK) (NITE n.d.).

The chemicals in this group are fluorescent brightening agents (FBA) derived from condensation reactions of 4,4'-diaminostilbene-2,2'-disulfonic acid (CAS RN 81-11-8) with cyanuric chloride (CAS RN 108-77-0) and various primary and secondary amines (Kramer 1992). They absorb light in the near-UV region (300–400 nm) and rapidly re-emit in the blue region via fluorescence (Kramer et al. 1996). In paper, textiles and plastics, this fluorescence causes a whitening effect against the yellowish shade of these materials.

FB-71 is mainly used in laundry detergents (>90%), with minor use in papermaking and textile finishing (<10%) (OECD 2005a). FB-220 and FB-28 are primarily used in papermaking, textile finishing and plastics manufacture, with some indicated use in laundry detergents (DeLima Associates n.d.; OECD 2001; 2005b). FB-220 is reportedly used in coatings, inks and paints (REACH n.d.-b). FB-28 is marketed as a laboratory chemical for use in fungal staining (NCBI n.d.).

Existing Australian regulatory controls

Environment

The industrial uses of chemicals in this group are not subject to any specific national environmental regulations.

International regulatory status

United Nations

Chemicals in this group are not currently identified as Persistent Organic Pollutants (POP) (UNEP 2001), ozone depleting substances (UNEP 1987), or hazardous substances for the purpose of international trade (UNEP & FAO 1998).

OECD

Chemicals in this group were independently sponsored by Germany under the Cooperative Chemicals Assessment Programme (CoCAP). FB-71 was recommended as a candidate for further work during the 21st Screening Information Data Set (SIDS) Initial Meeting Assessment (SIAM 21) in 2005 (OECD 2005a). FB-220 was recommended as a candidate for further work during SIAM 13 and FB-28 was recommended as a low priority for further work during SIAM 20 (OECD 2001; 2005b).

United States of America

Chemicals, FB-71 and FB-28 are listed on the US EPA Safer Chemical Ingredients List (US EPA n.d.). This list identifies chemicals deemed to be safer alternatives to other chemicals employed for the same functional use. The criteria for adding chemicals to the list cover a broad range of human health and environmental toxicological effects.

Environmental exposure

Chemicals in this group are expected to be found as FBAs in household and commercial products available for use in Australia. Formulated products on the Australian market are assumed to be similar to those available internationally. Concentrations of FB-71 in laundry detergents are 0.05–0.35% (OECD 2005a). Concentration ranges of FB-220 and FB-28 for paper and textile whitening are 0.05–0.5% and 0.1–0.3%, respectively (OECD 2001; 2005b).

Chemicals will be released into the environment when products containing these chemicals are used. Water, sediment and soil are expected to be the main compartments affected by the use of chemicals in this group. FBAs strongly adsorb to sludge during treatment in STPs. The remainder is released to surface water in sewage outfall or industrial effluents, leading to sediment exposure. Application of STP biosolids to agricultural land will lead to soil exposure, as will re-use of treated effluent for irrigation.

These chemicals (FBAs) are emitted to wastewater as a normal part of their use in laundry detergents. Between 20–95% of FBAs contained in detergents adhere to fabrics during washing (Kramer 1992). The remainder is discharged to sewers and received by STPs for treatment. End-product containers may be rinsed of residual detergent before disposal to landfill.

Chemicals in this group (FBAs) are contained in wastewater and paper sludge from industrial papermaking and recycling (OECD 2009). FBAs are emitted to wastewater during industrial use in textile finishing (OECD 2004). Industrial wastewater is typically reclaimed, discharged to sewers or managed *in situ* before release to sewers, agricultural land, or surface water. Paper sludge is landfilled, applied to agricultural soil, or incinerated for energy recovery.

The National Pollution Inventory (NPI) requires reporting of a number of pollutants, but FBAs are not one of them (NPI n.d.). However, reported emissions of other pollutants reflect how wastewater and sludge are disposed of in Australia. According to NPI data, there are currently three facilities from the *Pulp, Paper and Converted Paper Product Manufacturing* industry reporting pollutant emissions to water or land and seven facilities transferring pollutants to off-site sewerage, treatment, landfill or recycling destinations (NPI n.d.). Facilities emitting to water operate on-site treatment plants or partially discharge trade waste to off-site STPs (NSA 2022; Plant et al. 2014; Scholes 2021). There are currently no facilities from the *Textile, Leather, Clothing and Footwear Manufacturing* industry reporting pollutant emissions to water and only four facilities transferring pollutants to on-site immobilisation or off-site sewerage and landfill destinations (NPI n.d.).

Paper and textile products containing FBAs are exported, landfilled or recycled following use. More than half of all paper fibre used in Australia is derived from recycled material (DAFF n.d.). Post consumer printing and communication paper containing FBAs is recycled into office products (including office paper) and tissue paper, as well as some packaging grades (Industry Edge 2019). Except for tissue paper, which is disposed to sewers, waste paper is ultimately composted, recycled or disposed to landfill (Industry Edge 2019). Textiles are largely imported as finished products, the bulk of which (87.5%) are disposed to landfill following use (Khan et al. 2023).

The use of chemicals in this group in plastics, inks, coatings and paints, or as laboratory chemicals, is not expected to lead to significant environmental release compared to other uses.

Environmental fate

Dissolution, speciation and partitioning

Chemicals in this group (FBAs) exist as anions in water but may form zwitterions at low environmental pH. They bind with dissolved cations in the environment, forming lipophilic ion pairs and clusters. FBAs are non-volatile from water but readily adsorb to suspended solids. They have low mobility in sediment and soil.

In water, FBAs will be anionic as the sulfonate groups are deprotonated at environmental pH (Poiger 1994). However, secondary and aromatic ring nitrogens may become protonated at low pH (pH <6), resulting in the formation of zwitterions. Sulfonate groups will bind with dissolved cations in the environment, especially Na^+, K^+, Mg^{2+} and Ca^{2+}, forming ion pairs and clusters with higher partition coefficients (log K_{OW}). For example, the ion pair of FB-71 with calcium has a log K_{OW} of 0.7–1.8, more than 2 orders of magnitude greater than the native FBA (Poiger 1994).

Chemicals in this group undergo rapid and reversible *E*–*Z* photo-isomerisation in the environment. In water, photo-stationary equilibrium is achieved within minutes and normally favours the non-fluorescent (*Z*)-isomer (Canonica et al. 1997). However, isomerisation rates decline in the presence of suspended solids, which shift the *E:Z* ratio at equilibrium toward the more strongly adsorbing (*E*)-isomer (Poiger 1994).

These chemicals (FBAs) rapidly adsorb to suspended solids in aqueous media. The adsorbed fraction can exceed 90% in activated sludge, leading to significant removal from wastewater in STPs (Poiger 1994). However, in rivers and coastal waters, the adsorbed fraction is likely to be <5%, based on available monitoring data for estuarine and coastal water in Japan (Hayashi et al. 2002; Managaki and Takada 2005). Sedimentation is nonetheless an important removal process for FBAs from surface water. For example, between April 1995 and April 1996, removal via sedimentation accounted for 27% of all FB-71 received by a small urbanised lake in Switzerland (Stoll 1997).

Chemicals in this group have low mobility in soil and sediment and are unlikely to leach from landfill or diffuse through soils via groundwater. Adsorption coefficients (K_{OC}) in sands, sandy loams and loamy sands are 860–2240 L/kg for FB-71 and 2470–10,043 L/kg for FB-220 (OECD 2001; 2005a). Adsorption coefficients in sediments collected from the Glatt River in Switzerland are 1025 and 4186 L/kg, for the (*Z*)- and (*E*)-isomers of FB-71, respectively (Poiger 1994). These values are consistent with low mobility in the environment.

Degradation

Chemicals in this group are resistant to degradation in the environment. Based on available data, FB-71 readily biodegrades in water but FB-220 and FB-28 are neither readily nor inherently biodegradable. Chemicals in this group undergo rapid photo-degradation but this is likely to lead to persistent degradants. They are not expected to degrade in soil or sediment.

Experimental data were retrieved from the substance REACH dossiers for FB-71, FB-220 and FB-28 (REACH n.d.-a; n.d.-b; n.d.-c). No abiotic degradation data were identified for FB-28 and available biodegradation data is limited to an inherent biodegradation test study.

The chemical, FB-71 is expected to biodegrade in water. Approximately 92% degradation by removal of dissolved oxygen (BOD) was achieved in a 28 day ready biodegradability test

study conducted according to OECD test guideline (TG) 301 D. While the test may have failed the 14 day window criterion, given the high degree of overall degradation, FB-71 is considered rapidly and ultimately biodegradable in water.

The chemical, FB-220 is not expected to biodegrade in water. It is not readily biodegradable based on available test data. Only 1.2% degradation by removal of dissolved organic carbon (DOC) was reported in a 28 day test study conducted according to OECD TG 301 A, while 0% degradation by oxygen consumption was reported in a separate 30 day test study conducted according to OECD TG 301 D. FB-220 is also not inherently biodegradable. In a 28 day test study conducted according to OECD TG 302 B, degradation peaked at 20.9% at day 5 but was approximately sustained throughout the remainder of the test. This behaviour is consistent with a slow adsorption process or the formation of persistent degradants. Therefore, FB-220 is neither readily nor inherently biodegradable in water.

The chemical, FB-28 is not expected to biodegrade in water. A test study conducted according to OECD TG 302 B was terminated after 24 hours as 84% of the test substance was adsorbed to DOC. As no reliable data were identified, biodegradation was read across from FB-220. The structures of FB-220 and FB-28 are similar, with identical backbones and sulfonate substituents on their aromatic rings, differing only by the presence of two additional sulfonate substituents in FB-220. Therefore, they would be expected to have similar degradation pathways. Furthermore, there is no evidence that FB-28 biodegrades more readily than FB-220. Hence, FB-28 is conservatively assessed to be neither readily nor inherently biodegradable in water.

Photo-degradation may be a significant dissipation pathway for chemicals in this group, but it is likely to lead to the formation of persistent degradants. The mechanism is thought to involve photo-oxidative cleavage of the internal stilbene, yielding alcohols and aldehydes, with further degradation leading to derivatives of melamine, which is persistent (AICIS 2022; AISE and Cefic 2004). The half-life to direct photolysis in sunlit natural water is 3–6 hours in laboratory tests of FB-71 and FB-220 (Kramer et al. 1996; Managaki and Takada 2005). However, dissipation rates in the environment will be seasonal and depth dependent, reaching their highest levels in the upper photic zone during summer but easing into winter (Poiger et al. 1999; Stoll and Giger 1997; Yamaji et al. 2010).

Chemicals in this group will not hydrolyse in the environment as they do not possess readily hydrolysable groups. In experimental studies conducted according to OECD TG 111, the half-lives of FB-71 and FB-220 to hydrolysis in water exceeded one year at pH 4, 7 and 9 (REACH n.d.-a; n.d.-b).

Based on available exposure and monitoring data, chemicals in this group are not expected to degrade in sediment or soil. Sediment core samples obtained from a Swiss lake in the 1990s contained a historical record of FBAs in layers deposited during the 1950–1960s (Poiger 1994; Stoll 1997). In an exposure study undertaken in Switzerland, soil plots amended with STP biosolids reportedly remained contaminated with FB-71 throughout the 45 month test period (AISE and Cefic 2004). The available data are not sufficient to establish lifetimes in sediment and soil but support conservative half-lives exceeding 6 months.

Bioaccumulation

Chemicals in this group are not expected to bioaccumulate in organisms.

Measured partition coefficients of chemicals in this group, while dependent on speciation, are below than the level expected to cause significant bioaccumulation in aquatic and terrestrial life (log K_{OW} <4.2 and log K_{OW} <2.0, respectively).

Available data for FB-71 indicates that chemicals in this group will not bioaccumulate in fish. According to a bioaccumulation test conducted according to OECD TG 305 C, bioconcentration factors (BCF) for FB-71 in Eurasian carp (*Cyprinus carpio*) are 6.4–28 and 1.4–4.7 L/kg at dosage levels of 0.02 and 0.2 mg/L, respectively (NITE n.d.; REACH n.d.-a). These are well below the threshold value for a bioaccumulation hazard to aquatic life (BCF <2000).

Environmental transport

Chemicals in this group are not expected to undergo long range transport in the environment. Riverbed sediments containing FBAs will eventually migrate into coastal and marine environments but are unlikely to travel significant distances (Hayashi et al. 2002; Managaki and Takada 2005; SERI 2011).

Predicted environmental concentration (PEC)

No Australian monitoring data were identified for chemicals in this group. International monitoring data and standard exposure modelling have been used to estimate reasonable worst-case PECs in affected compartments.

Considering river flows can consist entirely of treated effluent in some drier parts of Australia, a reasonable worst case PEC for chemicals in this group is 6.6 µg/L per compound in rivers impacted by sewage outfall and 39 µg/L FB-220 in rivers impacted by the pulp and paper industry. These values were derived from the highest reported concentrations in sewage effluent and industrial effluents, respectively (SERI 2011; Yamaji et al. 2010).

In sediments affected by sewage outfall, a reasonable worst case PEC for chemicals in this group is 4.4 mg/kg per compound. This value was derived from recent monitoring data from Sweden, where the topmost (0–2 cm) sediment layer near an effluent discharge site was analysed for chemicals in this group (SERI 2011).

The calculated PEC for chemicals in this group in Australian agricultural soil amended with biosolids is 0.86 mg/kg soil/year per compound, based on the highest reported biosolids concentration of 112 mg/kg per compound (Poiger et al. 1998), typical biosolids application rates and a soil bulk density of 1300 kilograms per cubic metre (kg/m^3) (EPHC 2009; Langdon et al. 2010).

Parameter	Value	Comment
PEC_{soil}	0.86 mg/kg soil/year per compound	$PEC_{soil} = \frac{C_{biosolids} \times BIOSOLIDS_{land}}{SOILMIX_{depth} \times SOIL_{density}}$
$C_{biosolids}$	112 mg/kg	Highest reported concentration in STP biosolids
$BIOSOLIDS_{land}$	1 kg/m^2/year	Default value
$SOILMIX_{depth}$	0.1 m	Default value
$SOIL_{density}$	1300 kg/m^3	Default value

Monitoring data

STP influent reportedly contains 10–100 µg/L of FBAs (Kramer 1992). Based on available data, influent concentrations are <1–23 µg/L per compound, removal rates in municipal STPs are 15–95% and residual concentrations in secondary effluent are <10 µg/L, or <0.05–6.6 µg/L per compound. FBA concentrations in STP biosolids are 56–169 mg/kg or 2.8–112 mg/kg per compound:

Chemical	Location	Ref	STP influent (µg/L)	Secondary effluent (µg/L)	Removal in STPs (%)	Biosolids (mg/kg)
FB-71	Sweden	1	≤1.0	0.059–0.49	>73	2.8–11 (4.5)
	Switzerland	2, 3	7.1	2.6–4.5	(89)	55–105 (72),
			6.6–12.9 (10.5)	1.8–2.8 (2.4)	-	86–**112** (100)
		4	-	~2.9–5.7	-	-
		5	-	1.9–3.6	-	-
	Germany	6	6.1–7.5	0.63–3.9	-	10.2–72
	Japan	7	2.9–8.2	0.68–4.9 (2.5)	15–79	-
		8	6.6–17.8	0.6–**6.6**	62.7–92.3	-
	Taiwan	9	-	0.042	-	-
FB-220	Sweden	1	~10	0.25–3.6	>90	15–62 (41)
	Germany	6	8.2–14.9	1.6–3.9	-	2.0–2.6*
FB-28	Sweden	1	~10	0.089–0.91	>90	35–83 (55)
	Switzerland	2	-	-	-	8–11 (9)
	Taiwan	9	-	1.58	-	-
Total FBAs	Sweden	1	20–24 (22)	0.43–5.1 (9.6)	-	56–160 (110)
	Switzerland	2	-		53–98	85–169 (118)

Overall averages are indicated in brackets.

References: [1] SERI (2011); [2] Poiger (1994); [3] Poiger et al. (1998); [4] Poiger et al. (1999); [5] Stoll (1997); [6] Van de Plassche et al. (1999); [7] Hayashi et al. (2002); [8] Yamaji et al. (2010); [9] Chen et al. (2006).

Based on monitoring data from the Swedish pulp and paper industry, average FBA concentrations in industrial effluent are <4 µg/L per compound, excluding one outlier containing 39 µg/L of FB-220 (SERI 2011).

Based on available data, FBA concentrations in surface water are reportedly <2 µg/L per compound. This excludes three outliers measured in rivers during the 1970–80s in Sweden (8.3 µg/L), the USA (40 µg/L) and Japan (≤45 µg/L):

Chemical	Location	Ref	River water (µg/L)	Lake water (µg/L)	Estaurine/Coastal water (µg/L)
FB-71	Sweden	1	<0.15	<0.02	<0.02
	Switzerland	2	0.036–0.439	-	-
		3	<0.6	-	-
		4	0.006–0.986	0.047–0.130	-
		5	-	0.053–0.098	-
	Germany	6	0.006–0.95	-	-
	Japan	7	0.1–0.4	-	~0.01–1
		8	-	-	0.001–1.3
		9	0.096–0.137 (0.123)	0.002–0.004	-
	USA	4	0.06–0.7	-	-
		6	40 (0.7)	-	-
	Taiwan	10	<LOQ	-	-
FB-220	Sweden	1	<0.3	<0.04	<LOQ
	Germany	6	<0.002–0.152	-	-
FB-28	Sweden	1	<0.05	<0.02	<0.02
	Taiwan	10	0.1–0.145	-	-
Total FBAs	Sweden	1	<0.45	0.01–0.05	<0.03
		6	≤8.3	-	-
	Japan	2, 6	≤45	-	-
	USA	4, 6	≤0.6	-	-

Overall averages indicated in brackets.

References: [1] SERI (2011); [2] Poiger (1994); [3] Poiger et al. (1999); [4] Stoll (1997); [5] Stoll and Giger (1997); [6] Van de Plassche et al. (1999); [7] Hayashi et al. (2002); [8] Managaki and Takada (2005); [9] Yamaji et al. (2010); [10] Chen et al. (2006).

Sediments contain a historical record of FBA deposits since their introduction (Stoll 1997). Concentrations therefore vary by location and sample depth, with the topmost layers (0–5 cm) being most indicative of recent exposure levels. Based on available data in upper sediment layers, sediment concentrations for chemicals in this group are ≤4.4 mg/kg dw per compound:

Chemical	Location	Ref	Depth (cm)	River sediment (mg/kg dw)	Lake sediment (mg/kg dw)	Coastal sediment (mg/kg dw)
FB-71	Sweden	1	0–2	-	≤0.43	<0.1, **4.4***
	Switzerland	2	0–50	-	≤0.3	-
		3	0–5	-	0.41–1.41	-
			5–10	-	0.43–1.79	-
			10–15	-	<0.23–3.60	-
			15–20	-	0–1.98	-
		4	0–5	-	0.65–1.42	-
	Japan	2	-	0.1–3.4	-	-
		5	0–2	0.02–1.55	-	0.02–0.37
		6	0–6	-	<0.1	-
FB-220	Sweden	1	0–2	-	<0.3	<0.1, 1.6*
FB-28	Sweden	1	0–2	-	<0.2	<0.1, 1.2*
Total FBAs	Sweden	1	0–2	-	<0.9	<0.2, 7.2*

**Measured near an effluent discharge site.*

References: [1] SERI (2011); [2] Poiger (1994); [3] Stoll (1997); [4] Stoll and Giger (1997); [5] Managaki and Takada (2005); [6] Yamaji et al. (2010).

Very little monitoring data for soil were identified. A regional PEC of 0.4 mg/kg soil/year FB-71 has been suggested in Switzerland but this is not expected to be representative of Australia (AISE and Cefic 2004). This value was derived from the first 12 months of data collected during an exposure study where two soil plots amended with the maximum permissible load of STP biosolids was analysed for FB-71 over a 45 month period.

Environmental effects

Effects on Aquatic Life

The toxicity of FBAs to aquatic organisms is well studied. No specific modes of action have been established. Aquatic toxicity tests are typically conducted under periodic exposure to a light source, indicating some potential for photo-degradation of the test substance. However, measured concentrations of FBAs, where available, were maintained during test timeframes.

Acute toxicity

The following measured median lethal and effect concentrations (LC50 and EC50, respectively) for freshwater model organisms across 3 trophic levels were retrieved from the REACH dossiers for chemicals in this group (REACH n.d.-a; n.d.-b; n.d.-c).

Fish

Chemical	Endpoint	Method
FB-71	96 h LC50 >319 mg/L*	*Danio rerio* (Zebrafish) Measured concentrations Static 12 light and 12 dark hours/day OECD TG 203
FB-220	96 h LC50 >1000 mg/L*	*D. rerio* Nominal concentrations Static 12 light and 12 dark hours/day OECD TG 203
FB-28	96 h LC50 >1000 mg/L*	*D. rerio* Nominal concentrations Static 12 light and 12 dark hours/day OECD TG 203

**No lethal effects observed at the highest test concentration.*

Invertebrates

Chemical	Endpoint	Method
FB-71	48 h EC50 = 6.85 mg/L	*Ceriodaphnia dubia* Immobilisation Nominal concentrations Static 16 light and 8 dark hours/day Australian NSW EPA test guideline
FB-220	48 h EC50 >113 mg/L*	*Daphnia magna* Immobilisation Measured concentration (limit test) Static 16 light and 8 dark hours/day OECD TG 202
FB-28	48 h EC50 >100 mg/L	*D. magna* Immobilisation Nominal concentration (limit test) Static 12 light and 12 dark hours/day OECD TG 202

**No lethal effects observed at the highest test concentration.*

Algae

Chemical	Endpoint	Method
FB-71	72 h EC50 = 82.5 mg/L	*Raphidocelis subcapitata* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201
FB-220	72 h EC50 >1000 mg/L	*Desmodesmus subspicatus* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201
FB-28	72 h EC50 >123 mg/L*	*R. subcapitata* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201

**No lethal effects observed at the highest test concentration.*

Chronic toxicity

The following measured lowest and no observed effect concentrations (LOEC and NOEC, respectively) were retrieved from the REACH registration dossiers for chemicals in this group (REACH n.d.-a; n.d.-b; n.d.-c):

Fish

Chemical	Endpoint	Method
FB-71	30 d NOEC = 2.5 mg/L	*D. rerio* Survival Nominal concentrations Flow-through 16 light and 8 dark hours/day OECD TG 210
FB-28	35 d LOEC = 11.2 mg/L	*D. rerio* Survival Measured concentrations Flow-through 16 light and 8 dark hours/day OECD TG 210

Invertebrates

Chemical	Endpoint	Method
FB-71	21 d NOEC = 11.3 mg/L	*D. magna* Reproduction Nominal concentrations Semi-static 16 light and 8 dark hours/day OECD TG 211
FB-220	21 d NOEC = 6.59 mg/L	*D. magna* Reproduction Measured concentrations Semi-static 16 light and 8 dark hours/day OECD TG 211
FB-28	21 d NOEC = 3.22 mg/L	*D. magna* Reproduction Measured concentrations Semi-static 16 light and 8 dark hours/day OECD TG 211

Algae

Chemical	Endpoint	Method
FB-71	72 h NOEC = 11.7 mg/L	*R. subcapitata* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201
FB-220	96 h NOEC = 500 mg/L	*D subspicatus* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201
FB-28	72 h NOEC = 30.8 mg/L	*R. subcapitata* Growth rate Nominal concentrations Static Continuous illumination OECD TG 201

Effects on sediment dwelling life

No sediment toxicity data were identified for chemicals in this group.

Effects on terrestrial Life

The following effect concentrations for earthworms were retrieved from the REACH dossiers for chemicals in this group (REACH n.d.-a; n.d.-b; n.d.-c):

Chemical	Endpoint	Method
FB-71	14 d LC50 >1000 mg/kg	*Eisenia fetida* Mortality Nominal concentrations Continuous illumination OECD TG 207
FB-220	14 d LC50 >10,000 mg/kg	*E. fetida* Mortality Nominal concentration (limit test) Photoperiod: not specified OECD TG 207
FB-28	14 d LC50 >5000 mg/kg*	*E. fetida* Mortality Nominal concentration (limit test) Photoperiod: not specified OECD TG 207

**No sublethal effects observed.*

Predicted no-effect concentration (PNEC)

Available data are sufficient to determine PNECs for chemicals in this group in water and soil, but not sufficient to determine PNECs in sediment.

Aquatic compartment

Aquatic PNECs for FB-71 and FB-28 were derived from measured chronic test data for fish and an assessment factor of 10. This assessment factor was selected as reliable chronic test data are available for three trophic levels (EPHC 2009). An assessment factor of 50 was used to calculate a PNEC FB-220 as reliable chronic test data are only available for aquatic invertebrates and algae:

Chemical	Pivotal endpoint (mg/L)	Endpoint	Assessment Factor	PNEC (µg/L)
FB-71	2.5	Fish NOEC	10	250
FB-220	6.59	Invertebrate NOEC	50	132
FB-28	3.22	Invertebrate NOEC	10	322

Sediment compartment

Sediment PNECs for chemicals in this group were not determined as no experimental toxicity data for sediment dwelling organisms were identified (EPHC 2009).

Terrestrial compartment

Soil PNECs for chemicals in this group were derived from the measured acute test data for earthworms and an assessment factor of 1000 (EPHC 2009). This assessment factor was selected as acute data are only available for one terrestrial macro-organism:

Chemical	Pivotal endpoint (mg/kg)	Assessment Factor	PNEC (mg/kg)
FB-71	>1000	1000	>1
FB-220	>10,000	1000	>10
FB-28	>5000	1000	>5

Categorisation of environmental hazard

The categorisation of the environmental hazards of the assessed chemicals according to Australian Environmental Criteria for Persistent, Bioaccumulative and/or Toxic Chemicals (DCCEEW n.d.) is presented below:

Persistence

Persistent (P). Based on environmental monitoring data for sediment and soil and available degradation data for FB-220 and FB-28 in water, chemicals in this group are categorised as Persistent.

Bioaccumulation

Not bioaccumulative (Not B). Based on low measured bioconcentration factors (BCF) in fish, low octanol-water partition coefficients (log K_{OW} <4.2) and no evidence of biotransformation, chemicals in this group are categorised as Not bioaccumulative.

Toxicity

Not toxic (Not T). Based on acute toxicity endpoints exceeding 1 mg/L and chronic toxicity endpoints exceeding 0.1 mg/L, chemicals in this group are categorised as Not toxic.

Environmental risk characterisation

Based on the PEC and PNEC values determined above, the following Risk Quotient (RQ=PEC ÷ PNEC) have been calculated for release of chemicals in this group into surface water and soil.

FB-71:

Compartment	PEC	PNEC	RQ
Surface water	6.6 µg/L (sewage outfall)	250 µg/L	0.03
Soil	0.86 mg/kg soil/year	>1 mg/kg	<0.86

FB-220:

Compartment	PEC	PNEC	RQ
Surface water	6.6 µg/L (sewage outfall) 39 µg/L (industrial effluent)	132 µg/L	0.05 0.30
Soil	0.86 mg/kg soil/year	>10 mg/kg	<0.09

FB-28:

Compartment	PEC	PNEC	RQ
Surface water	6.6 µg/L (sewage outfall)	322 µg/L	0.02
Soil	0.86 mg/kg soil/year	>5 mg/kg	<0.18

For water and soil, a worst-case RQ of less than 1 indicates that chemicals in this group are not expected to pose a significant risk to the environment based on estimated emissions, as environmental concentrations are below levels likely to cause harmful effects.

A RQ for sediment could not be determined for chemicals in this group, due to a lack of information about toxicity to sediment dwelling organisms. The highest FBA levels occur near effluent discharge sites in urbanised catchments, where concentrations can exceed 1 mg/kg per compound. However, available monitoring data from international jurisdictions indicate that sediment concentrations rapidly decline away from these sites (SERI 2011; Stoll 1997). Given these generally low sediment concentrations, and in the absence of evidence of significant toxicity to sediment-dwelling life, these chemicals are not anticipated to pose a significant risk to the ecosystems in the sediment compartment.

Uncertainty

This evaluation was conducted based on a set of information that may be incomplete or limited in scope. Some relatively common data limitations can be addressed through use of conservative assumptions (OECD 2019) or quantitative adjustments such as assessment factors (OECD 1995). Others must be addressed qualitatively, or on a case-by-case basis (OECD 2019).

The most consequential areas of uncertainty for this evaluation are:

- Insufficient information is available to characterise the terrestrial and sediment toxicity of chemicals in this evaluation. The outcomes of the evaluation may change if additional information becomes available.
- No Australian monitoring data are available for chemicals in this evaluation and overseas information is used as a surrogate. The outcomes of this evaluation may change if new monitoring information become available to indicate that environmental concentrations of these chemicals in Australia are higher than currently assessed.

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