Arkema Coatings Resins Limited

Solvent Management Plan 2016

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SOLVENT MANAGEMENT PLAN 2016

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CONTENTS

Summary

Arkema Coatings Resins Limited operates a batch structural resins manufacturing process which has been authorised in accordance with the Environmental Protection Act 1990. In order to comply with the requirements for solvent emission activities in the Industrial Emissions Directive it is necessary to demonstrate that solvent losses from process operations do not exceed 3% of the total solvent input.

A solvent balance in accordance with the methodology provided in guidance note PG 6/44(11) has been undertaken based on solvent purchase and disposal records provided by Arkema Coating Resins Limited and site measurements.

For the period January to December 2016 the assessment indicated a total solvent release from process operations equivalent to 1.1% of the total solvent input. The assessment therefore indicates compliance with the applicable total emission limit value for the period under review.

1 Introduction

Arkema Coatings Resins Limited (Arkema) operates a batch structural resins manufacturing process which has been authorised in accordance with the Environmental Protection Act 1990. Arkema are obliged to meet the requirements of process guidance note PG 6/44 (11) which take into account the requirements for solvent emission activities in the Industrial Emissions Directive (European Union Directive 2010/75/EU).

Arkema have opted for the "Total Emission Limit Value" option (PG 6/44 (11) SE Box 6, IED Article 59, Annex VII, Parts 2, 3 & 4) as their preferred method of showing compliance with solvent emission limits. As Arkema use more than 1000 tonnes of solvent per annum their total emission limit value is 3% of their solvent input.

Arkema contracted Environmental Scientifics Group (ESG) to prepare a solvent management plan to determine the annual total solvent emission and solvent input from their resin manufacturing process in order to determine compliance with the applicable emission limit value.

This solvent management plan covers the period January to December 2016.

2 Site and process operations

The Arkema site is located at Stallingborough near to Immingham Docks around 6 km from Grimsby. Figure 1 illustrates the site location and boundary.

The site currently operates a structural resins manufacturing process with two main generic products; unsaturated polyester resins (UPR) and Gelcoats. These are manufactured in two dedicated buildings; the Polyester Mixing Building (PMB) and Gelcoats building respectively as shown in Appendix 1, Figure A1.1.

The manufacturing process comprises the mixing of base resins with styrene and other materials as appropriate for the product. Calcium carbonate is used as a filler where required.

2.1 Delivery of raw materials

The base resin is imported from Europe, largely by road tanker and offloaded directly to on-site storage tanks. The storage tanks currently in use are denoted as polyester resin hold tanks (PRHT) A to F, K to M and T to V. These are located in two distinct areas as shown in Figure A1.1. Off-loading to tanks K, L, M, T, U and V use a plc controlled manifold loading system, while off-loading to tanks A to F is by pressure transfer using a dedicated line for each tank.

The tank farms are contained within concrete bunds. Resins are transferred by pipe to the production buildings.

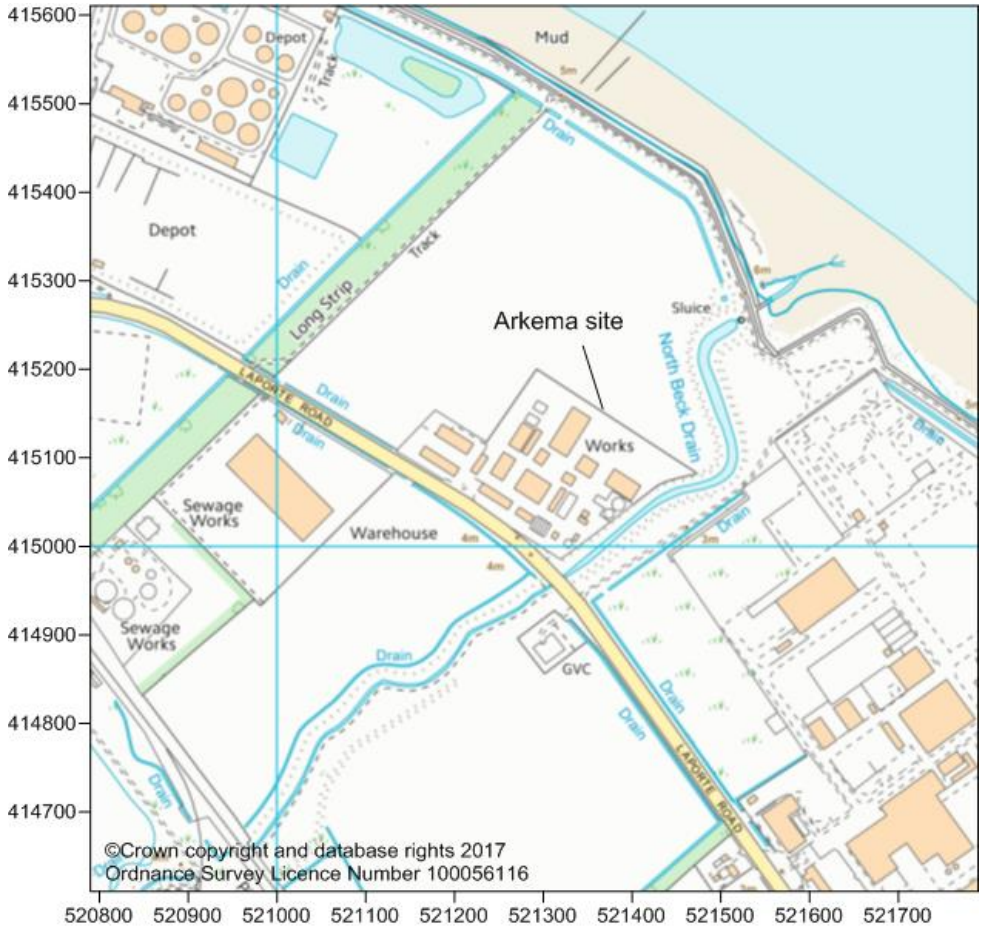
Base intermediate resins are also delivered in drums or intermediate bulk containers (IBCs) and are stored in a dedicated area on the northern boundary of the site.

Styrene is also delivered by road tanker and stored in a dedicated tank (RMT01) within a bunded area.

All storage tanks will be subject to some release of volatile organic compounds (VOCs) due to breather losses and displacement during filling.

Other liquid materials are delivered in a range of containers with 20—205 l drums and 1000l IBCs. These also have a dedicated storage area (see Figure A1.1).

Figure 1 Arkema site location



2.2 Polyester Mixing Building

In the Polyester Mixing Building (PMB) base unsaturated polyester resins are mixed with styrene and other materials in a cold mixing process. The range of other materials added will depend on the required characteristics of the final product resin. The PMB building has eight mixing vessels with batch capacities of between 1 and 18 tonnes.

Base resin is generally metered to the mixing vessels from the bulk storage tanks using a closed system, although smaller amounts of resin may be added from drums or IBCs using a semi-closed pumped transfer system. Other amounts of fillers and additives may be added manually depending on the product specification. The resin metering systems limit the release of VOCs during transfer, although there will be some release, together with fugitive releases during manual addition.

Mixer 8 has a closed system allowing addition of calcium carbonate from its bulk silo. In order to remove the air that is entrained during addition of powdered materials a vacuum is required on mixer 8. The vacuum is applied for around 30-45 minutes per batch and will result in a release of VOCs.

Following completion of mixing samples will be taken for quality control checking within the PMB laboratory. This procedure will also give rise to a release of VOCs. Further additions of materials, mixing and QC checks may be required in order to meet the final product specification.

Final products are pumped from the mixing vessels, via filtration systems, to filling points for pails, drums and IBCs or to road tankers in the case of bulk batches These operations also have the potential for VOC release.

There will be additional releases of VOCs during the changing of filters and in the cleaning of the mixers, although this is minimised as far as possible by the use of dedicated mixers for certain products.

The PMB building and laboratory is equipped with a range of local exhaust ventilation (LEV) systems to capture released VOCs with subsequent emission to atmosphere. There will also be some release of VOCs from the general building atmosphere due to natural building ventilation.

The PMB building has a production capacity of around 17,500 tonnes resin per year. Operation is normally on 7 day a week basis for 16 hours/day. There are plant shutdowns at Easter and Christmas of around 14 days.

2.3 Gelcoats Building

Operations in the Gelcoats building are similar to those in the PMB, although on a smaller scale with 10 mixers ranging in capacity from 20 kg to 6 tonnes. The process also allows further blending of the base gelcoat to meet various customer specifications.

The main production area includes eight small mixers, container filling points and materials storage areas. Although base resin and styrene is loaded using closed transfer systems from the bulk storage tanks, there is manual loading of all other raw materials. Releases of VOCs can therefore occur during loading, mixing, sampling and containerisation stages of the process.

Mixers 6 and 8 are high speed dispersion mixers which require a vacuum to remove entrained air. This operation will also result in a release of VOCs.

The final product is packaged in pails, drums or IBCs. There is no bulk transfer facility in the Gelcoats process.

The Gelcoats building also houses a laboratory for QC checking with associated potential for release of VOCs.

The Gelcoats building and laboratory is equipped with a range of LEV systems to capture released VOCs with subsequent emission to atmosphere. There will also be some release of VOCs from the general building atmosphere due to natural building ventilation.

The Gelcoats building has a production capacity of around 3,000 tonnes resin per year. Operation is normally on 5 day a week basis for 8 hours/day. There are plant shutdowns at Easter and Christmas of around 14 days.

2.4 Cleaning operations

Process equipment cleaning is performed in situ. Fixed mixing vessels in both production buildings are cleaned, where necessary between batches by recirculating styrene around the system, and where possible, using the mixing blades to create a spray effect on the walls of the vessel. Whilst these operations are ongoing the vessels remain sealed. By recirculating styrene around the system associated pipework, pumps and filters etc. are also cleaned.

Occasionally, where required for maintenance purposes, mixing vessels and storage tanks may be cleaned by external contractors using high pressured water jetting equipment. This method would typically be used where entry may be required into a vessel for inspection or non-destructive testing.

These operations will result in a release of VOCs and produce a solvent containing liquid waste stream for disposal.

Physical cleaning techniques are also used for small items of equipment, such as removable mixing blades, using brushes and small quantities of styrene and acetone. Laboratory equipment and some process valves are cleaned using acetone.

Dedicated cleaning locations are served by LEVs.

2.5 Polynt Building

Arkema manufacture resins under an operational agreement with Polynt Composites UK, who have a building containing administration offices and a laboratory within the site boundary. As part of the research and development activities undertaken within this building there is a demonstration spray booth and laboratory which both give rise to releases of VOCs. The affected areas are served by LEVs.

2.6 Waste disposal

The site generates two main streams of solvent containing wastes:

Residual solvent in emptied drums and IBCs
General process wastes

Arkema return empty drums and IBCs for recycling following use. It is assumed that there will be some residual solvent in each container which will represent a solvent loss from the process. When ‘emptied’ Arkema contract R Spivey and Sons and Schutz UK to recycle drums and IBCs respectively.

Arkema generate a number of process waste streams, although only the waste designated a ‘hazardous’ has a significant solvent content. This waste is sent off-site to an appropriately registered contractor for disposal.

The hazardous waste streams include:

Waste mixed polyester resin (liquid) – from line clearance, container residue draining, filter waste etc. which is removed in drums and IBCs.
Retain tins containing resin – mixed polyester resin / Gelcoat resin in 0.5 l tins, which are placed into an empty 205l drum (still in the tins) for disposal.
Solid waste – waste liquid resin and Pyrosorb from any spillages or leaks which are removed from site in 205 l drums.
Contaminated pails and cans – drained pails and cans which have previously contained pigment or resin are placed onto a pallet, shrink wrapped for disposal.

Arkema maintain a register of disposals of waste designated as hazardous.

3 Methodology

Arkema's solvent management plan is based on the British Coatings Federations (BCF) guidance ("The VOC Workbook – Guidance for coatings manufacturing installations: demonstrating compliance with PG6/44 VOC emission limits and preparing solvent management plans") as recommended in PG 6/44 (11).

The basis of the method is to determine solvent input to the process and solvent output in terms of releases. The VOC Workbook defines general input and output streams for coating processes. Those considered applicable to Arkema's Stallingborough site are summarised in Table 1.

Table 1 Process solvent flows

IED		Code	Applicability to Arkema
Inputs			
I1	Purchases of solvent and solvent containing preparations	I1.1	Purchased solvents
		I1.2	Solvent in purchased resins
		I1.3	Solvent content of other purchased materials
Outputs			
O1	Solvent emissions in waste gases	O1.1	Powered vents (e.g. local exhaust extraction)
		O1.4	Bulk storage vessel (solvents and resins) breather vents
O4	Uncaptured emissions	O4.1	Fugitive releases from the natural ventilation of buildings
O6	Solvents in collected wastes	O6.1	Residual solvent or solvent containing materials in emptied drums and IBCs sent for disposal
		O6.2	Solvent containing liquid and solid waste sent for disposal

The solvent inputs and outputs in Table 1 were determined for the assessment period using information from Arkema, site measurements and methodologies recommended in the 'VOC Workbook'. Table 2 summarises the methodology employed to determine the relevant solvent input and output flows.

Table 2 Determination of process solvent flows

Code	Activity	Determination methodology
I1.1	Purchased solvents	Records of purchases of solvent and solvent containing materials were provided by Arkema for the assessment period (Appendix 2).
I1.2	Solvent in purchased resins	
I1.3	Solvent content on other purchased materials	
O1.1	Powered vents (e.g. local exhaust extraction)	Releases of volatile organic compounds from the exhaust vents serving the processes were measured by ESG over the 3 to 6 July and 22 to 23 August 2017 (ESG reports LNO13703, 27 July and 28 August 2017). Methodology in the VOC Workbook, together with Arkema's estimates of vent operating time, were then used to determine the annual releases of VOCs (Appendix 3)
O1.4	Bulk storage vessel (solvents and resins) breather vents	Arkema provided details of the resin/solvent throughput for each of the 13 bulk storage tanks at the Stallingborough site. VOC Workbook methodology (see Appendix 4) was then used to determine releases of solvents from tank breathing and filling.

Code	Activity	Determination methodology
O4.1	Fugitive releases from the natural ventilation of buildings	The VOC content of the ambient atmosphere in the PMB and Gelcoats building and the ventilation rate was measured by ESG on the 22 and 23 August 2017. Based on these and an estimate of the duration of access door opening a fugitive solvent release rate was determined (see Appendix 5).
O6.1	Residual solvent or solvent containing materials in emptied containers sent for disposal	The number of drums and IBCs of solvents and solvent containing materials that were emptied and subsequently removed from site over the assessment period was determined from purchase records provided by Arkema. The loss of solvent was determined based on an assumed residual solvent content (Appendix 6).
O6.2	Solvent containing liquid/solid waste sent for final disposal	Records of the disposals of solvent containing materials for the assessment period were provided by Arkema. The solvent removed from site in waste was determined based on the gross tonnage of waste and mean solvent content of purchased materials.

4 Determination of solvent releases

The methodology in Table 2 was employed to determine the solvent input and output from Arkema's resin manufacturing process at their Stallingborough site. The following section summarises the determination of solvent inputs and outputs in the context of the allowable total emission limit value.

4.1 Solvent purchases

Arkema supplied details of all solvent and solvent material containing purchases for 2016 as detailed in Appendix 2. Analysis of these records indicated the process solvent inputs in Table 3.

Table 3 Summary of solvent purchases

Item		Total tonnes	Mean solvent content %	Total solvent tonnes
I1.1	Purchased solvents (Styrene)	1771	100	1771.0
I1.2	Solvent in purchased resins (bulk)	13063	31.1	4062.7
	Solvent in purchased resins (IBCs, drums)	2158	31.0	669.0
I1.3	Solvent content of other purchased materials	1950	19.0	370.4
I1 Total		18942	36.3	6873.1

4.2 Releases from powered vents

The PMB and Gelcoat building process areas and laboratories are served by a range of LEV systems which release to atmosphere via 14 release points as summarised in Table 4 and located as shown in Figure A1.2.

Table 4 Summary of powered vent release points and releases

Point	Location	Source	Solvent release (kg/year)
A1	PMB	PMB Mixer 8 vacuum vent	47
A2	PMB	Mixer 8 vent (not powered)	2
A3	PMB	PMB LEV for mixers 1-9	1527
A5	Gelcoats	Mixers 6 and 8 LEV	1130
A6	Gelcoats	Colour mixer LEV	622
A7	Gelcoats	Laboratory LEV	291
A8	Gelcoats	Spray booth vent	156
A9	Yard	Styrene storage tank vent	9
A29	Polynt	Demonstration area LEV	10
A30	Polynt	Laboratory LEV	450
A31	Yard	Gelcoats vacuum seal vent	15
A32	Engineering workshop	Workshop LEV	10
A35	PMB	Laboratory LEV	136
A36	PMB	Drumming off mixer 8 LEV	28
O1.1 Total solvent release from powered vents (t/annum)			4.4

It should be noted that A2 is not a powered vent, but is included in this section as the release composition is common with the powered vents.

In order to determine the annual releases from these vents exhaust VOC concentrations, and where possible volume flow rates, were measured and combined with Arkema's estimate of annual operating hours to determine a mass release of solvent. Where flow rates could not be measured due to access limitations LEV test results from 2016 were employed.

Detailed methodology and calculations are presented in Appendix 3.

4.3 Releases from bulk storage vessels

There are 13 bulk storage vessels which will each be subject to losses of VOCs. The two routes for loss are due to filling and breathing. Breathing losses are caused by vapour being expelled from the tank either by thermal expansion or a change in atmospheric pressure. Filling losses occur during filling through the displacement of the air and vapour by the rising level of the liquid.

Appendix 4 provides details of the methodology and calculation of solvent losses from the bulk storage vessels. These calculations are summarised in Table 5.

Table 5 Summary of bulk storage vessel and associated solvent losses

Tank	Solvent (kg/annum)		
	Filling losses	Breathing losses	Total release
A	89.6	21.7	111.3
B	55.7	21.7	77.4
C	37.6	21.7	59.3
D	0.0	0.0	0.0
E	13.1	21.7	34.7
F	7.4	21.7	29.1
K	9.3	16.6	25.9
L	0.0	0.0	0.0
M	15.5	16.6	32.1
T	8.3	11.5	19.8
U	5.5	11.5	16.9
V	25.3	11.5	36.7
RMT01	46.8	6.0	52.7
O1.4 Total releases from bulk storage vessels (tonnes/annum)			0.5

4.4 Fugitive releases from natural ventilation of buildings

The PMB and Gelcoat buildings will be subject to loss of VOCs due to the natural ventilation of the buildings. The methodology and details assessment of losses for these buildings are presented in Appendix 5 and summarised in Table 6.

Table 6 Summary of solvent losses by natural ventilation

Building		Gelcoat	PMB
Annual fugitive release	kg styrene/annum	17881	8186
O4.1 Total annual solvent release by natural ventilation (tonnes/annum)		26.1	

4.5 Releases of residual solvent in emptied containers

Arkema return empty drums and IBCs for recycling following use. It is assumed that there will be some residual solvent in each container which will represent a solvent loss from the process. Both solvent containing resins and other solvent containing materials are delivered in drum and IBCs. When 'emptied' Arkema contract R Spivey and Sons and Schutz UK to recycle drums and IBCs respectively. It is assumed that the containers leaving site for recycling contain residual material equivalent to 1% of that originally present. This represents a loss of solvent from the process.

Based on the recorded resin and raw material deliveries in Appendix 2 the losses of solvent due to recycling of spent containers are estimated in Appendix 6 and summarised in Table 7.

Table 7 Summary of solvent losses in containers removed from site

Container	No. of containers recycled	Solvent content kg
Raw materials in drums	1206	346
Raw material in IBCs	372	3308
Resins in drums	343	213
Resins in IBCs	1346	4173
O6.1 Solvent losses in emptied containers (tonnes/annum)		8.0

4.6 Residual solvent in wastes sent for disposal

Arkema generate a number of process waste streams, although only the waste designated a 'hazardous' has a significant solvent content. This waste is sent off-site to an appropriately registered contractor for disposal (see section 2.6).

Arkema recorded the total hazardous waste quantity disposed of in 2016 as 106.8 tonnes. For the purposes of determining a solvent loss in this stream it is assumed that the solvent content is equivalent to the mean solvent content of all materials purchased in 2016. An analysis of purchased solvent containing materials in 2016 (Table 3) indicates a mean solvent content of 36.3 %. It is therefore considered that the solvent lost from the process in wastes sent for disposal in 2016 is 38 .8 tonnes as summarised in Table 8.

Table 8 Summary of solvent losses in wastes sent for disposal

Quantity of waste removed	tonnes	106.8
Mean solvent content	%	36.3
O6.2 Solvent losses in waste sent for disposal (tonnes/annum)		38.8

4.7 Solvent balance and limit compliance

Based on the assessments of process solvent input and outputs and the methodology of PG 6/44(11), Table 9 presents the process solvent balance for 2016.

Table 9 Solvent flows January to December 2016

Activity		Solvent flow	
		tonnes	% of input
I1.1	Purchased solvents	1771.0	-
I1.2	Solvent in purchased resins	4731.7	
I1.3	Solvent content on other purchased materials	370.4	
Solvent input		6873.1	
O1.1	Powered vents (e.g. local exhaust extraction)	4.4	0.064
O1.4	Bulk storage vessel (solvents and resins) breather vents	0.5	0.007
O4.1	Fugitive releases from the natural ventilation of buildings	26.1	0.379
O6.1	Residual solvent or solvent containing materials in emptied containers sent for disposal	8.0	0.117
O6.2	Solvent containing liquid/solid waste sent for final disposal	38.8	0.565
Solvent output		77.8	1.132

Determination of the solvent flows and application of the calculation guidance in the PG 6/44(11) and the VOC Workbook indicates that the total solvent release for the period January to December 2016 was equivalent to 1.1% of the solvent input. This is below the applicable total emission limit value of 3%.

This analysis also provides some indication of the major sources of solvent loss and areas where mitigation might be effective. Fugitive releases by natural ventilation and solvent losses in wastes for disposal account for over 80% of total solvent losses.

Appendix 1 Arkema Coating Resins Limited, Stallingborough site

Figures A1.1 and A1.2 illustrate the site arrangement and locations of point source emission points respectively.

Figure A1.1 Arkema site arrangement

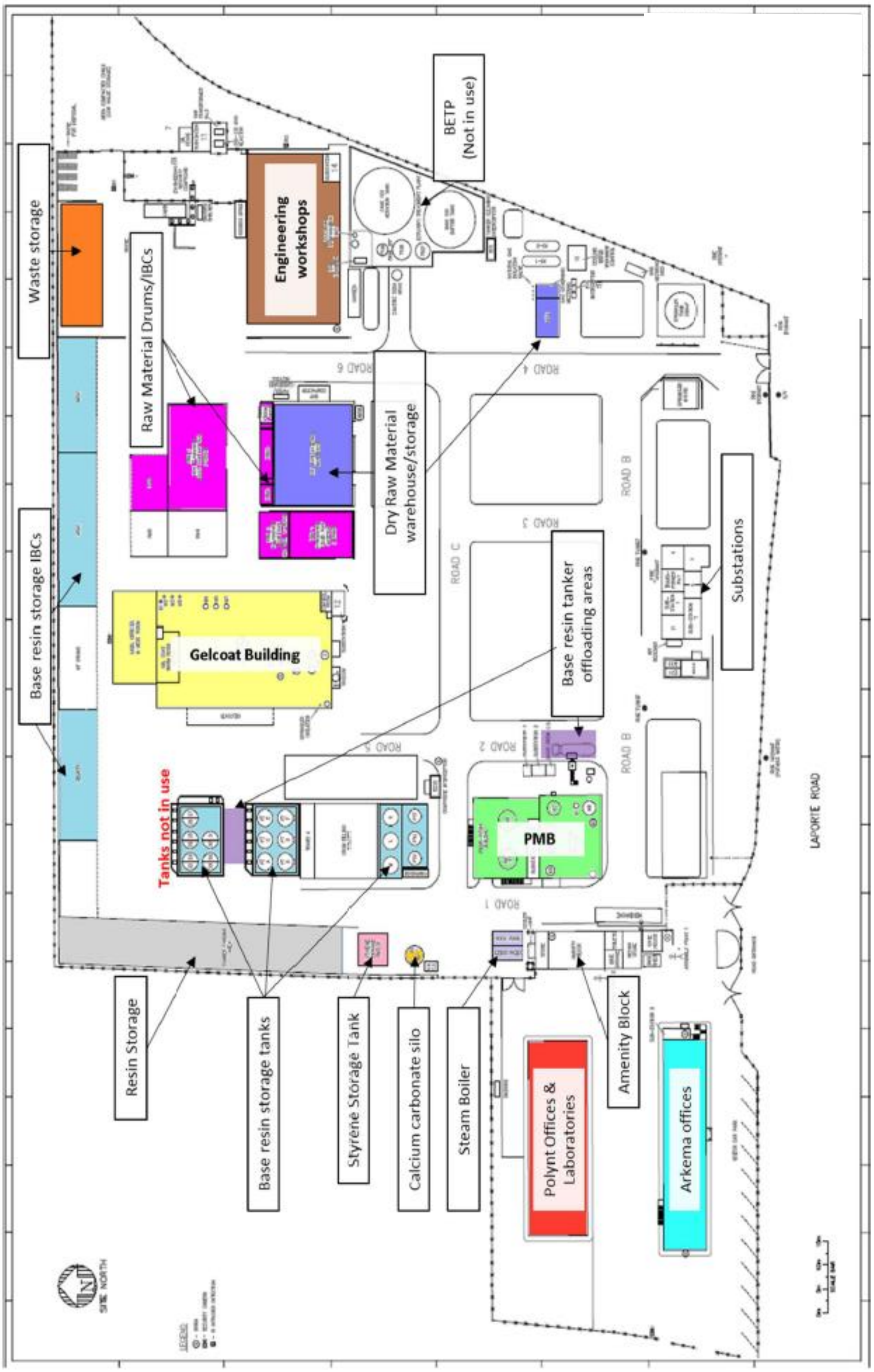
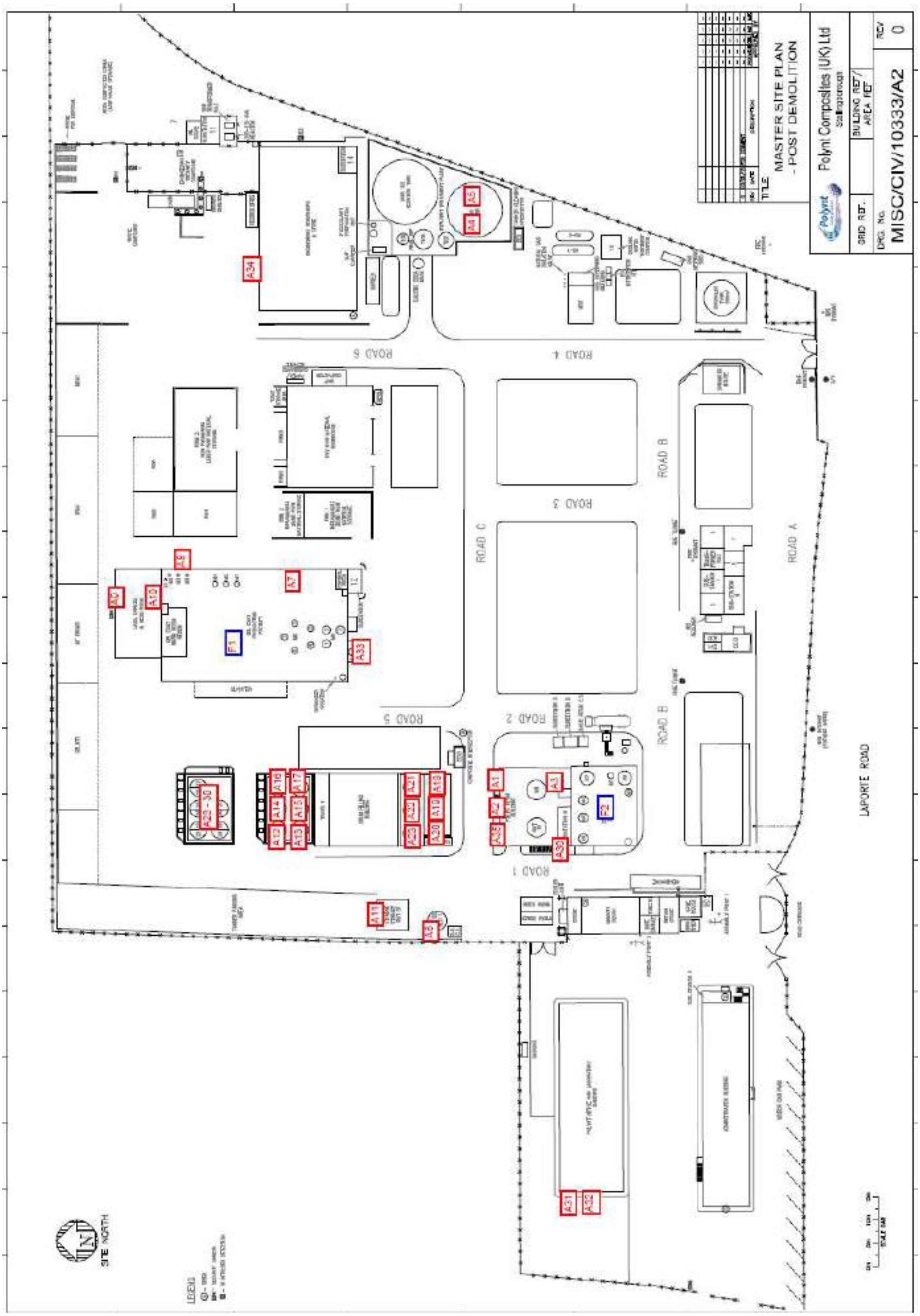


Figure A1.2 Location of point source release points



Appendix 2 Solvent purchase records 2016

Arkema provided the following information on solvent and solvent containing raw material purchases for 2016.

I1.1 Bought in new solvents (styrene)
I1.2 Solvents in bought in resins

Amount of solvent and resin delivered by tanker and transferred to bulk storage tanks

Year	Type	Tonnes	
2016	Bulk Resin Tankers	13066	See breakdown below, per storage tank
	Styrene Tankers	1771	
		14837	

Amount of resins delivered in drums and IBCs and approximation of container volumes and number of each.

Year	Type	Container Qty	Tonnes	Solvent Content %	Solvent quantity (T)
2016	Overall	1689	2158	31%	668.98
2016	Drums (205 Litres)	343	679	31%	210.49
	IBCs (1000Litres)	1346	1479	31%	458.49
		1689	**2158**		**668.98**

The specific material in each of the bulk storage tanks and either the individual usage for each vessel or the total amount of each material used.

Product	Storage Tank	Tonnes	Solvent Content %	Solvent quantity (T)
IP13239	PTA	4380	35%	1533
IP66109	PTB	2723	28%	762.44
IP61119	PTC	1839	26%	478.14
IP45120	PTE	638	26%	165.88
IP45121	PTF	362	33%	119.46
IP25246	PTK	454	35%	158.9
IP13239	PTL	-	35%	0
IP61115	PTM	757	30%	227.1
IP18125	PTT	408	34%	138.72
IP92223	PTU	268	36%	96.48
IP15239	PTV	1234	31%	382.54
Styrene	RMT 01	1771	100%	1771
		14834		**5833.66**

Note: IP codes relate to base polyester resin storage tanks

	t	tsolvent
Bulk resin	13063	4063
Drum and IBC resin	2158	669
Raw materials	1950	370
Styrene	1771	1771
total in	18942	6873

I1.3 Bought in raw materials

Item Code	Description	Annual Quantity (Kg)	Solvent Content	Solvent Quantity	Container Type
11003	(R2072) 1,4 NAPTHAQUINONE (R)	2,262	0%	-	KEGS
11005	(VRM986) SILICA FINE (G)	66,880	0%	-	BAGS
11010	(VRM706) ALPHA METHYL STYRENE (B)	4,320	100%	4,320	DRUMS
11014	(R683) PROPYLENE GLYCOL (G)	88,720	100%	88,720	IBC
11019	(R788) PARA TERTIARY BUTYL CATECHOL (Y)	484	0%	-	BAGS
11020	HYDROQUINONE	800	0%	-	KEGS
11021	(R1637) CHOLINE CHLORIDE (G)	1,140	0%	-	DRUMS
11027	(R1312) MONOTERTIARY BUTYL HYDROQUINONE (B)	100	0%	-	KEGS
11028	(R1573) TOLUHYDROQUINONE (B)	400	0%	-	KEGS
11032	(VRM2020) COPPER NAPTHENATE 6% (B)	1,080	75%	810	DRUMS
11031	ACETYLE ACETONE	1,135	100%	1,135	DRUMS
11044	(R1575) ACCELERATOR NL65/100 - DMPT (R)	168	0%	-	KEGS
11048	(R1313) DIETHYLANILENE (R)	3,040	0%	-	DRUMS
11049	(R1779) DIMETHYL ANILENE (R)	1,900	0%	-	DRUMS
11119	ARQUAD O-50	480	35%	168	DRUMS
11122	(VRM2012) BYK R 605 (Y)	-	45%	-	DRUMS
11135	BISOMER PTE	2,400	0%	-	DRUMS
11176	(VRM1001) BYK-S 750 (G)	6,435	75%	4,826	DRUMS
11177	(VRM1131) BYK 052 (B)	10,325	86%	8,828	DRUMS
11180	(VRM930) BYK A 555	-	75%	-	DRUMS
11181	BYK 163	75	85%	64	DRUMS
11200	(R568) STYRENE MONOMER (Y)	1,771,000	100%	1,771,000	BULK TANKERS
11203	(R1442) METHYL METHACRYLATE MONOMER (Y)	98,020	100%	98,020	IBC
11214	(R1477) POLYOXYETHYLENE 20 SORBITAN /SURFALINE20/TWEEN20 (G)	13,120	0%	-	IBC
11222	(VRM1015) PAT 657 C (G)	7,560	0%	-	DRUMS
11223	(F326) COCONUT OIL (G)	43,040	0%	-	IBC
12007	MARTINAL ON 313	158,330	0%	-	BAGS
12202	(VRM2023) BYK A 560 (B)	5,100	86%	4,386	DRUMS
12301	GARAMITE 1210	100	0%	-	
20137	ACCELERATOR COBALT FREE	400	19%	76	DRUMS
21265	(R1337) N-PEL 128 (Y)	7,920	0%	-	DRUMS
21271	(R1700) 4- METHOXYPHENOL (Y)	100	0%	-	KEGS
21439	(VRM411) PHENO THIAZINE (Y)	100	0%	-	KEGS
21602	ANTIMONY TRIOXIDE	15,750	0%	-	BAGS
25342	2,5-DI-TERT-BUTYL HYDROQUINONE (DTBHQ) (B)	100	0%	-	KEGS
25336	PAT 672	100	0%	-	KEGS
25565	(R173) ACETONE (B)	2,748	100%	2,748	DRUMS
25567	Solid 1,2,3,6-Tetrahydrophthalic anhydride	11,000	0%	-	BAGS
25576	(R1954) DOWANOL DPM (G)	1,560	100%	1,560	DRUMS
25583	(R2067) PHENYL DIETHANOLAMINE (R)	5,200	0%	-	DRUMS
25588	(R2077) DIETHYL ACETOACETAMIDE(B)	2,184	0%	-	DRUMS
25594	(R215) TRIETHANOLAMINE (R)	1,000	0%	-	DRUMS
25631	(R834) HORDARESIN NP70 (G)	62,000	0%	-	BAGS
25646	(VRM555) PIGMENT SILVER GREY BS 10A03 (G)	6,200	0%	-	DRUMS
25647	(VRM558) OIL BLUE A DYE (G)	15	0%	-	KEGS
25680	(VRM830) TRIMETHYL HYDROQUINONE (Y)	625	0%	-	KEGS
25681	(VRM831) NUOSYN POTASSIUM 10 (R)	2,850	38%	1,069	DRUMS
25691	(VRM876) LOWINOX 44 S 36 (B)	100	0%	-	BAGS
25695	(VRM885) SATINTONE SPECIAL (G)	165,640	0%	-	BAGS
25715	(VRM906) MONOMIX G (G)	269,594	0%	-	BAGS
25719	(VRM912) COBALT HYDROXY TEN-CEM 21% (R)	2,866	10%	287	DRUMS
25729	(VRM955) KRONOS 2160 (G)	42,000	0%	-	BAGS
25730	(VRM956) AEROSIL R 972 (G)	2,640	0%	-	BAGS
25737	(VRM971) DECABROMODIPHENYL OXIDE (B)	3,025	0%	-	BAGS
25746	(D412) AEROSIL 200 HV (G)	47,520	0%	-	BAGS
25995	(VRM1002) ISODECANE (G)	48,680	100%	48,680	IBC
26039	(VRM996) ETHYL DIGLYCOL (B)	4,000	100%	4,000	IBC
29061	(VRM1082) EFKA-FA4612 (Y)	1,200	80%	960	DRUMS
29068	EFKA 2020 (B)	35,770	86%	30,762	IBC / DRUMS
29151	(VRM1127) PIGMENT JET BLACK (G)	50	0%	-	DRUMS
29174	(VRM1129) LITHIUM ETHYL HEXANOATE (B)	180	36%	65	DRUMS
29393	(VRM2016) BYK LPX 20505 (B)	2,160	36%	778	DRUMS
29476	(VRM2010) BYK S 706 (B)	740	40%	296	DRUMS
29591	(R1003) BUTYLATED HYDROXY TOLUENE (G)	50	0%	-	KEGS
29630	TCPP [FYROL PCF]	237,480	0%	-	IBC / DRUMS
29702	EFKA PB 2720	2,325	63%	1,465	DRUMS
29722	HUNGARIAN PARAFFIN WAX 60/62	1,000	85%	850	BAGS
29745	COBALT 2-ETHYL HEXANOATE 6% IN WHITE SPIRIT	67,284	75%	50,463	IBC
29966	BYK LPN6587 (G)	800	6%	48	DRUMS
70165	(D949) TIOXIDE RTC90 (G)	256,084	0%	-	BAGS
70277	(VRM907) ZEOTHIX 177 (G)	5,225	0%	-	BAGS
70390	DISTITRON 152	29,050	35%	10,168	IBC
70475	VRM 670 EPSILON PHTALO BLUE	50	0%	-	BOX
70476	VRM 675 BASE VIOLET B	50	0%	-	BOX
70477	(VRM891) PIGMENT YELLOW 970 Y 875 (G)	425	1%	4	DRUMS
70478	(VRM892) PIGMENT YELLOW 970 Y 842 (G)	3,375	1%	34	DRUMS
70479	(VRM893) PIGMENT ORANGE 970 Y 841 (G)	4,425	1%	44	DRUMS
70480	(VRM894) PIGMENT RED 970 Y 840 (G)	50	1%	1	DRUMS
70481	(VRM895) PIGMENT YELLOW 970 Y 805 (G)	3,550	1%	36	DRUMS
70482	(VRM896) PIGMENT RED 970 R 845 (G)	125	1%	1	DRUMS
70483	(VRM897) PIGMENT RED 970 R 804 (G)	125	1%	1	DRUMS
70484	(VRM898) PIGMENT VIOLET 970 M 806 (G)	25	1%	0	DRUMS
70485	(VRM899) PIGMENT BLUE 970 L 837 (G)	100	1%	1	DRUMS
70486	(VRM900) PIGMENT BLUE 970 L 847 (G)	180	1%	2	DRUMS
70488	(VRM902) PIGMENT GREEN 970 G 802 (G)	400	1%	4	DRUMS
70489	(VRM903) PIGMENT BLACK 970 B 803 (G)	29,240	1%	292	DRUMS
70490	(VRM904) PIGMENT WHITE 970 W 826 (G)	31,450	1%	315	DRUMS
70491	(VRM980) PIGMENT RED 970 R 855 (G)	100	1%	1	DRUMS
70492	VRM 991 JAUNE CITRON	50	1%	1	DRUMS
70493	VRM 992 JAUNE SAFRAN	250	1%	3	DRUMS
70650	(R1314) PARAFFIN WAX 52 / 54 (G)	8,240	50%	4,120	BAGS
70708	(VRM887) BENTONE 128 (G)	3,525	0%	-	BAGS
70758	SOYA LECITHIN	350	0%	-	DRUMS
70776	DIMETHYL SILICONE [RHODORSIL 47 V 100]	200	0%	-	BAGS
70782	EVERSORB 74 (Y)	800	0%	-	BAGS
			TOTAL SOLVENT	**2,141,409**	

Appendix 3 Solvent releases from powered vents

The concentration of volatile organic compounds (VOC) in the exhaust releases from the 12 of the 13 powered exhaust vents were measured by ESG over the 3 to 6 July and 22 to 23 August 2017 (ESG reports LNO13703, 27 July and 28 August 2017).

VOC concentration was reported as a carbon equivalent (e.g. mgC/m^3). In order to convert from total carbon to mass of VOC it was assumed that the vapour phase composition of the VOC emission corresponded to the liquid phase composition of the solvents used in the processes served by the vent (i.e. primarily styrene with smaller amounts of propylene glycol, methyl methacrylate, acetone and isodecane).

The partial vapour pressure of each solvent component corresponds to its molar fraction in the vapour. The partial pressure of each solvent in the vapour can be calculated using Antoine's Law:

$$P_i = 10^{\exp\left[A - \frac{B}{(T_{LS} + C)}\right]}$$

where

P_i	partial pressure of solvent (kPa).
T_{LS}	average daily temperature of the surface of the liquid obtained from the Hull Park East weather station.
A,B & C	Antione's constants specific to the individual solvent

The weight fraction of the vapour (W_V) is given by

$$W_i = M_i \left(\frac{P_i}{\sum P_i} \right)$$

where

M_i	Molecular weight of solvent i

The % weight vapour composition (V_i) is given by

$$V_i = 100 \left(\frac{W_i}{\sum W_i} \right)$$

By multiplying the % carbon content of each solvent (C_i) by the % weight vapour composition (V_i) the contribution to the % carbon content of the vapour (CV_i) can be calculated:

$$CV_i = \frac{C_i V_i}{100}$$

By dividing the emission concentration (EC) expressed as total carbon by the sum of the % carbon content of the vapour the emission concentration (ECVOC) is converted to a VOC basis:

$$EC_{VOC} = \frac{100EC}{\left(\sum CV_i\right)}$$

The annual release of volatile organic compounds from each point (E) is:

$$E = \frac{EC_{VOC}Qh}{10^{-6}}$$

where

Q Exhaust gas volume flow rate (m^3/h) at Standard Temperature and Pressure (STP)
h Annual operating hours (h)

For the period January to December 2016 the solvent releases from the site powered release points were determined as below:

Calculation of vapour composition

Solvent	Mol Wt.	% Carbon	Antoine constants			Vapour pressure	% Weight of vapour	% Vapour composition	% Carbon in vapour
i	M	C_i	A	B	C	P_i	W_i	V_i	CV_i
Acetone	58.1	62	6.2548	1216.689	230.275	16.61	56.63	95.60	59.27
Styrene	104.2	92.3	6.3479	1629.2	230	0.40	2.43	4.10	3.78
Propylene glycol	76.1	47.3				0.01	0.05	0.08	0.04
Methyl methacrylate	100.1	60	5.3779	1945.56	-7.569	0.02	0.13	0.22	0.13
Total						17.04	59.24		63.23

Mean daily temperature of the surface of the liquid (Ta) 11.4 °C

Calculation of mass release from stacks

Vent	Concentration		Volume flow	Operating hours	Mass release
	mgC/m^3	$mgsolvent/m^3$	m^3/h	h/annum	kg/annum
A1	11418	18059	n.a.	n.a.	47
A2	505	799	n.a.	n.a.	2
A3	67	106	3660	3936	1527
A5	64	101	2837	3936	1130
A6	37	59	2702	3936	622
A7	12	19	3895	3936	291
A8	31	49	12925	246	156
A9	3913	4239	n.a.	n.a.	9
A29	6	10	4178	246	10
A30	30	47	4816	1968	450
A31	798	1262	n.a.	214	15
A32	6	9	4178	246	10
A35	10	16	1030	8424	136
A36	103	163	580	292	28
Total					4432

While it is recognised that styrene is the predominant solvent present in the processes served by the powered release points, the consideration of all likely solvents present provides a very conservative estimate of process solvent releases. The effective carbon content of the combined release (63.2%) is lower than if the release was assumed to comprise entirely styrene which has a relatively high carbon content (92.3%).

Arkema provided information on the typical operating periods for each of the powered release points. The site closes for around 14 days per year over the Easter and Christmas periods. Generally the PMB operation runs for 7 days per week operating 16 hours per day. Processes in the Gelcoats building operated 8 hours per day over 5 days per week. The following operating assumptions were made.

Point	Operating time (h/year)	Comment
A1	110	LEV is operational for a maximum of 45 minutes per batch. In 2016 there were 146 batches. The total air displacement per batch is 18 m^3.
A2	not applicable	The total air displacement per batch is 18 m^3 and there were 146 batches processed in 2016.
A3	3936	Operation is for 16 hours per day for 246 days per year.
A5	3936	Operation is for 16 hours per day for 246 days per year.
A6	3936	Operation is for 16 hours per day for 246 days per year.
A7	3936	Operation is for 16 hours per day for 246 days per year. Exhaust flow rate is based on LEV test results.
A8	246	Operation is for a maximum of 1 hour per day for 246 days per year. Exhaust flow rate is based on LEV test results.
A9	not applicable	The total air displacement is estimated at 2017 m^3, based on 1771 tonnes of styrene purchased.
A29	246	Operation is for a maximum of 1 hour per day for 246 days per year.
A30	1968	Operation is for 8 hours per day for 246 days per year.
A31	214	Operation is for a maximum of 20 minutes per batch. In 2016 there were 641 batches. An air displacement of 18m^3 per batch is assumed.
A32	246	Operation is for a maximum of 1 hour per day for 246 days per year. This is used infrequently. A conservative estimate for the exhaust gas flow rate and emission concentration of 4178 m^3/h and 6 mgC/m^3 as measured at A29 is assumed.
A35	8424	Operation is assumed to be continuous at all times the site is operational (i.e. 351 days per year).
A36	292	Operation is estimated at 2 hours per batch, with 146 batches in 2016. Exhaust flow rate is based on LEV test results.

Where it was not possible to undertake a volume flow measurements at the release point the results of the most recent LEV tests have been employed.

Appendix 4 Solvent releases from bulk storage vessels

The total mass emission from the fixed roof tanks is the sum of breathing losses and working losses. The breathing losses are caused by vapour being expelled from the tank either by thermal expansion or a change in atmospheric pressure. Filling losses occur during filling through the displacement of the air and vapour by the rising level of the liquid.

The breathing and filling losses from the storage vessels were calculated using methods described in the American Petroleum Institute (API) bulletin 2518 'Evaporation loss from fixed roof tanks'

A4.1 Filling losses

Filling losses are determined from:

$$FL = MP_{VA}\left(\frac{V}{8.31437T}\right)$$

where

FL	filling losses (kg/year)
P_{VA}	vapour pressure at the average temperature of the liquid surface (kPa)
V	volume of annual solvent throughput (m^3) - provided by Arkema
T	mean ambient temperature (K) – 11.4^{o}C for Hull Park East January to December 2016

The temperature of the mass of liquid in a tank (T_{LM}) is given by:

$$T_{LM} = T + (3.33\alpha) - 0.55$$

where

α	Solar absorbance of tank – assumed as 0.74 (VOC Workbook, A5.2.2)

The temperature of the surface of the liquid (T_{LS}) is given by:

$$T_{LS} = (0.44T) + (0.56T_{LM}) + (0.00503\alpha I)$$

where

I	Solar radiation incidence (J/cm^{2}day) – assumed as 911 for the Grimsby area (www. eosweb.larc.nasa.gov - VOC Workbook, A5.2.1.2)

The vapour pressure at the average surface temperature of the liquid is given by:

$$P_{VA} = 10^{\left[A - \frac{B}{(C + T_{LS})}\right]}$$

where

A, B, C	Antoine constants for the material – taken from VOC Workbook, A5.1

A worst case assessment is considered where all of the materials are assumed to be styrene

A4.2 Breathing losses

Breathing losses are calculated from:

$$BL = 365V_{vap}conc_{vap}K_E K_s$$

where

BL	breathing losses (kg/year)
V_{vap}	free space volume above liquid (m^3)
$conc_{vap}$	vapour concentration (kg/m^3)
K_E	coefficient of expansion of the vapour
K_S	vapour saturation factor

The vapour concentration the tank is given by:

$$conc_{vap} = M\left(\frac{P_{VA}}{8.3143T_{LS}}\right)$$

The vapour saturation factor is given by:

$$K_S = \frac{1}{1+(0.1114P_{VA}h_v)}$$

where

h_v	The height of free space in the tank (m) – it is assumed that the tank will be half full

The coefficient of expansion of the vapour is given by:

$$K_E = \frac{\Delta T_V}{T_{LS}} + \left[\frac{(\Delta P_V - \Delta P_S)}{P_A - P_{VA}}\right]$$

where

ΔT_V	daily temperature range of vapour (K)
ΔP_V	daily vapour pressure range (kPa)
ΔP_S	breather vent pressure range (kPa), assumed to be 0.4

The daily temperature range of the vapour is given by:

$$\Delta T_V = (0.72\Delta T_A) + (0.0155\alpha I)$$

where

ΔT_A daily ambient temperature range (K) - determined as 8.1°C for the Hull Park East station for the period January to December 2016

The daily vapour pressure range is given by:

$$\Delta P_V = P_{V\max} - P_{V\min}$$

with

$$P_{V\max} = 10^{\left[A - \frac{B}{(C + T_{L\max})}\right]} \text{ and } P_{V\min} = 10^{\left[A - \frac{B}{(C + T_{L\min})}\right]}$$

$$T_{L\max} = T_{LS} + \left(0.25 \Delta T_V\right) \text{ and } T_{L\min} = T_{LS} - \left(0.25 \Delta T_V\right)$$

where

$T_{L\max}$ maximum temperature of the surface of the liquid (°C)
$T_{L\min}$ minimum temperature of the surface of the liquid (°C)

A4.3 Losses in 2016

For the period January to December 2017 the solvent releases arising from filling and breathing losses in the 13 bulk storage tanks are summarised in Table A4.1 and the detailed calculations for each tank follow.

Table A4.1 Filling and breathing losses from bulk storage tanks (January to December 2016)

Tank	Fill volume (m^3/annum)	Area (m)	Height (m)	Solvent (kg/annum)		
				Filling losses	Breathing losses	Total release
A	3865	10.46	10.01	89.6	21.7	111.3
B	2403	10.46	10.01	55.7	21.7	77.4
C	1623	10.46	10.01	37.6	21.7	59.3
D	0	10.46	10.01	0.0	0.0	0.0
E	563	10.46	10.01	13.1	21.7	34.7
F	319	10.46	10.01	7.4	21.7	29.1
K	401	10.18	7.86	9.3	16.6	25.9
L	0	10.18	7.86	0.0	0.0	0.0
M	668	10.18	7.86	15.5	16.6	32.1
T	360	5.94	9.10	8.3	11.5	19.8
U	236	5.94	9.10	5.5	11.5	16.9
V	1089	5.94	9.10	25.3	11.5	36.7
RMT01	2017	7.07	4.0	46.8	6.0	52.7
Total				314.1	182.2	495.9

Tank dimensions were provided by Arkema. The fill volume for resins is based on the delivery tonnage and a mean density of 1.13 t/m^3. The density for styrene is assumed to be 0.878 t/m^3 at the mean ambient temperature (11.4°C).

Tank A Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank A	3865	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	3865	m^3
Filling losses (F_L)	89.63	kg/year

Breathing losses

Tank area (A)	10.46	m^2
Tank depth (D)	10.012	m
Height of free space in tank -assuming half full (h_v)	1.825	m
Free space volume above liquid (V_{vap})	52.363	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9033	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	21.69	kg/year

Total losses from tank (T_L)	111.32 kg Styrene /year

Tank B Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank B	2403	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	2403	m^3
Filling losses (F_L)	55.73	kg/year

Breathing losses

Tank area (A)	10.46	m^2
Tank depth (D)	10.012	m
Height of free space in tank -assuming half full (h_v)	1.825	m
Free space volume above liquid (V_{vap})	52.363	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9033	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	21.69	kg/year

Total losses from tank (T_L)	77.42 kg Styrene /year

Tank C Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm² day
Annual throughput of Styrene in Tank C	1623	m³

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm² day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	1623	m³
Filling losses (F_L)	37.64	kg/year

Breathing losses

Tank area (A)	10.46	m²
Tank depth (D)	10.012	m
Height of free space in tank -assuming half full (h_v)	1.825	m
Free space volume above liquid (V_{vap})	52.363	m³
Vapour concentration (C_{vap})	0.023	kg/m³
Vapour saturation factor (K_S)	0.9033	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	21.69	kg/year

Total losses from tank (T_L)	59.33 kg Styrene /year

Tank E Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm² day
Annual throughput of Styrene in Tank E	563	m³

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm² day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	563	m³
Filling losses (F_L)	13.06	kg/year

Breathing losses

Tank area (A)	10.46	m²
Tank depth (D)	10.012	m
Height of free space in tank -assuming half full (h_v)	1.825	m
Free space volume above liquid (V_{vap})	52.363	m³
Vapour concentration (C_{vap})	0.023	kg/m³
Vapour saturation factor (K_S)	0.9033	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	21.69	kg/year

Total losses from tank (T_L)	34.75 kg Styrene /year

Tank F Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank F	319	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	319	m^3
Filling losses (F_L)	7.40	kg/year

Breathing losses

Tank area (A)	10.46	m^2
Tank depth (D)	10.012	m
Height of free space in tank -assuming half full (h_v)	1.825	m
Free space volume above liquid (V_{vap})	52.363	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9033	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	21.69	kg/year

Total losses from tank (T_L) 29.09 kg Styrene /year

Tank K Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank K	401	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	401	m^3
Filling losses (F_L)	9.30	kg/year

Breathing losses

Tank area (A)	10.18	m^2
Tank depth (D)	7.86	m
Height of free space in tank -assuming half full (h_v)	1.800	m
Free space volume above liquid (V_{vap})	40.007	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9045	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	16.59	kg/year

Total losses from tank (T_L) 25.89 kg Styrene /year

Tank is conical in parts. Depth is based on a capacity of 80 m^3 and base cross sectional area of 10.18 m^2.

Tank M Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank M	668	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	668	m^3
Filling losses (F_L)	15.49	kg/year

Breathing losses

Tank area (A)	10.18	m^2
Tank depth (D)	7.86	m
Height of free space in tank -assuming half full (h_v)	1.800	m
Free space volume above liquid (V_{vap})	40.007	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9045	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	16.59	kg/year

Total losses from tank (T_L)	32.09 kg Styrene /year

Tank is conical in parts. Depth is based on a capacity of 80 m^3 and base cross sectional area of 10.18 m^2.

Tank T Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank T	360	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	360	m^3
Filling losses (F_L)	8.35	kg/year

Breathing losses

Tank area (A)	5.94	m^2
Tank depth (D)	9.1	m
Height of free space in tank -assuming half full (h_v)	1.375	m
Free space volume above liquid (V_{vap})	27.027	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9254	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	11.47	kg/year

Total losses from tank (T_L)	19.82 kg Styrene /year

Tank U Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank U	236	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	236	m^3
Filling losses (F_L)	5.47	kg/year

Breathing losses

Tank area (A)	5.94	m^2
Tank depth (D)	9.1	m
Height of free space in tank -assuming half full (h_v)	1.375	m
Free space volume above liquid (V_{vap})	27.027	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9254	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	11.47	kg/year

Total losses from tank (T_L) 16.94 kg Styrene /year

Tank V Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank V	1089	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank (α)	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	1089	m^3
Filling losses (F_L)	25.26	kg/year

Breathing losses

Tank area (A)	5.94	m^2
Tank depth (D)	9.1	m
Height of free space in tank -assuming half full (h_v)	1.375	m
Free space volume above liquid (V_{vap})	27.027	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9254	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	11.47	kg/year

Total losses from tank (T_L) 36.72 kg Styrene /year

Tank RMT01 Styrene

Average temperature range	8.1	°C
Ambient mean temperature	11.4	°C
Solar absorbance of the tank	0.74	
Solar radiation incidence	911	J/cm^2 day
Annual throughput of Styrene in Tank RMT01	2017	m^3

Filling losses

Mean ambient temperature (T_a)	284.55	K
Solar absorbance of tank ( ) α	0.74	
Solar radiation incidence (I)	911	J/cm^2 day
Temperature of the mass of the liquid (T_{LM})	286.46	K
Temperature of the surface of the liquid (T_{LS})	289.01	K
Antoine constant A	6.3479	
Antoine constant B	1629.2	
Antoine constant C	230	
Vapour pressure at surface liquid temperature (P_{VA})	0.527	kPa
Molecular weight (M)	104.2	g/mol
Volume of liquid pumped into tank (V)	2017	m^3
Filling losses (F_L)	46.78	kg/year

Breathing losses

Tank area (A)	7.07	m^2
Tank depth (D)	4	m
Height of free space in tank -assuming half full (h_v)	1.500	m
Free space volume above liquid (V_{vap})	14.140	m^3
Vapour concentration (C_{vap})	0.023	kg/m^3
Vapour saturation factor (K_S)	0.9191	
Daily ambient temperature range (ΔT_a)	8.1	°C
Daily temperature range of vapour (ΔT_V)	16.28	°C
Maximum temperature of liquid surface (T_{LMAX})	19.93	°C
Minimum temperature of liquid surface (T_{LMIN})	11.79	°C
Maximum daily vapour pressure (P_{VMAX})	0.675	kPa
Minimum daily vapour pressure (P_{VMIN})	0.407	kPa
Daily vapour pressure range (ΔP_V)	0.268	kPa
Breather vent pressure range (ΔP_S)	0.4	kPa
Atmospheric pressure (P_A)	101.3	kPa
Coefficient of vapour expansion (K_E)	0.055	
Breathing losses (B_L)	5.96	kg/year

Total losses from tank (T_L)	52.74	kg Styrene /year

Appendix 5 Fugitive releases from natural ventilation

The fugitive solvent emission from the PMB and Gelcoat buildings was estimated by multiplying the background solvent concentration for the production area with the fugitive volume flow rate of air exiting the building and the number of hours of fugitive release per annum:

$$F = C_S Q h 10^{-6}$$

where

F	Fugitive mass solvent release (kg/annum)
C_S	Ambient concentration of solvent in building ambient atmosphere – from sampling on the 22 and 23 August 2017 by ESG (mgstyrene/m^3)
Q	Volume flow of air to outside through open doors, windows and building leakage, based on the difference between measurements of net air flow into building and air extraction through LEVs as determined by ESG on the 22 and 23 August 2017 (m^3/h)
h	Duration that access doors are open (h/annum)

ESG undertook measurements of the air flow into each building through open doors. This represents the maximum air flow into the building in the case where all doors are open. The corresponding fugitive release, with air exiting the building via open doors windows and general building leakage, is the difference between the air flow in and the air extracted through the building LEVs (Appendix 3). Under normal circumstances access doors remain closed when not in use in order to minimise fugitive losses. The measured situation is therefore a worst case. With all doors closed it might be expected that fugitive emissions would be minimal with the building being under slightly negative pressure due to the suction of the LEVs which provide an approximate ventilation rate of around 3 air changes per hour in each building.

The conceptual model for fugitive release assumes that with the building access doors closed there is no fugitive release and all releases of VOCs are captured by the LEVs and released to atmosphere via the corresponding external vents. It is recognised that access to each building will be required and that certain access doors will need to be open for periods. It is assumed that all doors to each building will be open for a cumulative period of one hour per 8 hour shift for each operational day. With the doors open the fugitive air flow from the building will be the difference between the net air in through open doors and the air extracted by LEVs. The fugitive VOC emission rate will therefore be determined from the measured mean ambient VOC concentration and the fugitive air flow and the number of hours that doors are open.

For the period January to December 2016 the fugitive solvent releases from the PMB and Gelcoat building were determined as below:

Building		Gelcoat	PMB
Days of operation	days/annum	246	351
Hours with doors open	h/day	1	2
	h/annum	246	702
Mean solvent concentration	mgstyrene/m^3	929	121
Volume of air entering building	m^3/s	28.40	28.34
	m^3/h	102240	102024
Volume of air removed by LEVs	m^3/h (at 20^{o}C)	23997	5656
Volume of fugitive air release	m^3/h (at 20^{o}C)	78243	96368
Annual fugitive release of solvent	kg styrene/annum	17881	8186

Annual operating hours for the Gelcoat building is based on an 8 hour working day for 5 days per week with 14 day plant shutdown. The PMB is assumed to operate for 16 hours/ day, 7 days and week with a 14 day plant shutdown.

Styrene is assumed to be the predominant solvent present in the ambient atmosphere.

The ambient temperature is assumed to be 20°C.

LEV extraction for the Gelcoats building is the sum of the measured volume flow rates at points A5, A6, A7 and A8. For the PMB the LEV extraction rate is based on measured volume flow rates at A3, A35 and A36 (see Appendix 3 – volumes expressed at STP).

Details of the measurements made are presented below. Measurements of VOC concentration were made around each building and air flow rate measurements were made at all access doors.

Ambient measurements within the Gelcoat building

Gelcoat Building

Door Number	Door Sizes (m) Width	Height	Area (m²)	Flow Rates (m/s) 1	2	3	Ave	In or Out	Volumetric Flow (m3/s)	Concentration (ppm styrene) 1	2	3	Ave	Concentration (mg/m³)	Release Rate (mg/s)	(kg/hour)
1	0.77	1.99	1.5323	1.6	2	1.9	1.8	In	2.81	0	0	0	0	0	0	0
2	0.8	2.04	1.632	2.1	2.2	1.8	2.0	In	3.32	0	0	0	0	0	0	0
3	0.8	2.02	1.616	1	1.2	1.7	1.3	In	2.10	0	0	0	0	0	0	0
4	3.12	2.5	7.8	1.9	2.9	3.1	2.6	In	20.54	0	0	0	0	0	0	0
5	0.8	2.03	1.624	1.1	1.4	1.6	1.4	In	2.22	0	0	0	0	0	0	0
6	0.8	2.05	1.64	0	0	0	0	-	0.00	208	192	229	210	975	0	0
7	3.84	4.77	18.3168	0	0	0	0	-	0.00	211	232	133	192	891	0	0
8	0.8	2.02	1.616	1.5	2	1.3	1.6	Out	2.59	229	234	241	235	1091	2820	10
								Flow into the building	30.988	m³/s						
								Flow out of the building	2.586	m³/s				Total	2820	10.15
								Combined Flow	28.40	m³/s into the building						

Building Volume

Section	Width	Length	Height	Volume	Description
1	25	40	6	6000	Main building
2	12.5	40	1	500	Pitched roof -North
3	12.5	40	1	500	Pitched roof -South
			Total volume	7000	

Building Concentrations

Position	Date	Time	Concentration (ppm styrene)
1	23/08/2017	11:00	243.9
2	23/08/2017	11:05	268.4
3	23/08/2017	11:10	243.1
4	23/08/2017	11:15	239.4
5	23/08/2017	11:20	240.3
6	23/08/2017	11:25	238.6
7	23/08/2017	11:30	237
8	23/08/2017	11:35	78.4
9	23/08/2017	11:40	178.7
10	23/08/2017	11:45	35.8
		Average	200

South

1	2
3	4
5	6

Ground Floor

South

7	8
9	10

Ambient measurements within the PMB

M8 & PMB Building

Door Number	Door Sizes (m) Width	Height	Area (m²)	Flow Rates (m/s) 1	2	3	Ave	In or Out	Volumetric Flow (m3/s)	Concentration (ppm styrene) 1	2	3	Ave	Concentration (mg/m³)	Release Rate (mg/s)	(kg/hour)
1	2.95	2.54	7.493	0.0	0.6	0.1	0.2	In	1.75	6.2	7.8	8.1	7.4	34.2	0	0
2	1.83	2.47	4.5201	0.2	1.7	1.1	1.0	In	4.54	0.0	0.0	0.0	0.0	0.0	0	0
3	2.83	3.03	8.5749	2.6	1.3	0.7	1.5	In	13.15	0.0	0.0	0.0	0.0	0.0	0	0
4	0.78	1.99	1.5522	3.9	2.6	3.1	3.2	In	4.97	0.0	0.0	0.0	0.0	0.0	0	0
5	2.99	3.18	9.5082	0.0	0.9	0.8	0.6	In	5.39	57.1	62.1	43.5	54.2	252.0	0	0
6	2.43	2.98	7.2414	0.0	0.0	0.6	0.2	Out	1.45	23.6	18.4	24.1	22.0	102.4	148.3	0.5
7	0.8	1.97	1.576	0.0	0.0	0.0	0.0	Out	0.00	48.1	53.4	38.9	46.8	217.5	0	0
															0	0
							Flow into the building		29.79	m³/s						
							Flow out of the building		1.45	m³/s				Total	148.3	0.5
								Combined Flow	28.34	m³/s into the building						

Building Volume

Section	Width	Length	Height	Volume	
1	14.8	16.8	8	1989	Lower end
2	14.8	16.8	0.5	124	Lower end pitched roof
3	15	8.2	8.7	1070	South East Corner
4	15	8.6	11.25	1451	North East Corner
			Total volume	4635	

Building Concentrations

Position	Date	Time	Concentration (ppm styrene)
1	23/08/2017	12:10	2.5
2	23/08/2017	12:12	0
3	23/08/2017	12:14	1.8
4	23/08/2017	12:16	1.8
5	23/08/2017	12:18	85.1
6	23/08/2017	12:20	18.7
7	23/08/2017	12:22	65.4
8	23/08/2017	12:24	33.3
		Average	26.1

South

1	2
3	4

Ground Floor

South

5	6
7	8

1st Floor

Appendix 6 Releases from empty containers sent for recycling

Arkema return empty drums and IBCs for recycling following use. It is assumed that there will be some residual solvent in each container which will represent a solvent loss from the process.

Arkema retain full records of the number of drums (205 l) and IBCs (1000l) containing solvent containing resins which are purchased annually (see Appendix 2). It is assumed that these containers are emptied and then sent off-site for recycling. In both cases it is assumed that there is a residual material content within the container equivalent to 1% of the original capacity with a solvent content equivalent to the mean content of the original material.

For other solvent containing raw materials Arkema retain an inventory of purchases (see Appendix 2) differentiating between material delivered in drums or kegs and those in IBCs. The number of drums and IBCs used is determined based on with assumed capacities of 100 kg and 1000 l respectively and the total amount of each material delivered. In both cases it is assumed that there is a residual material content within the container equivalent to 1% of the original capacity with a mean solvent content of equivalent to the mean for material delivered in each container.

The total residual solvent present in the containers sent off-site is assumed to be a loss from the process. For the period January to December 2016 solvent losses due to residual solvent present in containers removed from site for recycling were determined as below:

Calculation of emissions from containers

Solvent containing material purchased in drums

Weight of solvent containing material purchased in drums	120649	kg
Weight of solvent contained in drums	34626	kg
Number of drums (assume a capacity of 100 kg)	1206	
Residual solvent in each drum (1 kg material)	0.29	kg
Estimated solvent release from drums	346	kg

Solvent containing material purchased in IBCs

Weight of solvent containing material purchased in IBCs	371524	kg
Weight of solvent contained in IBCs	330812.7	kg
Number of IBCs (assume a capacity of 1000 kg)	372	
Residual solvent in each drum (assume 10 kg material)	8.90	kg
Estimated solvent release from IBCs	3308	kg

Solvent containing resin purchased in drums

Weight of solvent containing resin purchased in drums	679	kg
Weight of solvent contained in drums	210	kg
Number of drums (assume a capacity of 205 l)	343	
Residual solvent in each drum (2 kg material)	0.62	kg
Estimated solvent release from drums	213	kg

Solvent containing resin purchased in IBCs

Weight of solvent containing resin purchased in IBCs	1479	kg
Weight of solvent contained in IBCs	458.49	kg
Number of IBCs (assume a capacity of 1000 kg)	1346	
Residual solvent in each drum (assume 10 kg material)	3.10	kg
Estimated solvent release from IBCs	4173	kg

Total solvent losses in containers	8040	kg

END OF REPORT

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