



Human & Environmental Risk Assessment on ingredients
of European household cleaning products

Polycarboxylates used in detergents

**Polyacrylic acid homopolymers (CAS 9003-01-4),
Poly- (acrylic/maleic) acid copolymers (CAS 52255-49-9)
and their sodium salts**

April 2009
Version 2.0

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1. EXECUTIVE SUMMARY

General

Water-soluble linear polycarboxylates are used in household cleaning products, i.e. in laundry detergents, automatic dishwashing detergents and various hard surface-cleaning formulations, and also in institutional and industrial cleaning processes and a variety of technical applications. For this updated version 2.0 the European consumption of polycarboxylates in detergent applications covered by HERA was updated to 80,000 tons/year in 2007. Polycarboxylates are used in low-phosphate and phosphate-free detergents for avoiding incrustation and soil redeposition. Their effect is not based on complexing with the hardness producers in the water but on the dispersion of calcium carbonate or of calcium phosphate and the soil detached during washing.

Polycarboxylates used in detergents products comprise two types of polymers: homopolymers of acrylic acid (P-AA) and copolymers of acrylic/maleic acid (P-AA/MA). The mean molecular weight (MW) of these polycarboxylates ranges from approximately 1,000 to 100,000. Most investigations have been performed on commonly used commercial polycarboxylates with MW of 4,500 (P-AA) and MW of 70,000 (P-AA/MA). They generally are used in neutralised form (pH 6-8) as sodium salts.

A comprehensive overview on their ecological and toxicological properties has been published by ECETOC (1993). The present HERA Targeted Risk Assessment updates this information and provides a focused risk assessment under the scope of HERA.

Environment

The main pathway of polycarboxylates into the environment is via domestic waste water and sewage treatment to surface waters. Thus, removal of polycarboxylates from waste water before and during waste water treatment is the crucial factor that governs the distribution of polycarboxylates into the environment.

Over the past 25 years, in a multitude of laboratory studies, the elimination of P-AA and P-AA/MA polycarboxylates from waste water has been investigated. The results indicate that the two types differ to some extent in their eliminability though they are alike in many other physical and ecological attributes. While adsorption onto solids and precipitation are the principal mechanisms of abiotic elimination for both polymer types, the degree of elimination has been shown to be generally lower in the case of P-AA homopolymers. However observed biological degradation processes indicate higher degrees for P-AA. Based on these data the Predicted Environmental Concentrations (PEC) in the different environmental compartments were calculated.

PNECs were calculated based on a multitude of acute as well as chronic data for the environmental compartments water, sediment, soil and sewage treatment plants (STP).

This updated version 2.0 incorporates new data about the terrestrial risk assessment. Recently generated data on plants and soil microorganism have been used to estimate the new PNEC in soil and therefore a revised PEC/PNEC ratio. In contrast to the first version a risk quotient < 1 has been established. Furthermore a detailed rationalization for the derivation of the $PNEC_{\text{water}}$ for P-AA/MA polycarboxylates had been included in this version. The thus refined risk

characterisation expressed by the PEC/PNEC ratio was below one for all environmental compartments. The outcome of this present environmental risk provides a sound basis for the conclusion that the use of polycarboxylates in detergent products does not pose a risk to the environment.

Human Health

Scenarios relevant to the consumer exposure to polycarboxylates have been identified and assessed using a Margin of Safety approach.

Polycarboxylates are of low toxicity by all exposure routes examined. Polycarboxylates are of low acute toxicity to the rat ($LD_{50} > 5$ g/kg bw/d). Homopolymers (P-AA) are not irritating to the rabbits skin and, at the most, slightly irritating to the eye, whereas the copolymers (P-AA/MA) based on the given data show no irritating potential on either target tissue. Further P-AA and P-AA/MA have no sensitising potential. The adverse effect after repeated inhalation dosing (91-d/rat) was a mild, reversible pulmonary irritation. This effect is considered not substance-related owing to the physical property of the respirable dust, which caused local and not systemic lung effects. Nevertheless, in a worst case scenario, the NOECs of 0.2 mg/m³ for P-AA and 1.0 mg/m³ for P-AA/MA were taken forward into a Margin of Exposure calculation under the worst case assumption of a ten percent deposition into the lung and 100% absorption of the deposited material. There was no evidence for a genotoxic potential of P-AA and P-AA/MA using a variety of genetic endpoints *in-vitro* and *in-vivo*, or for developmental toxicity or reprotoxicity in the rat. Based upon the available data, it is considered that exposure to polycarboxylates does not any particular hazard to humans.

Owing to the presence of polycarboxylates in many commonly used household detergents, consumers are exposed to polycarboxylates mainly via the dermal route, but also to a minor extent via the oral and inhalation route. The exposure resulting from dermal contact was estimated for P-AA as 4.4 µg/kg bw/day and for P-AA/MA as 26 µg/kg bw /day. The exposure by oral uptake was estimated for P-AA as 2.48 µg/kg bw/day and for P-AA/MA as 2.36 µg/ kg bw/day. Based on an NOAEL of $1,136$ mg/kg bw/day, as a worst case scenario in the absence of a dermal NOAEL, from an oral study in rats a Margin of Exposure (MOE) of 2.5×10^5 can be assessed for P-AA for dermal contact. For P-AA/MA, an MOE of 7.2×10^4 is calculated from the NOEL of a 28d dermal study in rabbits.

The exposure resulting from oral uptake via substance residues on machine washed eating utensils and via drinking water is estimated to amount to 2.48 µg/ kg bw/ day for P-AA and approx. 2.36 µg/ kg bw/day for P-AA/MA. From the NOEL of the 28 d rat study an MOE of 4.6×10^5 is assessed for this scenario and for P-AA/MA based on a NOAEL of $1,871$ mg/kg bw/d from a subchronic drinking water study in rats an MOE of 7.9×10^5 .

For exposure of inhalation a separate MOE of 2×10^5 was calculated for P-AA assuming 100% bioavailability of a hypothetical inhalable dust burden. For P-AA/MA a similar worst case MOE of 1.7×10^5 was calculated. All MOEs indicate no risk for human health.

In summary, based on the available data, the human risk assessment considers the use of polycarboxylates in household laundry products and automatic dishwashing detergents as safe and of no concern with regard to consumer use.

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3. SUBSTANCE CHARACTERISATION

3.1 Chemical structure and composition

Polymers used in detergents are homopolymers of acrylic acid or copolymers of acrylic acid and maleic acid, generally as sodium salts.

The various polycarboxylates are distinguished by the monomers used for their preparation, acrylic acid (AA) and maleic acid (MA) and their molecular weight (MW).

In this report the polycarboxylates are designated by codes consisting of the corresponding abbreviations, P-AA for polyacrylic acid and P-AA/MA for copolymers of acrylic acid and maleic acid:

P-AA: a homopolymer of acrylic acid (or its sodium salt)

P-AA/MA: an acrylic and maleic acids copolymer (or its sodium salt)

Tables 1-1 and 1-2 show the most important CAS Registry Numbers for the types of P-AA and P-AA/MA used as (co-) builders in household cleaning products.

Table 1-1: CAS Numbers for P-AA of acrylic acid (or their sodium salts)

CAS No.	CAS Name
9003-01-4	2-Propenoic acid, homopolymer
9003-04-7	2-Propenoic acid, homopolymer, sodium salt
25549-84-2	2-Propenoic acid, sodium salt, homopolymer
28603-11-4	2-Propenoic acid, homopolymer, sodium salt, isotactic
114739-92-3	2-Propenoic acid, homopolymer, 2-mercaptoethanol terminated, sodium salt

Linear homopolymers P-AA cover a molecular weight range of 1,000 to 78,000. P-AA representative for use in detergents with a typical molecular weight (MW) of approximately 4,500 have been taken into account in this HERA risk assessment. The structural formula is shown in figure 1.

Figure 1: Structure of P-AA

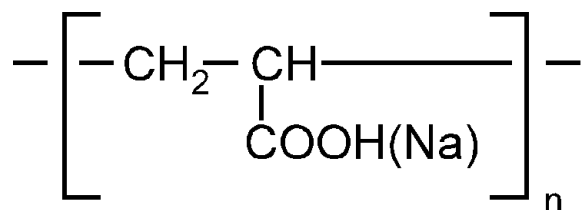


Table 1-2: CAS Numbers for P-AA/MA of acrylic acid and maleic acid (or their sodium salts)

CAS No.	CAS Name
29132-58-9	2-Butenedioic acid (Z), polymer with 2-propenoic acid
51025-75-3	2-Butenedioic acid (Z), monosodium salt, polymer with sodium 2-propenoate
51344-35-5	2-Butenedioic acid (Z), sodium salt, polymer with sodium 2-propenoate
60449-78-7	2-Butenedioic acid, disodium salt, polymer with sodium 2-propenoate
60472-42-6	2-Butenedioic acid (Z), polymer with 2-propenoic acid, sodium salt
61842-61-3	2-Butenedioic acid (Z), disodium salt, polymer with 2-propenoic acid
61842-65-7	2-Butenedioic acid (Z), monosodium salt, polymer with 2-propenoic acid
63519-67-5	2-Butenedioic acid (Z), sodium salt, polymer with 2-propenoic acid
112909-09-8	2-Butenedioic acid (Z), disodium salt, polymer with sodium 2-propenoate
126595-54-8	2-Butenedioic acid (Z), polymer with sodium 2-propenoate
52255-49-9	2-Propenoic acid, polymer with 2,5-furandione, sodium salt

Linear copolymers P-AA/MA cover a molecular weight range of 12,000 to 100,000. P-AA/MA representative for use in detergents with a typical molecular weight (MW) of approximately 70,000 have been taken into account in this HERA risk assessment. The structural formula is shown in figure 2.

Figure 2: Structure of P-AA/MA

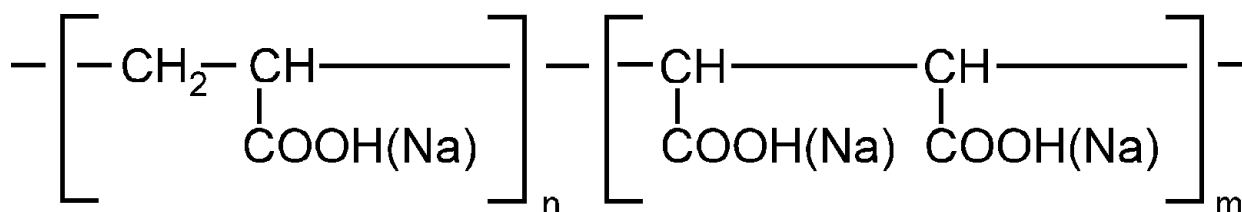


Table 2: Physical-chemical data of P-AA and P-AA/MA

Parameter	P-AA			P-AA/MA		
	Data	Reliability	Reference	Data	Reliability	Reference
Typical molecular weight (g/mol)	4500	2	BASF AG, 2002	70,000	2	BASF AG, 2002
Molecular weight distribution M_w/M_n	app. 2	2	BASF AG, internal data	app. 10	2	BASF AG, internal data
Melting Point	> 150°C (decomp.)	2	BASF AG internal data	> 150°C (decomp.)	2	BASF AG internal data
Boiling Point	not applicable			not applicable		
Vapour Pressure	not applicable			not applicable		
Water Solubility	> 40%	2	BASF AG internal data	> 40%	2	BASF AG internal data
Viscosity	not applicable			not applicable		
pKa	not applicable			not applicable		
pH (10 % in water at 20°C)	app. 8	2	BASF AG, 2002	app. 8	2	BASF AG, 2002

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Depending on the reaction process, the residual content of acrylic acid (or its sodium salt) in P-AA and P-AA/MA, respectively, can amount 0.5%; in most cases it is < 0.1%, often much lower. P-AA/MA copolymers may contain residual maleic anhydride or maleic acid (or its sodium salt) up to 0.5%; in most cases it is < 0.1%.

3.2 Manufacturing Route and Production/Volume Statistics

Polycarboxylates used in detergents are generally prepared by free-radical polymerisation of acrylic acid, or acrylic acid and maleic anhydride in aqueous solution. The molecular weight is influenced by the reaction conditions such as temperature and concentration, but the most important factors are the proportion and nature of initiators and chain-transfer agents used. For initiation, peroxides, azo compounds and redox systems such as iron (II) and hydrogen peroxide or sulphite and peroxodisulphate are employed. The most important chain-transfer agents include alcohols, amines and mercaptans (Jung et al, 1980). Residual levels of unreacted initiators and chain-transfer agents in polycarboxylates are low (< 0.1%).

The annual consumption of polycarboxylates has been raised over the last years. This updated risk assessment is based on the most recent and realistic market survey (EU 27) by AISE (AISE, 2009) which estimated a total consumption tonnage of about 80,000 tonnes for the year 2007 for household, industrial and institutional uses. The following breakdown for P-AA and P-AA/MA was used for the risk calculations:

P-AA	14,300 tonnes per annum
P-AA/MA	65,700 tonnes per annum

3.3 Use applications summary

Polycarboxylates are used in low-phosphate and phosphate-free detergents for household and industrial and institutional uses for avoiding incrustation and soil redeposition. P-AA is used mainly in automatic dishwashing detergents whereas their use in laundry detergents is of minor importance. P-AA/MA is used predominantly in laundry detergent powders and tablets but to a small extent in automatic dishwashing detergents, too. The most important source of P-AA/MA release to waste water is the use in phosphate-free laundry detergents. Typical mean concentrations of polycarboxylates range between 0.5 % for P-AA and 3.0 % for P-AA/MA in laundry detergents. P-AA and P-AA/MA are not used in manual dishwashing detergents and spray cleaners.

4. ENVIRONMENTAL ASSESSMENT

An environmental report on polycarboxylates as used in detergents was prepared by ECETOC (1993) and has been used as the basis of this HERA Environmental Risk Assessment.

4.1 Environmental exposure assessment

Polycarboxylates as high production volume detergent ingredients are predominantly used in countries where phosphate-reduced or phosphate-free detergents dominate the market. However, the use of such polycarboxylate-containing detergents is not evenly distributed in Europe, so that the prerequisite of the HERA exposure scenario may not totally apply (HERA Methodology Document, 2002). For this reason and to keep the conservative frame this polycarboxylate-specific scenario deviates from the HERA scenario in terms of the regional release. The local release of the HERA scenario remained unchanged as it is not affected by the uneven distribution of polycarboxylate use in detergents. Comparable to the assumptions of the HERA risk assessment for Zeolite A (HERA, 2004) the regional scenario for polycarboxylates was modified as follows.

Italy is the country with the highest per capita use of detergents and with nearly 100 % use of phosphate-free detergents. Hence, Italy represents the worst case situation of the regional release of polycarboxylates as it is described in the HERA risk assessment report for Zeolite A, (HERA 2002 and HERA, 2004).

Compared to the average per capita consumption of household laundry detergents in Europe (10 kg/year), the consumption in Italy is higher (12 kg/year). To maintain the conservative frame conditions of this polycarboxylate-specific exposure scenario, 12% of the polycarboxylate continental tonnage was assumed to go to the region (instead of 7% as assumed in the HERA standard exposure scenario) (AISE, 2001). Based on these conservative considerations, the following regional polycarboxylate consumption data were used as input parameter for the exposure assessment:

1,700 t/a homopolymers P-AA per region
7,900 t/a copolymers P-AA/MA per region

In contrast to other HERA risk assessments, the use of polycarboxylates in the industrial and institutional detergents which is about 10% of the annual consumption of polycarboxylates (AISE 2009) was not excluded from this risk assessment.

In consideration of this specific consumption scenario, the exposure calculations are based on the following general conditions:

- Fraction connected to sewer systems: 80 % regional release scenario
- Fraction of emission directed to waste water: 100 %
- Local tonnage: Calculation based on detergent use per capita in Italy, percentage of amount in detergent and 10,000 inhabitants assumed to be connected to a standard STP
- STP elimination: Polycarboxylates are not readily biodegradable. However, polycarboxylates are eliminated in sewage treatment plants by precipitation and adsorption processes by at least the following elimination degrees as the worst case assumption: Homopolymers P-AA 10 % and copolymers P-AA/MA 90 %.

4.1.1 Environmental Fate and Removal of P-AA

In the following, the available environmental fate and removal data of P-AA (table 3) are listed and evaluated in terms of their reliability according to the criteria by Klimisch et al. (1997).

Aerobic Biodegradation and Elimination

Data on the biodegradation and elimination of a number of P-AA types with different MW are available and are summarised and evaluated in table 3. Although the polymer with MW 4,500 is most representative for P-AA used in detergents, the test results for lower and higher MW species are considered helpful for better understanding of the mechanisms responsible for the removal of these polymers in the environment.

Table 3: Summary of biodegradation and elimination data of P-AA

Mean MW	Method/Remark	Result	Reliability	Reference
Water				
1,000	CO ₂ Evolution Test, river water, ¹⁴ C tagged	20 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
1,000	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	43 % CO ₂ after 90 days	1	Procter & Gamble, 1985 c
1,000	OECD 302 A, domestic activated sludge (SCAS Test)	45 % DOC after 7 days	1	Procter & Gamble, 1983 a
2,000	CO ₂ Evolution Test, river water, ¹⁴ C tagged	10 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
2,000	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	19 % CO ₂ after 90 days	1	Procter & Gamble, 1985 c
2,000	OECD 302 A, domestic activated sludge (SCAS Test)	21 % DOC after 7 days	1	Procter & Gamble, 1983 b
4,500	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	10 % CO ₂ after 31 days	1	Procter & Gamble, 1985 d
4,500	OECD 302 A, domestic activated sludge (SCAS Test)	40 % DOC after 7 days	1	Procter & Gamble, 1984 b
10,000	CO ₂ Evolution Test, river water, ¹⁴ C tagged	7 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
10,000	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	17 % CO ₂ after 90 days	1	Procter & Gamble, 1985 c

Mean MW	Method/Remark	Result	Reliability	Reference
Water				
15,000	OECD 302 A, domestic activated sludge (SCAS Test)	58 % DOC after 7 days	1	Procter & Gamble, 1985 a
15,000	OECD 302 B, industrial activated sludge	< 10 % DOC	2	BASF, 1989
70,000	OECD 302 A, domestic activated sludge (SCAS Test)	93 % DOC after 7 days	1	Procter & Gamble, 1983 c

Sediment				
1,000	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	58 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
2,000	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	37 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
4,500	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	6 % CO ₂ after 106 days	1	Procter & Gamble, 1984 a
10,000	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	12 % CO ₂ after 135 days	1	Procter & Gamble, 1985 b
Soil				
1,000	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	35 % CO ₂ after 165 days	1	Procter & Gamble, 1985 e
2,000	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	11 % CO ₂ after 165 days	1	Procter & Gamble, 1985 e
4,500	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	6 % CO ₂ after 81 days	1	Procter & Gamble, 1985 d
10,000	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	5 % CO ₂ after 165 days	1	Procter & Gamble, 1985 e
Sewage treatment plant (STP)				
1,000	OECD 303 A, domestic activated sludge (Activated sludge simulation test)	A: 9 % (DOC influent concentration 15 mg/l) B : 24 % (DOC influent concentration 10 mg/l)	1	Procter & Gamble, 1984
2,000	OECD 303 A, domestic activated sludge (Activated sludge simulation test)	A : 13 % (DOC influent concentration 18 mg/l) B : 24 % (DOC influent concentration (10 mg/l)	1	Procter & Gamble, 1983 d
4,500	Activated sludge simulation test, domestic, radio labelled	76 ± 8 % removal of the polymer	1	Rohm & Haas, 1991 d
78,000	OECD 303 A, domestic activated sludge (Coupled Unit Test)	78 ± 8 % DOC	2	Henkel KGaA, 1987

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Conclusion:

Based on the available data it can be concluded that P-AA is not readily biodegradable but is partly accessible to ultimate biodegradation particularly under long incubation conditions (cf. mineralisation data) (Procter & Gamble, 1985 b and Procter & Gamble, 1985 e). Lower molecular weight homopolymers (MW < 2,000) are partly biodegradable under the conditions of soil or sediment inoculation. Test results with activated sludge inoculum indicate partial elimination, probably due to adsorption processes. The elimination tends to increase with higher molecular weight. The STP removal data of P-AA with MW 4,500 and MW 2,000 show strong differences, while the first is almost identical with the result obtained for the MW 78,000 representative. Considering the fact that material with MW 4,500 does contain considerable moiety of low MW polymer chains the use of the high removal value seems inappropriate.

Therefore for the conservative frame of this P-AA exposure assessment a lower removal rate of 10% will be used for the EUSES calculations.

Anaerobic Biodegradation and Elimination

The anaerobic biodegradation of P-AA (70,000 g/mol) was investigated in batch experiments (Schumann and Kunst, 1991). About 80 % of the radio-labelled carbon was adsorbed on the sludge phase and about 3 % was mineralised to CO₂. This result could be confirmed by studies simulating the digestion of sewage sludge. Therefore, no anaerobic degradation of P-AA was assumed in the context of the HERA risk assessment.

4.1.2 Environmental Fate and Removal of P-AA/MA

In the following, the available environmental fate and removal data of P-AA/MA (table 4) are listed and evaluated in terms of their reliability according to the criteria by Klimisch et al. (1997).

Aerobic Biodegradation and Elimination

Data on the biodegradation and elimination of a several P-AA/MA types with different MW are available and are summarised and evaluated in table 4. Although the polymer with MW 70,000 is the most representative for P-AA/MA used in detergents, the results for lower MW species are considered helpful for better understanding of the mechanisms responsible for the removal of these polymers in the environment.

Table 4: Summary of biodegradation and elimination data of P-AA/MA

Mean MW	Method/Remark	Result	Reliability	Reference
Water				
12,000	CO ₂ Evolution Test, river water, ¹⁴ C tagged	A: 21 % CO ₂ after 100 days (chain labelled) B: 31 % CO ₂ after 100 days (carboxyl labelled)	1	Procter & Gamble, 1985 f
12,000	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	A: 39 % CO ₂ after 90 days (chain labelled) B: 13 % CO ₂ after 90 days (carboxyl labelled)	1	Procter & Gamble, 1985 h
12,000	OECD 302 A, domestic activated sludge (SCAS Test)	83 % DOC after 7 days	1	Procter & Gamble, 1983 e
70,000	CO ₂ Evolution Test, river water, ¹⁴ C tagged	12 % CO ₂ after 100 days (chain labelled)	1	Procter & Gamble, 1985 g
70,000	CO ₂ Evolution Test, domestic activated sludge, ¹⁴ C tagged	A: 13 % CO ₂ after 90 days (chain labelled) B: 18 % CO ₂ after 90 days (carboxyl labelled)	1	Procter & Gamble, 1985 h
70,000	OECD 302 B (Zahn - Wellens Test)	97-99 % DOC (2 days), domestic activated sludge	2	BASF AG, 1990
70,000	ISO 18749 (Adsorption Test modified to Zahn - Wellens)	90-100 % DOC (1 day), domestic activated sludge	2	BASF AG, 2001
70,000	OECD 302 A, domestic activated sludge (SCAS Test)	95 % DOC after 7 days	1	Procter & Gamble, 1983 f
80,000	OECD 301 A (Die Away Test)	20-30 % DOC (28 days) domestic activated sludge	1	BASF AG 1996

Mean MW	Method/Remark	Result	Reliability	Reference
Sediment				
12,000	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	A: 41 % CO ₂ after 100 days (chain labelled) B: 6 % CO ₂ after 100 days (carboxyl labelled)	1	Procter & Gamble, 1985 g
70,000	CO ₂ Evolution Test, river water and sediment, ¹⁴ C tagged	A: 11 % CO ₂ after 100 days (chain labelled) B: 13 % CO ₂ after 100 days (carboxyl labelled)	1	Procter & Gamble, 1985 g
Soil				
12,000	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	A: 32 % CO ₂ after 165 days (chain labelled) B: 10 % CO ₂ after 165 days (carboxyl labelled)	1	Procter & Gamble, 1985 i
70,000	CO ₂ Evolution Test, sludge treated soil, ¹⁴ C tagged	A: 8 % CO ₂ after 165 days (chain labelled) B: 11 % CO ₂ after 165 days (carboxyl labelled)	1	Procter & Gamble, 1985 i
STP				
12,000	OECD 303 A, domestic activated sludge (Simulation test)	A: 71 % DOC removal (15 mg/l DOC influent concentration) B: 80 % DOC removal (30 mg/l DOC influent concentration)	1	Procter & Gamble, 1983 d
70,000	OECD 303 A, domestic activated sludge (Simulation test)	93 % 15 mg/l DOC influent	1	Procter & Gamble, 1983 d
70,000	OECD 303 A domestic activated sludge (Simulation test)	> 94 % DOC removal	2	Opgenorth, 1987
70,000	OECD 303 A domestic activated sludge (Simulation test)	97-98 % DOC removal	2	Schumann, 1990

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

The elimination of copolymers was determined out in various test systems. In batch tests with activated sludge like the Zahn-Wellens or the SCAS test, DOC removal rates of 90 % and more were observed. Similarly to P-AA, the use of ¹⁴C-radiolabelled P-AA/MA showed that this removal is only marginally related to ultimate biodegradation (cf. mineralisation data).

The sorptive-precipitative nature of the elimination mechanism of P-AA/MA was shown in flask tests with activated sludge (water hardness 2-17 °d; 1°h = 10 mg/l CaO) when biodegradation was excluded by the test design (Opgenorth, 1989). It can be assumed that the combination of adsorption and precipitation is mainly responsible for the elimination rate which increases with higher molecular weight. In continuous activated sludge tests, the high elimination of P-AA/MA observed in batch tests was generally confirmed.

Conclusion:

In summary, the results from screening and simulation tests suggest that copolymers in biological waste water treatment plants are predominantly eliminated by adsorption/ precipitation in contact with activated sludge (Procter & Gamble, 1983 d and Opgenorth, 1987). Based on higher tier data from STP model tests a removal rate of 90 % in STP was conservatively assumed for P-AA/MA in this HERA exposure assessment. This figure represents the lower edge of the spectrum of elimination data measured for P-AA/MA of MW 70,000 in STP model tests.

Anaerobic Biodegradation and Elimination

The anaerobic biodegradability of P-AA/MA (70,000 g/mol) was investigated by incubation of radiolabelled P-AA/MA in a mixture of digester sludge and nutrient solution over 258 days at 35°C (Opgenorth, 1990). The results indicated biodegradability of between 11 and 16 %. Therefore, no anaerobic degradation of P-AA/MA was assumed in the context of the HERA risk assessment.

4.1.3 Abiotic degradability of P-AA and P-AA/MA

Photodegradation

Considering the high water solubility and low volatility of P-AA and P-AA/MA in general and the fact that the emissions are directed to sewage, the atmospheric compartment is not a relevant fate pathway and therefore not considered in this assessment.

Hydrolytic stability

Polycarboxylates are very stable compounds as the carboxyl part of the molecule is the only functional group. The presence of the multiple neighbouring carboxyl groups along the polymer chain adds further to the stability. Therefore, the hydrolytic stability of these compounds is very high.

Conclusion:

Abiotic degradation mechanisms like photolytic and hydrolytic processes do not influence significantly the environmental fate of polycarboxylates

4.1.4 Bioconcentration of P-AA and P-AA/MA

Experimental data on the bioaccumulation potential of polycarboxylates are not available. However, substances with a molecular weight of > 700 are not readily taken up by cell membranes, because of possible steric hindrance at the passage (TGD, 2003). In addition, the high water solubility of the parent compound together with its property to form insoluble calcium salts in natural waters suggests that bioaccumulation is unlikely.

4.1.5 Monitoring Data

Monitoring data are not available.

4.1.6 PEC Calculations

Polycarboxylates represent a group of high production volume detergent ingredients predominantly used in phosphate-reduced or phosphate-free detergents in the Western European market (EU27). Therefore, the tonnage data reported in Chapter 3.2 will be used for the following PEC calculations according to the standard EU TGD methodology (EUSES).

Based on a conservative assessment (see chapter 4.1.1 and 4.1.2) a 10% removal for P-AA and a 90% removal for P-AA/MA by sewage treatment were assumed.

PEC calculations were performed by using the EUSES scenario according to EU TGD (EU, 2003; Industry category 5: Personal & domestic use, Use category 9: Cleaning/ washing agents and additives).

The relevant input-data used for the exposure calculations are summarised in table 5-1 and 5-2:

Table 5-1: Substance Data used for exposure calculations of P-AA

Name/endpoint	Value/remarks
General name	Acrylic acid homopolymers
CAS-number	See table 1
Molecular weight [g/mol]	4,500
Percentage of treated sewage at regional scale [%]	80
Use volume released	14,300 t/a
STP Removal	10 %
Fraction of emission directed to air	0
Fraction of emission directed to water	0.90
Fraction of emission directed to sludge	0.1
Default values: log Kow	-1
Water solubility [mg/l]	450

Table 5-2: Substance Data used for exposure calculations of P-AA/MA

Name/endpoint	Value/remarks
General name	Acrylic acid maleic acid copolymers
CAS-number	See table 2
Molecular weight [g/mol]	70,000
Percentage of treated sewage at regional scale [%]	80
Use volume released	65,700 t/a
STP Removal	90 %
Fraction of emission directed to air	0
Fraction of emission directed to water	0.10
Fraction of emission directed to sludge	0.90
Default values: log Kow	-1
Water solubility [mg/l]	450

The results of the PEC calculations for P-AA and P-AA/MA are presented in tables 6 to 9.

Aquatic Compartment

Table 6: C_{local} and PEC_{water} for P-AA and P-AA/MA

Water	Polycarboxylate	PEC
PEC _{regional, water} [mg/l]	P-AA	0.094
	P-AA/MA	0.307
PEC _{local, water} [mg/l]	P-AA	0.226
	P-AA/MA	0.375

Sediment Compartment

Table 7: C_{local} and PEC_{sediment} for P-AA and P-AA/MA

Sediment	Polycarboxylate	PEC
$PEC_{\text{regional, sediment}}$ [mg/kg]	P-AA	0.070
	P-AA/MA	0.230
$PEC_{\text{local, sediment}}$ [mg/kg]	P-AA	0.193
	P-AA/MA	0.319

Soil Compartment

Table 8: C_{local} and PEC_{soil} for P-AA and P-AA/MA

Soil	Polycarboxylate	PEC
$PEC_{\text{regional, soil}}$ [mg/kg]	P-AA	0.005
	P-AA/MA	0.189
$PEC_{\text{local, soil}}$ [mg/kg]	P-AA	0.363
	P-AA/MA	19.389

No biological degradation of P-AA/MA was assumed for the calculation of $PEC_{\text{local, soil}}$. There are, however, some findings, which indicate a small degree of biodegradability of at least 10 % (cf. Table 5). However, consideration of these biodegradation data would not significantly affect the results.

Sewage Treatment Plant (STP)

Table 9: PEC_{stp} for P-AA and P-AA/MA

STP	Polycarboxylate	PEC
$PEC_{\text{local, stp}}$ [mg/l]	P-AA	1.320
	P-AA/MA	0.675

4.2. Environmental Effects Assessment

In the following, the available ecotoxicity data of P-AA (table 10-12) and P-AA/MA (table 13-15) are listed and evaluated in terms of their reliability according to the criteria by Klimisch et al. (1997).

4.2.1 Ecotoxicity of P-AA

P-AA has a low acute ecotoxicity profile (see table 10). With the exception of algae, in all ecotoxicity studies the $L(E)C_{50}$ is above the highest tested concentration (≥ 200 mg/l). Toxicity to aerobic bacteria is low as well. Several chronic studies on fish, *Daphnia* and algae are available (table 11). The low ecotoxicity of polycarboxylates is confirmed by NOEC values which are predominantly in the range between 10 and ≥ 100 mg/l. Several studies on sediment or soil ecotoxicity are available confirming again the low ecotoxicity of P-AA (table 12).

Table 10: Acute Aquatic Ecotoxicity of P-AA

Mean MW	Test species	Method	LC/EC ₅₀ [mg/l] Exposure time	Reliability	Reference
Acute Toxicity to Fish					
1,000	<i>Brachydanio rerio</i>	OECD 203 (range finding)	> 200 (96 h)	1	Procter & Gamble, 1983 g
1,000	<i>Salmo gairdneri</i>	Standard method for acute toxicity tests	> 1000 (96 h)	1	Rohm & Haas, 1983 a
1,200	<i>Leuciscus idus</i>	DIN 38412 part 15	> 500 (96 h)	1	BASF AG, 1987 a
2,000	<i>Brachydanio rerio</i>	OECD 203 (range finding)	> 200 (96 h)	1	Procter & Gamble, 1983 g
2,500	<i>Leuciscus idus</i>	DIN 38412 part 15	> 500 (96 h)	1	BASF AG, 1987 b
4,500	<i>Brachydanio rerio</i>	US and European guidelines	> 200 (96 h)	4	Freeman et al., 1993
4,500	<i>Lepomis macrochirus</i>	OECD 203	> 1000 (96 h)	1	Procter & Gamble, 1984 d
4,500	<i>Lepomis macrochirus</i>	Standard method for acute toxicity tests	> 1000 (96 h)	1	Rohm & Haas, 1983 b
4,500	<i>Salmo gairdneri</i>	US and European guidelines	700 (96 h)	4	Freeman et al., 1993
8,000	<i>Leuciscus idus</i>	DIN 38412 part 15	> 500 (96 h)	1	BASF AG, 1987 c
10,000	<i>Lepomis macrochirus</i>	US EPA, 1975	> 1000 (96 h)	1	Procter & Gamble, 1983 h
15,000	<i>Leuciscus idus</i>	DIN 38412 part 15	> 10 000 (96 h)	1	BASF AG, 1987 d
78,000	<i>Brachydanio rerio</i>	ISO 7346/3	> 400 (96 h)	2	Henkel KGaA, 1987
Acute Toxicity to Aquatic Invertebrates					
1,000	<i>Daphnia magna</i>	OECD 202	> 200 (48 h)	1	Procter & Gamble, 1983 i
1,000	<i>Daphnia magna</i>	Standard method for acute toxicity tests	> 1000 (48 h)	1	Rohm & Haas, 1983 c
2,000	<i>Daphnia magna</i>	OECD 202	> 200 (48 h)	1	Procter & Gamble, 1983 i

Mean MW	Test species	Method	LC/EC ₅₀ [mg/l] Exposure time	Reliability	Reference
4,500	<i>Daphnia magna</i>	OECD 202	> 200 (48 h)	1	Procter & Gamble, 1984 e
4,500	<i>Daphnia magna</i>	Standard method for acute toxicity tests	> 1,000 (48 h)	1	Rohm & Haas, 1983 d
78,000	<i>Daphnia magna</i>	OECD 202	276 (24 h)	2	Henkel KGaA, 1987
Acute Toxicity to Algae					
8,000	<i>Selenastrum capricornutum</i>	US EPA TSCA 797.1050	40 (72 h)	1	BASF Corp., 1989
78,000	<i>Scenedesmus subspicatus</i>	OECD 201	44 (96 h)	2	Henkel KGaA, 1987
Acute Toxicity to Bacteria					
1,000	Activated sludge	OECD 209 (range finding)	EC ₅₀ > 100	2	Procter & Gamble, 1985 a
2,000	Activated sludge	OECD 209 (range finding)	EC ₅₀ > 100	2	Procter & Gamble, 1985 a
4,500	Activated sludge	ESD standard method VIII-D-1, 1982	EC ₅₀ > 1,000	1	Procter & Gamble, 1985 j
15,000	Activated sludge	OECD 209	EC ₂₀ > 1,000 (30 min)	2	BASF AG, 1989
78,000	<i>Pseudomonas putida</i>	DIN 38412 part 8	EC ₁₀ 16 (16 h)	2	Henkel KGaA, 1987

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Conclusion for the PNEC_{STP} derivation based on bacteria toxicity data

The acute oxygen consumption inhibitory test study has the highest validation score and was used for derivation of the PNEC_{STP} (Procter & Gamble, 1985 j). Although the EC₅₀ value for P-AA (4,500) was > 1000 mg/l, an EC₅₀ = 1000 mg/l was conservatively assumed and an application factor of 100 was used, resulting in a PNEC_{STP} of 10 mg/L.

Table 11: Chronic Aquatic Ecotoxicity of P-AA

Mean MW	Test species	Method	NOEC [mg/l] Exposure time	Reliability	Reference
Chronic Toxicity to Fish					
4,500	<i>Pimephales promelas</i>	TSCA 797.1600, Early life stage	56 (32 days)	2	Rohm & Haas, 1991 a
4,500	<i>Brachydanio rerio</i>	OECD 204	> 450 (28 days)	1	Procter & Gamble, 1986 a
78,000	<i>Brachydanio rerio</i>	OECD 204	> 400 (14 days)	2	Henkel KGaA, 1987
Chronic Toxicity to Aquatic Invertebrates					
4,500	<i>Daphnia magna</i>	US and European guidelines	5.6 (21 days)	4	Freeman et al, 1993
4,500	<i>Daphnia magna</i>	OECD 202	450 (21 days)	1	Procter & Gamble, 1989 a
4,500	<i>Daphnia magna</i>	TSCA 797.1330	58 (21 days)	1	Rohm & Haas, 1991 e
4,500	<i>Daphnia magna</i>	OECD 202	12 (21 days)	2	Rohm & Haas, 1991 b
78,000	<i>Daphnia magna</i>	OECD 202 (Life-Cycle)	100 (21 days)	2	Henkel KGaA, 1987
Chronic Toxicity to Algae					
4,500	<i>Scenedesmus subspicatus</i>	OECD 201	180 (96 h)	2	Hennes, 1991
78,000	<i>Scenedesmus subspicatus</i>	OECD 201	32.8 (96 h)	2	Henkel KGaA, 1987

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Conclusion for the PNEC_{water} derivation based on aquatic toxicity data

As chronic data for all trophic are available, these have been used for the PNEC_{water} derivation. The 21 d reproduction life cycle study with *Daphnia magna* of NOEC = 12 mg/l was used for the PNEC derivation of P-AA (Rohm & Haas, 1991 b). This study provided the most conservative NOEC value for aquatic organisms. Since all three acute and chronic trophic levels were covered, an application factor of 10 can be used according to EU TGD (EU, 2003), resulting in a PNEC_{water} of 1.2 mg/L.

Table 12: Ecotoxicity of P-AA to Terrestrial and Sediment Organisms

Mean MW	Test species	Method	Effect [mg/kg] Exposure time	Reliability	Reference
Toxicity to Soil Dwelling Organisms					
4,500	<i>Eisenia foetida</i>	US and European guidelines	EC0=1,000 (96 h)	4	Freeman et al, 1993
4,500	<i>Eisenia foetida foetida</i>	OECD 207	EC0=1,000 (14 days)	1	Rohm & Haas, 1991 c
78,000	<i>Eisenia foetida andrei</i>	Earthworm tox. Test (UBA, 1984)	EC0=1,000 (14 days)	2	Henkel KGaA, 1987
Toxicity to Terrestrial Plants					
4,500	<i>Corn, soybean, wheat and grass seeds</i>	No data available	EC0 = 225	4	Hennes, 1991
78,000	<i>Brassica rapa</i>	EEC Directive 79/831, Annex V	NOEC=1,000 (21 days)	2	Henkel KG aA, 1987
Toxicity to Sediment Dwelling Organisms					
4,500	<i>Chironimus Riparius (larvae)</i>	Sediment batch system	EC0= 4,500 mg/kg dw (96 h)	1	Procter & Gamble, 1989 b

MW Molecular Weight (g/mol)

Reliability criteria of IUCLD acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Conclusion for PNEC_{soil} and PNEC_{sediment} derivation based on terrestrial and sediment toxicity data

The PNEC_{soil} calculation is based on the most reliable data from an acute earthworm study (*Eisenia foetida*, EC0 = 1,000 mg/kg) for P-AA (Rohm & Haas, 1991 c) using an application factor of 1,000 according to EU TGD (EU, 2003), resulting in a PNEC_{soil} of 1 mg/L.

Experimental data on sediment-dwelling organisms are available for P-AA (*Chironimus riparius*, table 12). The PNEC_{sediment} for P-AA was conservatively derived from the EC0 = 4,500 mg/kg using an application factor of 1000. Additionally the calculation of the PNEC_{sediment} carried out using the equilibrium partitioning method is 1.02 mg/kg. Furthermore, due to the chemical structure of P-AA the determination of the Koc by HPLC methodology and a subsequent derivation of a Kd value is debatable (BASF SE, 2009). Therefore the calculation of PNEC_{sediment} by the equilibrium partitioning method was only considered to compare experimental and calculated PNEC_{sediment} data. It also has to be kept in mind that the applicability of this method is limited, since it does not consider the effects of chemicals that are adsorbed to soil particles and taken up by ingestion (TDG, 2003).

The comparison of this theoretical calculated PNEC_{sediment} with PNEC_{sediment} of 4.5 mg/kg, derived from experimental data, shows that the application of the equilibrium partitioning method is more conservative. Based on the experimental data which are in general regarded as more significant for a substance assessment, a PNEC_{sediment} of 4.5 mg/kg was derived.

4.2.2 Ecotoxicity of P-AA/MA

P-AA/MA has a favourable ecotoxicological profile (see table 13 and 15). For a number of ecotoxicity studies on fish, *Daphnia* and algae, the L(E)C50 could not be determined because the effect values were above the highest tested concentration. Acute toxicity to aerobic bacteria, soil and terrestrial organisms is low as well.

Table 13: Acute Aquatic Ecotoxicity of P-AA/MA

Mean MW	Test species	Method	LC/EC ₅₀ [mg/l] Exposure time	Reliability	Reference
Acute Toxicity to Fish					
12,000	<i>Brachydanio rerio</i>	OECD 203 (range finding)	> 200 (96 h)	1	Procter & Gamble, 1982 a
50,000	<i>Leuciscus idus</i>	DIN 38412 part L15	> 500 (96 h)	2	BASF AG, 1987 e
70,000	<i>Brachydanio rerio</i>	OECD 203 (range finding)	> 100 (96 h)	1	Procter & Gamble, 1982 b
100,000	<i>Brachydanio rerio</i>	OECD 203	> 100 (96 h)	1	BASF AG, 2002 a
Acute Toxicity to Aquatic Invertebrates					
12,000	<i>Daphnia magna</i>	OECD 202 (range finding)	> 200 (48 h)	1	Procter & Gamble, 1984 f
70,000	<i>Daphnia magna</i>	OECD 202 (range finding)	> 100 (48 h)	1	Procter & Gamble, 1982 b
70,000	<i>Daphnia magna</i>	OECD 202	> 500 (48 h)	1	BASF AG, 1985
100,000	<i>Daphnia magna</i>	OECD 202	> 100 (48 h)	1	BASF AG, 2002 b
Acute Toxicity to Algae					
70,000	<i>Scenedesmus subspicatus</i>	OECD 201	> 500 (96 h)	1	BASF AG, 1985 c
70,000	<i>Chlorella vulgaris</i>	OECD 201	> 500 (96 h)	1	BASF AG, 1987 g
100,000	<i>Scenedesmus subspicatus</i>	OECD 201	> 100 (72 h)	1	BASF AG, 2002 c
Acute Toxicity to Bacteria					
12,000	Activated sludge, domestic	OECD 209	> 100	1	Procter & Gamble, 1985 a
70,000	Activated sludge, domestic	OECD 209	> 200	1	Procter & Gamble, 1985 a
70,000	<i>Pseudomonas putida</i>	DIN 38412	> 500	2	BASF AG, 1987 h

Mean MW	Test species	Method	LC/EC ₅₀ [mg/l] Exposure time	Reliability	Reference
70,000	<i>Photo-bakterium phosphoreum</i>	DIN 38412	> 500	2	BASF AG, 1985 d
80,000	<i>Pseudomonas putida</i>	DIN EN ISO 10712	463 (16 h)	1	BASF AG, 1997

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Conclusion for the PNEC_{STP} derivation based on bacteria toxicity data

As the most valid study, the toxicity from the acute oxygen consumption inhibitory test with activated sludge was used for derivation of the PNEC_{STP}. The EC₅₀ > 200 mg/l (Procter & Gamble, 1985 a) for P-AA/MA (70,000) together with an application factor of 100 resulted in a conservative PNEC_{STP} of 2 mg/L.

Table 14: Chronic Aquatic Ecotoxicity of P-AA/MA

Mean MW	Test species	Method	NOEC [mg/l] Exposure time	Reliability	Reference
Chronic Toxicity to Fish					
70,000	<i>Brachydanio rerio</i>	OECD 204	100 (14 days)	2	BASF AG, 1986 a
70,000	<i>Brachydanio rerio</i>	OECD 210	100 (42 days)	1	BASF AG, 1986 b
Chronic Toxicity to Aquatic Invertebrates					
70,000	<i>Daphnia magna</i>	OECD 202	350 (21 days)	1	Procter & Gamble, 1986 b
70,000	<i>Daphnia magna</i>	OECD 202	6.2 (21 days)	1	BASF AG, 1986 n
70,000	<i>Daphnia magna</i>	OECD 202	7.5 (21 days)	1	BASF AG, 1985 e
70,000	<i>Daphnia magna</i>	OECD 202	3.75 (21 days)	1	BASF AG, 1985 f
Chronic Toxicity to Algae					
100,000	<i>Scenedesmus subspicatus</i>	OECD 201	37.2 (72 h)	1	BASF AG, 2002 c
70,000	<i>Scenedesmus subspicatus</i>	OECD 201	EC ₁₀ = 32 (96 h)	4	Schumann, 1990

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

For aquatic organisms chronic data (table 14) are available and have been used for the PNEC derivation. Noticeable is the observed variability of chronic aquatic toxicity results for *Daphnia magna* with the same molecular weight representative of P-AA/MA. The solubility behaviour of P-AA/MAA in water gives reason for these observations as the aquatic toxicity and bioavailability of P-AA/MA is directly linked to its solubility behaviour in water and its complexing behaviour towards bivalent calcium or magnesium cations. In excess of 2^+ -ions, i.e. at low PAA/MA concentration in water, polycarboxylates form insoluble precipitates because available carboxylic groups of the polycarboxylates are saturated. With increasing concentration of polycarboxylates in water, e.g. in excess of polycarboxylates compared to 2^+ -ions, this phenomenon declines. This means that less to no precipitation occurs at high P-AA/MA concentrations in water under the guideline test conditions. This correlation was confirmed in a recent study by BASF (BASF SE, 2008 a). Here the water solubility of P-AA/MA was determined in dependence of water hardness and P-AA/MA concentration. The solubility behaviour of P-AA/MA in concentration between 11 to 1000 mg/L was measured in distilled water (= without 2^+ ions) and in the OECD 202 guideline medium of *Daphnia magna* (= medium M4 with a water hardness of 13.8 °dH, which is equivalent to 2.46 mmol/L CaO). The solubility was determined analytically via the ratio of dissolved organic carbon (DOC) and total organic carbon (TOC). In distilled water P-AA/MA was 100 % soluble in all concentrations. In M4 medium P-AA/MA was completely soluble at concentrations higher than 500 mg/L. At concentrations below 500 mg/L the precipitation process starts and under 25 mg/L almost all P-AA/MA existed in an insoluble Ca-form.

The precipitation of P-AA/MA at concentrations below 10 mg/L was investigated in more detail by microscope, showing that the observed chronic effects on *Daphnia magna* of P-AA/MA at low concentrations are likely due to precipitated polycarboxylates products. Under conditions with low exposure concentration of P-AA/MA, the colour of the gastro-enteric tract of *Daphnia magna* changed from green, i.e. the typical colour resulting from the algae feed, to grey, i.e. the colour of the precipitated polycarboxylates (BASF AG, 1990 a). Thus, the observed effects at low concentrations may not be caused by intrinsic toxic properties of the polymer, but by secondary effects of the uptake of precipitates.

This observed secondary effect is probably not occurring under realistic environmental conditions. In comparison with the 50 ml incubation beaker of the OECD 202 test design the dilution in surface water in natural compartments is unlimited. Furthermore due to the high removal and elimination degree of P-AA/MA in waste water treatment plants the presence of P-AA/MA precipitates in surface waters is unlikely. For these reasons an uptake of precipitate products by filter feeding aquatic invertebrates cannot be expected in surface water.

Conclusion for the PNEC_{water} derivation based on aquatic toxicity data

Consequently for aquatic invertebrates the chronic daphnia study by Procter & Gamble (1986 b) is the most reliable study, which reflects the polymer intrinsic properties. The chronic *Daphnia* toxicity study by BASF (BASF AG, 1985 f) is due to tested concentration influenced by secondary precipitation effects and has not been used for the PNEC derivation.

The available algae study (BASF, 2002c) provides the most sensitive NOEC value 37.2 mg/l, which therefore will be used for the derivation of the PNEC_{water}. Since, all three acute and chronic trophic levels were covered an application factor of 10 was used according to EU TGD (EU, 2003), resulting in a PNEC_{water} of 3.7 mg/L.

Table 15: Toxicity to Terrestrial organisms of P-AA/MA

Mean MW	Test species	Method	Effect [mg/kg] Exposure time	Reliability	Reference
Toxicity to Soil Dwelling Organisms					
70,000	<i>Eisenia fetida</i>	EDWARDS, Commission of the European Community, 1983	EC0=1,600 (14 days)	2	BASF AG, 1986 o
Toxicity to Terrestrial Plants					
70,000	<i>Oats Avena sativa</i>	German guideline according to UBA	NOEC >1,000 (18 days)	2	BASF AG, 1985 g
70,000	<i>Oats seed</i>	No data available	NOEC = 400	4	Opgenorth, 1987
70,000	<i>Avena sativa</i>	OECD 208	EC10=2,490	1	BASF SE, 2009
70,000	<i>Brassica napus</i>	OECD 208	EC10=3,963	1	BASF SE, 2009
70,000	<i>Vicia sativa</i>	OECD 208	EC10=2,623	1	BASF SE, 2009
Toxicity to Bacteria					
70,000	<i>Nitrogen transformation</i>	OECD 216	EC10 >10,000	2	BASF SE, 2008 c
70,000	<i>Carbon transformation</i>	OECD 217	EC10 >10,000	2	BASF SE, 2008 d

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Data are available for toxicity to plants and microorganisms in soil. The toxicity to higher plants *Avena sativa*, *Brassica napus* and *Vicia sativa* was determined at different endpoints such as the emergence rate of the seedlings, fresh and dry matter and shoot length. For all three species and all tested endpoints the EC₅₀ values were above 5000 mg/kg soil, which indicates the low toxicity of P-AA/MA to these terrestrial organisms. The lowest test result showed an EC₁₀ value of 2,490 mg/kg P-AA/MA for *Avena sativa*, based on the determination of shoot length. It was observed visually that the consistency of the soil was altered. The emergence rate of *Brassica napus* was affected at concentrations above 625 mg/kg soil. In order to test possible influences of soil compaction and subsequent mechanical effects on the emergence rate of the seedlings an additional study was performed (BASF SE, 2008 b). The result of this study demonstrates that the soil pressure (compaction) was significantly increased even at the lowest tested concentration of 313 mg P-AA/MA/kg soil. This confirms the preliminary observation of the alteration of the soil structure at P-AA/MA concentrations of 300 mg P-AA/MA/kg soil.

It was also observed that the emergences process of the seedlings was interrupted, i.e. after an initial emergence phase, the shoots were physically hindered from fully breaking through the soil, due to the mechanical compaction of the soil. This mechanism should be interpreted as a secondary effect, which is probably dependent on the guideline test conditions and is not realistic for the environment. Consequently these secondary effects on the emergence rate of *Brassica napus* were not considered for the derivation of the PNEC_{soil} of P-AA/MA.

Conclusion for PNEC_{soil} and PNEC_{sediment} derivation based on terrestrial and sediment toxicity data

The PNEC_{soil} calculation has been derived from the *Avena sativa* study with an EC₁₀ of 2,490 mg/kg for P-AA/MA (BASF SE, 2008). The available data cover different plant species and microbial activity, which can be regarded as long-term data. Therefore an application factor of 50 was used for the PNEC_{soil} derivation according to EU TGD, 2003, resulting in a PNEC_{soil} of 49.8 mg/kg.

In the absence of experimental sediment toxicity data, the PNEC_{sediment} of P-AA/MA calculation was derived by application of the equilibrium partitioning method as described in the EU TGD (EU, 2003). As described in chapter 4.2.1 the equilibrium partitioning method has some limitation on calculation of PNEC_{sediment} for polycarboxylates. However, results by equilibrium partitioning method were much more conservative in comparison to experimental data for P-AA (see chapter 4.2.1) For this approach a logK_{oc} was defined at -1 (see table 5.2) and was used in the EUSES calculation. This assumed value was justified due to the high water solubility of P-AA/MA. Therefore in accordance with the conservative frame of this risk assessment the PNEC_{sediment} for P-AA/MA was calculated as 3.15 mg/kg.

4.2.3 Derivation of PNEC

Short-term and long-term toxicity data exist for all three aquatic trophic levels, e.g. fish, daphnia and algae. In addition, in this updated HERA risk assessment version 2.0 supplementary recent data on terrestrial toxicity could be used for a refinement of the PNEC_{soil} derivation. Data and assessment factors used for the PNEC derivation are summarised in Table 16.

Table 16: Summary of the PNEC calculations of P-AA and P-AA/MA

PNEC for compartment	Substance type	Reference (No)Effect concentration	Application Factor	PNEC	
PNEC _{water} [mg/l]	P-AA P-AA/MA	NOEC = 12 mg/l NOEC = 37 mg/l	10 10	1.2 3.7	
PNEC _{sediment} [mg/kg dw]	P-AA P-AA/MA	EC0 = 4,500 mg/kg n.d.(EUSES calculation acc. to equilibrium partitioning method)	1,000 10	4.5 3.15	
PNEC _{soil} [mg/kg dw]	P-AA P-AA/MA	EC0 = 1,000 mg/kg EC10 = 2,490 mg/kg	1,000 50	1 49.8	
PNEC _{stp} [mg/l]	P-AA P-AA/MA	EC50 > 1,000 mg/l EC50 > 200 mg/l	100 100	10 2	

4.3. Environmental Risk Characterisation

In the following table 17 the Risk Characterisation Ratio (RCR) for the environmental compartments water, sediment, soil and STP is calculated from the PECs summarised in table 6-9 and the PNECs derived from table 16.

Table 17: Environmental Risk Characterisation Ratio RCR for P-AA and P-AA/MA

Risk Characterisation Water compartment		RCR
PEC _{regional, water} /PNEC _{water}	P-AA	0.078
	P-AA/MA	0.083
PEC _{local, water} /PNEC _{water}	P-AA	0.188
	P-AA/MA	0.101
Risk Characterisation Sediment compartment		
PEC _{regional, sed} /PNEC _{sed}	P-AA	0.016
	P-AA/MA	0.073
PEC _{local, sed} /PNEC _{sed}	P-AA	0.043
	P-AA/MA	0.101
Risk Characterisation Soil compartment		
PEC _{regional, soil} /PNEC _{soil}	P-AA	0.005
	P-AA/MA	0.004
PEC _{local, soil} /PNEC _{soil}	P-AA	0.358
	P-AA/MA	0.386
Risk Characterisation Sewage Treatment Plant		
PEC _{local, stp} /PNEC _{stp}	P-AA	0.132
	P-AA/MA	0.338

4.4 Discussion and Conclusions

The environmental risk assessments of P-AA and P-AA/MA were conducted according to the EU TGD (2003) employing the EU calculation model HERA and EUSES. The exposure calculations were based on two conservative assumptions: Firstly the use and consumption of polycarboxylate containing detergents is not evenly distributed in Europe. Therefore, the HERA exposure scenario was modified, taking into account a worst case assumption of release based on phosphate-free detergents as well as the highest laundry detergents consumption per capita. Secondly the elimination data obtained in STP model tests which were taken into account for the calculation were also based on worst case assumption.

Short-term and long-term toxicity data exist for all three aquatic trophic levels, e.g. fish, daphnia and algae. Recent studies showed that the water solubility of P-AA/MA depends strongly on the water hardness and the test concentration. The solubility and precipitation behaviour of P-AA/MA in presence of 2⁺-ions like ubiquitous calcium and magnesium ions has an important impact on the interpretation of the available chronic aquatic toxicity test results of P-AA/MA. It also explains the observed large variability with *Daphnia magna* in the range of NOEC 3.75 to 350 mg/L. P-AA/MA forms insoluble precipitation products at low concentrations. These insoluble products caused secondary mechanically based effects and were not considered in the risk assessment. Additionally current supplementary studies on higher plants and microbial activity allowed a refinement of the evaluation of the terrestrial compartment.

The present refined HERA risk assessment report does not indicate an environmental risk for all relevant compartments water, sediment, soil and sewage treatment plant (STP) displaying risk characterisation ratios (RCR) far below 1. The outcome of this present environmental risk provides a sound basis for the conclusion that the use of polycarboxylates in detergent products does not pose a risk to the environment.

5. HUMAN HEALTH ASSESSMENT

5.1 Consumer Exposure

Polycarboxylates are used in low-phosphate and phosphate-free detergents for avoiding incrustation and soil redeposition. Homopolymers are used mainly in automatic dishwashing detergents whereas their use in laundry detergents is of minor importance. Copolymers are used almost exclusively in laundry detergent powders and tablets as well as in automatic dishwashing detergents. Polycarboxylates are usually not contained in manual dishwashing detergents. Typical mean concentrations of polycarboxylates range between 0.5 % for P-AA and 3.0 % for P-AA/MA in laundry detergents.

See also 3.3.

5.1.1 Consumer Contact Scenarios

As relevant consumer contact scenarios, the following consumer exposure routes were identified and assessed:

- Direct skin contact from hand-washed laundry, direct skin contact via laundry/dishwashing tablets or powder
- Indirect skin contact via release from cloth fibres to skin
- Oral ingestion of residual amounts on dishes and eating utensils
- Oral ingestion of residues in drinking water
- Inhalation of detergent dust during washing processes
- Accidental or intentional overexposure

5.1.2 Consumer Exposure Estimates

There is a consolidated overview concerning habits and uses of detergents and surface cleaners in Western Europe issued by AISE, 2002. This list reflects the consumers' use of detergents in g/cup, tasks/week, duration of task and other uses of products and is relevant data for the calculation and reflection about consumer exposure in the following.

5.1.2.1 Direct skin contact via hand-washed laundry

P-AA und P-AA/MA under alkaline conditions are soluble depending on the molecular weight. The contact time with the polycarboxylates in the course of handwashing is, according to AISE, very short (approx. 10 min) and the percutaneous absorption of high molecular weight polymers will be very low to non-existent. Likewise uptake via the intact skin of ionic, low molecular weight substances has also been reported to be very low (Schaefer and Redelmeier, 1996). Thus, it can be assumed that the amount of polycarboxylates systemically available via percutaneous

absorption, if any, is very low. In the following calculations the worst case assumption has been made that 1% of the polycarboxylates are available for percutaneous absorption.

Additionally, the following worst case assumptions should adequately address this scenario:

- Concentration of laundry detergent in handwashing is approx. 1 % corresponding to 10 mg/ml (cm³).
- Highest concentration of P-AA in laundry detergents in handwashing amounts to 0.5% and for P-AA/MA 3%
- Contact of hands and forearms with laundry detergent solution would expose about 1980 cm² of skin (EU EU TGD 1996)
- Assuming a fluid film thickness of 100 µm (0.1 mm or 0.01 cm) (Vermeire, 1993) on the skin and, as a worst case assumption, a percutaneous absorption of 1% for polycarboxylates in 24 h exposure time, the following amount of polycarboxylates absorbed via skin can be calculated:

For P-AA:

1980 cm² x 0.01 cm/day x 0.01 (fraction absorbed) x 10 mg/ml (ml = cm³; 1% of detergent in washing fluid) x 0.005 (fraction of P-AA in detergent; 0.5%) = 0.0099 mg/day

0.0099 mg P-AA absorbed in 24 hours

In 15 min contact time a smaller amount of substance will be absorbed; for the sake of simplicity and as it can be assumed that the rate of percutaneous absorption is not linear in 24 hours and is possibly at its maximum in the first hour, 0.0099 mg is used in the assessment resulting in an estimated dose of (60 kg bw assumed):

$$\text{Exp}_{\text{sys}(\text{direct skin contact})} = 0.165 \mu\text{g}/\text{kg bw}/\text{day}$$

The same calculations for **P-AA/MA:**

1980 cm² x 0.01 cm/day x 0.01 (fraction absorbed) x 10 mg/ml (ml = cm³; 1% of detergent in washing fluid) x 0.03 (fraction of P-AA/MA in detergent; 3%) = 0.059 mg / day

0.059 mg P-AA/MA absorbed in 24 hours

$$\text{Exp}_{\text{sys}(\text{direct skin contact})} = 0.99 \mu\text{g}/\text{kg bw}/\text{day}$$

5.1.2.2 Direct skin contact from pre-treatment of laundry

Consumers typically spot-treat stains on the laundry by hand with the help of either a detergent paste (i.e. water/laundry powder = 1:1) or a concentrated laundry liquid which is applied directly to the garment. In this exposure scenario, at most the skin surface of both hands is exposed and the time for this task is typically shorter than ten minutes. The following parameters are considered to represent a worst case scenario for this application:

- Concentration of laundry detergent in hand washing is approx. 60 % .
- The potentially affected skin surface is 840 cm²
- Film thickness and absorption rate over one day with one task per day are the same as above

For **P-AA**:

$840 \text{ cm}^2 \times 0.01 \text{ cm/day} \times 0.01 \text{ (fraction absorbed)} \times 600 \text{ mg/ml (ml = cm}^3\text{; 60\% of detergent in washing fluid)} \times 0.005 \text{ (fraction of P-AA in detergent; 0.5\%)} = 0.25 \text{ mg/day}$

0.25 mg P-AA absorbed in 24 hours

In 10 min contact time a smaller amount of substance will be absorbed; for the sake of simplicity and as it can be assumed that the rate of percutaneous absorption is not linear in 24 hours and is possibly at its maximum in the first hour, 0.25 mg is used in the assessment resulting in an estimated dose of (60 kg bw assumed):

$$\text{Exp}_{\text{sys(direct skin contact)}} = 4.2 \text{ }\mu\text{g/kg bw/day}$$

The same calculations for **P-AA/MA**:

$840 \text{ cm}^2 \times 0.01 \text{ cm/day} \times 0.01 \text{ (fraction absorbed)} \times 600 \text{ mg/ml (ml = cm}^3\text{; 60\% of detergent in washing fluid)} \times 0.03 \text{ (fraction of P-AA/MA in detergent; 3\%)} = 1.5 \text{ mg / day}$

1.5 mg P-AA/MA absorbed in 24 hours

$$\text{Exp}_{\text{sys(direct skin contact)}} = 25 \text{ }\mu\text{g/kg bw/day}$$

5.1.2.3 Direct skin contact via laundry / dishwashing tablets or powder

Contact with laundry and dishwashing tablets occurs frequently when the tablets are unwrapped and placed into the washing or dishwashing machine. However, the contact time is very low (<1 min) and the area of contact with skin is so small (only the tips of thumb and index finger of one hand are exposed (approx. 2 cm^2 skin) that the amount taken up percutaneously is considered insignificant.

Some parts of the body, mainly the hand, might also come in contact with washing or dishwashing powder when transferring the product from the container into the machine or accidentally spilling some powder. Contact time during these scenarios is very low (<1 min), the skin area affected is small (usually much less than the area of one hand) and exposure occurs only occasionally and not regularly with product use. Thus, the systemic exposure of polycarboxylates resulting from this scenario is also considered to be negligible.

5.1.2.4 Indirect skin contact wearing clothes

Residues of components of laundry detergents may remain on textiles after washing and could come in contact with the skin via transfer from textile to skin. Polycarboxylates, despite their solubility in water, are deposited in solid form and thus as a first rough estimation, the small amount of polycarboxylates absorbed via this route should be insignificant.

The fact that only minor amounts of polycarboxylates could be percutaneously absorbed is demonstrated by the following calculation, assuming the worst case scenario:

$$\text{Exp}_{\text{sys}} = F_1 \times C' \times S_{\text{der}} \times n \times F_2 \times F_3 \times F_4 / \text{bw} \text{ [mg/kg bw/ day]}$$

F_1 = percentage (%) weight fraction of substance in product

C' = product load in [mg/cm²]

S_{der} = surface area of exposed skin in [cm²]

n = product use frequency in number [events/day]

F_2 = percentage (%) weight fraction transferred from medium to skin

F_3 = percentage (%) weight fraction remaining on skin

F_4 = percentage (%) weight fraction absorbed via skin

bw = body weight in [kg]

Determination of C' (“product applied to skin via fabric wash (hand, machine) and wear”)

$$C' = M \times F' \times \text{FD} / w_1 \text{ [mg/cm}^2\text{]}$$

M = amount of undiluted product used in [mg]

F' = percentage (%) weight fraction of substances deposited on fabric

FD = fabric density in [mg/cm²]

w_1 = total weight (of fabric per wash; 1 kg) in [mg]

According to these algorithms cited above, the following calculations were done:

Determination of C'

M 200,000 [mg] product/cup maximum

F' 5 (%) = 0.05 (worst case assumption!) Matthies et al. 1990

FD 10 [mg/cm²] Procter & Gamble, 1996

w_1 1 000,000 [mg] (estimated)

$$C' \text{ (P-AA) and } C' \text{ (P-AA/MA)} = 0.1 \text{ mg/cm}^2$$

Calculation for the systemic exposure:

F_1 0.5 % (P(AA)); 3% for P(AA-MA)

C' 0.1 [mg/cm²]

S_{der} 17,600 [cm²] 2003)

n 1 [event/day]

F_2 1 [%]= 0.01

F_3 100 [%]= 1 (worst case assumption)

F_4 1 [% bioavailability]= 0.01 (Schaefer et al. 1966; Worst Case for High Molecular Weight carboxylates; see section 5.1.3.1)

bw 60 [kg]

$\text{Exp}_{\text{sys}} \text{ (P-AA)} = 0.0147 \text{ } \mu\text{g/kg bw/day}$ $\text{Exp}_{\text{sys}} \text{ (P-AA/MA)} = 0.088 \text{ } \mu\text{g/kg bw/day}$
--

5.1.2.5 Oral ingestion of substance residues on dishes and eating utensils

Machine dishwashing powder and tablets contain up to 0.5 % of polyacrylates and 3 % of polycarboxylates. Thus, residual P-AA and P-AA/MA may remain on dishes and eating utensils after cleaning and may be ingested upon migration into food and drink. According to AISE (2002) the maximum amount of detergent used per wash is 50 g. A typical dishwashing programme consists of three to four wash-cycles using approximately 4.3 l water each. After each wash-cycle the washing liquor is pumped off and only 0.2-0.3 l remain (Bauknecht GmbH, 2002).

Based on the given data, the P-AA concentration is 58 mg/l (P-AA/MA: 349 mg/l) during the first cycle. In the remaining washing liquor after the pumping-off process, 17.4 mg P-AA (105 mg P-AA/MA) remain in the dishwashing machine. The P-AA concentration is decreased to 0.25 mg/l (P-AA/MA: 1.5 mg/l) assuming three wash-cycles during which 0.3 l is left after pumping-off of the washing liquor and 4.3 l of fresh water are added.

0.55 µl liquor remain on a surface of 1 cm² at the end of the wash process (O. J. France, 1990). Thus, a P-AA load of 0.14 x 10⁻⁶ mg/cm² (P-AA/MA: 0.82 x 10⁻⁶ mg/cm²) can be calculated. The systemic oral exposure can then be determined according to the following algorithm (HERA Guidance Document 2002):

$\text{Exp}_{\text{sys}}(\text{P-AA}) = F_1 \times C'_{\text{P-AA}} \times S \times F'' \times F_9 / \text{bw} = 1.2 * 10^{-2} \text{ µg/kg bw /day}$ $\text{Exp}_{\text{sys}}(\text{P-AAMA}) = F_1 \times C'_{\text{P-AA/MA}} \times S \times F'' \times F_9 / \text{bw} = 7.3 * 10^{-2} \text{ µg/kg bw/day}$

The terms are defined with the following values:

- F1** = (weight fraction of substance in product; not used, already included in C'_{P-AA} and C'_{P-AA/MA}, respectively)
- C'_{P-AA}** = 0.14 x 10⁻⁶ mg/cm² (substance load)
- C'_{P-AA/MA}** = 0.82 x 10⁻⁶ mg/cm² (substance load)
- S** = 5,400 cm² (surface area of dishes/eating utensils used per day, (O. J. France, 1990))
- F''** = 1 (weight fraction of substance transferred from article and ingested; it is assumed that all of the substance present on the article is transferred to food or drink and ingested)
- F9** = 1 (weight fraction absorbed)
- bw** = 60 kg

5.1.2.6 Inhalation of detergent dust during washing processes

Fabric washing powders are manufactured to rigorous specifications of particle size, enhanced by the exclusion of particles small enough to be inhaled into the lungs. Tests on fabric washing powders over many years have shown a very low level of dust in these products and, within the dust, the level of respirable particles is extremely low and therefore negligible. According to van de Plassche et al. (1999), studies indicate an average exposure of about 0.27 µg dust per cup of product used for machine laundering, of which up to

0.5% eq. 0.0014 µg/use is P-AA and
up to 3% eq. 0.008 µg/use is P-AA/MA.

For the estimated systemic dose (60 kg bw) can be calculated:

$$\begin{aligned} \text{Exp/use} &= 0.000023 \text{ } \mu\text{g/kg bw P-AA} \\ \text{Exp/use} &= 0.00014 \text{ } \mu\text{g/kg bw P-AA/MA} \end{aligned}$$

On average one use per day is estimated, therefore the values for the daily exposure apply.

5.1.2.7 Oral route via drinking water containing polycarboxylates

As detailed in Chapter 4.1.6 in Tables 5.1 and 5.2, an elimination of up to 10 % of P-AA and >90 % of P-AA/MA during the process of waste water treatment was estimated. Additional potential elimination during drinking water preparation was not accounted for. Therefore the values presented below are worst case assumptions based on the $C_{\text{local, water}}$ values according to TGD Part I, appendix III, Table 3. In the course of the HERA environmental risk assessment of polycarboxylates, a $C_{\text{local, water}}$ of 0.132 mg/l for P-AA and 0.068 mg/l for P-AA/MA was calculated (cf. Table 6) in drinking water under the (worst case) assumption that only surface water is used for processing. In this calculation the HERA and EUSES scenarios are identical. Taking into account the uptake of 2 l drinking water per day (WHO, 1996) the following doses can be calculated:

$$\begin{aligned} \text{Exp}_{\text{sys (oral route)}} (\text{P-AA}) &= 132 \text{ } \mu\text{g/l} \times 2 \text{ l/day} / 60 \text{ kg bw} \\ &= 4,4 \text{ } \mu\text{g/kg bw/day} \\ \text{Exp}_{\text{sys (oral route)}} (\text{P-AA/MA}) &= 68 \text{ } \mu\text{g/l} \times 2 \text{ l/day} / 60 \text{ kg bw} \\ &= 2,27 \text{ } \mu\text{g/kg bw/day} \end{aligned}$$

This is a worst case scenario with the assumption that only surface water contributes to drinking water.

5.1.2.8 Accidental or intentional overexposure

Accidental or intentional overexposure to polycarboxylates may occur via laundry detergents. As this product may contain up to 0.5% P-AA and 3 % P-AA/MA this source of exposure is marginal.

We know no fatal cases arising from oral uptake of polycarboxylates. The accidental or intentional overexposure to polycarboxylates directly is not considered a likely occurrence for consumers, but it may occur via laundry detergents. The German Federal Institute for Health Protection of Consumers and Veterinary Medicine (BgVV, 1999) recently published a report on products involved in poisoning cases. No fatal case of poisoning with detergents was reported in this publication. Detergent products were not mentioned as dangerous products with a high incidence of poisoning.

Equally, in the UK, the Department of Trade and Industry (DTI) produces an annual report of the home accident surveillance system (HASS). The data in this report summarizes the information recorded at accident and emergency (A&E) units at a sample of hospitals across the UK. It also includes death statistics produced by the Office for National Statistics for England and Wales. The figures for 1998 show that for the representative sample of hospitals surveyed, there were 33 reported accidents involving detergent washing powder (the national estimate being 644) with none of these resulting in fatalities (DTI, 1998). In 1996 and 1997, despite there being 43 and 50

cases, respectively, no fatalities were reported either.

5.1.2.9 Total Exposure

In the unlikely event of maximum worst case exposure from all sources the total exposure to polycarboxylates from their use in household cleaning products would be 37 µg/kg bw/day. The individual sources of exposure leading to the overall exposure are summarized in Table 18

Table 18: Worst case exposure estimates from different consumer contact scenarios

Task	Worst case exposure estimate [µg/kg bw/day]	
	P-AA	P-AA/MA
Direct skin contact via hand-washed laundry	0.165	0.99
Direct skin contact from pre-treatment of laundry	4.2	25
Indirect skin contact from wearing laundered clothes	0.0147	0.088
Inhalation of laundry powder dust	2.3×10^{-5}	1.4×10^{-4}
Indirect oral exposure from dish washing	1.2×10^{-2}	7.3×10^{-2}
Oral exposure from drinking water	4,4	2,27
Total exposure	8,8 µg/kg bw/day	28,3 µg/kg bw/day

5.2 Hazard Assessment

5.2.1 Summary of the available toxicological data

In the following data, reliability has been assigned according to the criteria defined by Klimisch et al. (1997), as outlined in the HERA Guidance Document (2002).

5.2.1.1 Acute Toxicity

5.2.1.1.1 Acute Oral Toxicity

Table 19: Summary table of the acute oral toxicity tests with homopolymers (P-AA)

Mean MW	Test species	Test Substance	LD ₅₀ [mg/kg bw]	Reliability	Reference
1,000	<i>Rat</i>	No data	LD ₅₀ > 5,000	2	Rohm & Haas, 1982
1,200	<i>Rat</i>	45% aq. solution	LD ₅₀ > 5,000	2	BASF, 1986 c

Mean MW	Test species	Test Substance	LD ₅₀ [mg/kg bw]	Reliability	Reference
2,500	<i>Rat</i>	45% aq. solution	LD ₅₀ > 5,000	2	BASF, 1986 d
3,500	<i>Rat</i>	10% aq. solution	LD ₅₀ > 1,000	2	Hicks et al., 1989
4,500	<i>Rat</i>	No data	LD ₅₀ >5,000	4	Freeman et al., 1993
8,000	<i>Rat</i>	45% aq. solution	LD ₅₀ > 5,000	2	BASF, 1986 e
15,000	<i>Rat</i>	undiluted	LD ₅₀ > 10,000	2	BASF 1978
70,000	<i>Rat</i>	40% aq. solution	LD ₅₀ > 10,000	2	BASF, 1976
78,000	<i>Rat</i>	No data	LD ₅₀ > 10,000	2	Degussa, 1983 a

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Studies reporting the acute oral toxicity of the homopolymers at the highest doses tested are summarised in table 19. Throughout the studies, the acute oral toxicity of the homopolymers with MW 1,000- 78,000 is very low.

In rats the reported LD₅₀ values range between 1000-10,000 mg/kg bw. The LD₅₀ of >1000 mg/kg bw is due to the attainable limit dose of a 10% aq. solution in this study (Hicks, 1989).

LD₅₀ rat for P-AA1,200; P-AA2,500; P-AA8,000 is > 5,000 mg/kg bw. Animals of both sexes showed sedation, curved body position and ruffled fur during the first 5 h after oral administration. All rats recovered within 2 days after dosing and survived until necropsy. No macroscopic organ changes were observed in 8 rats, whereas 2 rats showed dark-red mottled lungs in the study with P-AA2,500 and P-AA8,000 (BASF, 1986).

Table 20: Summary table of the acute oral toxicity tests with copolymers (P-AA/MA)

Mean MW	Test species	Test Substance	LD ₅₀ [mg/kg bw]	Reliability	Reference
50,000	<i>Rat</i>	undiluted	LD ₅₀ > 5,000	2	BASF, 1986
70,000	<i>Rat</i>	No data	LD ₅₀ > 5,000	2	BASF 1992

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Table 20 summarises the acute toxicity of the copolymers with molecular weight up to 70,000 which demonstrates the low acute oral toxicity. No deaths occurred within the 14-day observation period and neither clinical nor any gross pathological findings were recorded.

5.2.1.1.2 Acute Dermal Toxicity

Table 21: Summary table of the acute dermal toxicity tests with homopolymers (P-AA)

Mean MW	Test species	Test Substance	LD ₅₀ [mg/kg bw]	Reliability	Reference
1,000	<i>Rabbit</i>	undiluted	LD ₅₀ > 5,000	2	Rohm & Haas, 1982
4,500	<i>Rabbit</i>	undiluted	LD ₅₀ > 5,000	4	Freeman et al., 1993
4,500	<i>Rabbit</i>	undiluted	LD ₅₀ > 5,000	2	Rohm & Haas, 1982

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

The dermal LD₅₀ in 2 rabbits using an occluded patch protocol was > 5,000 mg/kg body weight. Well defined erythema without oedema was noticed on day 1 with recovery by the second day. No mortality did occur (Rohm & Haas, 1982). No deaths were reported in the study with P-AA1,000 (Rohm & Haas, 1982)

Acute dermal toxicity data are not available for P-AA/MA.

Conclusion

Homo- and copolymers with molecular weights ranging between 1,000 and 78,000 have a low acute oral toxicity. One study seemingly indicating a higher toxicity was tested as a 10% aqueous solution and therefore did not exceed an effective concentration of 1000 mg/kg bw as limit dose. The data on acute dermal toxicity also indicate low acute dermal toxicity to rabbits. Data on acute inhalation toxicity are not available.

5.2.1.2 Skin Irritation

Table 22: Summary table of the skin irritation data of homopolymers (P-AA)

Mean MW	Test species	Test Substance	Result	Reliability	Reference
1,000	<i>Rabbit</i>	undiluted	Not classifiable as irritating	2	Rohm & Haas, 1982
1,200	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 f
2,500	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 g
No data	<i>Rabbit</i>	15% aq. solution	Not classifiable as irritating	4	Finnegan, 1953
4,500	<i>Rabbit</i>	undiluted	Not classifiable as irritating	4	Freeman et al., 1993

Mean MW	Test species	Test Substance	Result	Reliability	Reference
4,500	<i>Rabbit</i>	undiluted	Not classifiable as irritating	2	Rohm & Haas, 1982
8,000	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 h
30,000	<i>Rabbit</i>	undiluted	Not classifiable as irritating	2	Rohm & Haas, 1988
70,000	<i>Rabbit</i>	40% aq. solution	Not classifiable as irritating	2	BASF, 1976
78,000	<i>Rabbit</i>	No data	Not classifiable as irritating	2	Degussa, 1983 b

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Several skin irritation studies on rabbits were investigated with P-AA of different molecular weights (1,000-78,000), concentrations between 15-45% or neat undiluted material.

Exposure was for 4 h -24 h with occlusive or semi-occlusive dressing. All studies show no skin irritation potential.

Three studies conducted in compliance with OECD Guideline 404 (4 h exposure, but occlusive dressing) with molecular weights of 1,200; 2,500; and 8,000, respectively, reflect the non-irritating potential. In all three studies the test substance was applied as a 45% solution to the intact skin (BASF, 1986 f; g; h).

Further studies with homopolymers of molecular weight 4,500; 70,000 and 78,000 were conducted neither in compliance with OECD Guideline 404 nor with GLP regulations, but they support indications of the non-irritating effect on skin.

Table 23: Summary table of skin irritation data of copolymers (P-AA/MA)

Mean MW	Test species	Test Substance	Result	Reliability	Reference
50,000	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 i
70,000	<i>Rabbit</i>	40% aq. solution	Not classifiable as irritating	2	BASF, 1982 a

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Two studies with P-AA/MA 50,000 and P-AA/MA 70,000, both performed according to OECD Guideline 404, showed no skin irritation (BASF 1986i, BASF 1982a). The test substances have been applied to the skin as a 45% aqueous solution. No erythema or oedema have been reported.

Conclusion

None of the homopolymers and copolymers tested either as undiluted neat substances or at very high concentrations has been reported to be irritating to the skin.

5.2.1.3 Eye Irritation

Table 24: Summary table of eye irritation data with homopolymers (P-AA)

Mean MW	Test species	Test Substance	Result	Reliability	Reference
No data	<i>Rabbit</i>	No data	irritating	4	Bottari, 1978
No data	<i>Rabbit</i>	No data	irritating	4	Finnegan, 1953
1,000	<i>Rabbit</i>	No data	Not classifiable as irritating	2	Rohm & Haas, 1982
2,500	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 k
1,200	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 j
4,500	<i>Rabbit</i>	undiluted	Not classifiable as irritating	2	Rohm & Haas, 1982
4,500	<i>Rabbit</i>	undiluted	Not classifiable as irritating	4	Freeman et al., 1993
8,000	<i>Rabbit</i>	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 l
70,000	<i>Rabbit</i>	40% aq. solution	Not classifiable as irritating	2	BASF, 1976
70,000	<i>Rabbit</i>	No data	Not classifiable as irritating	2	ECETOC, 1993
78,000	<i>Rabbit</i>	No data	Not classifiable as irritating	2	Degussa, 1983 c

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Three eye irritation studies with P-AA of molecular weight 1,200; 2,500 and 8,000, respectively, using a 45% aq. solution were conducted with rabbits according to OECD Guideline 405 (BASF 1986), but not according to GLP. The eyes were examined after 1, 24, 48 and 72 h after test substance administration. In studies with P-AA1,200 and P-AA2,500 all animals showed moderate to severe discharge within 1 h, which was completely reversible after 24 h. With the exception of one female animal treated with P-AA1,200 that still showed slight discharge 24 h after application, however, the symptoms were reversible 48 h after treatment. The test substance is classified as not irritating to the eye (BASF, 1986 j, k). Similarly, evidence of slight eye irritation was observed for P-AA4,500, which is based on the conjunctiva effects at 24 h with recovery after 72 h. P-AA8,000 with slight discharge in the first hour after application and recovery after 24 h indicates a non-irritant potential (BASF, 1986 l).

Two non-OECD protocol studies with P-AA of high molecular weight of 70,000 and 78,000 were also slightly irritant to the rabbits' eyes with recovery after 72 h and 24 h, respectively (ECETOC, 1993; Degussa 1983).

Table 25: Summary table of eye irritation data with copolymers (P-AA/MA)

Mean MW	Test species	Test Substance	Result	Reliability	Reference
50,000	Rabbit	45% aq. solution	Not classifiable as irritating	2	BASF, 1986 j
70,000	Rabbit	40% aq. solution	Not classifiable as irritating	2	BASF, 1982 b

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

A non-irritating effect has been observed in two studies performed according to standard OECD protocol, but not according to GLP. P-AA/MA50,000 and P-AA/MA70,000 have been applied in 40% and 45% aqueous solutions, respectively. In the case of P-AA/MA70,000 severe discharge and slight erythema have been noted (2/3), in the case of P-AA/MA50,000 only slight discharge has been reported (2/3). In both studies the effects were reversible after 24 h.

Conclusion

Homopolymers tested either as undiluted neat substances or at very high concentrations show a non- to slight irritation potential to the rabbit eye whereas, based on the given data, the copolymers have no irritating property at similar high substance concentrations tested.

5.2.1.4 Sensitisation

Table 26: Summary table of sensitisation data with homopolymers (P-AA)

Mean MW	Test species	Test Method	Result	Reliability	Reference
4,500	<i>Guinea pig</i>	Maximisation test	Not sensitising	2	Rohm & Haas, 1988
78,000	<i>Guinea pig</i>	Maximisation test	Not sensitising	4	Henkel, 1990

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

P-AA4,500 and P-AA78,000 have been demonstrated to be non-sensitisers in the Magnusson and Kligman Guinea Pig Maximisation test. A concentration of 5% P-AA4,500 has been used as induction and challenge dose (Rohm & Haas, 1988).

P-AA78,000 has been tested as a 0.1% aqueous solution (0.1 ml intra-dermal) as one of the induction doses and as a 20% aqueous solution (0.2 ml) as the occluded patch induction dose. This was applied for 48 h. After the appropriate period, all animals received a challenge dose of 0.2 ml of a 2.5% solution of the test compound as a single occluded patch administration for 24 h. No skin reactions were observed in the test group or in the control group (Henkel, 1990).

In both studies no reactions were observed.

Table 27: Summary table of sensitisation data with copolymers (P-AA/MA)

Mean MW	Test species	Test Method	Result	Reliability	Reference
70,000	<i>Guinea pig</i>	Maximisation test	not sensitising	2	Rohm & Haas, 1988
70,000	<i>Guinea pig</i>	Maximisation test	not sensitising	2	BASF, 1986 m

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

P-AA/MA70,000 was tested in the Magnusson and Kligman Guinea pig maximisation assay. I.d. induction was done with a 20% test substance preparation in aqua dest./Freund's adjuvans (1:1). Percutaneous induction was done with the neat test substance one week after i. d. Animals were exposed to about 0.3 g of the test substance. The duration of exposure was 48 h and readings were done about 48 h after the beginning of application. 1st and 2nd challenge were performed with 80% test substance in aqua dest. After i.d. induction with 0.1 ml of the test substance formulation, distinct erythema and oedema were observed at all injection sites of the test animals. Percutaneous induction led to incrustation, distinct erythema and oedema. Two separate challenge doses of 80% of the test substance formulation were applied and no sensitisation was observed. The challenges were given at day 19 and 26 following the induction phase (Rohm & Haas, 1988; BASF, 1986 m).

Conclusion:

Neither P-AA nor P-AA/MA showed a sensitising potential when tested in the GPMT as a low or high molecular weight polymer.

5.2.1.5 Repeated Dose Toxicity**Table 28: Summary table of the repeated dose toxicity tests with P-AA**

Molecular Weight	Test species	Duration	Route	Estimated NO(A)EL	Doses	Reliability	Reference
2,500	<i>Rat</i>	4 weeks	Oral feed	NOAEL = 1136 mg/kg bw/d	1136 mg/kg bw/d	2	Unilever 1993
4,500	<i>Rat</i>	91 days	Inhalation	NOEC _{lung} = 0.2 mg/m ³ NOEC _{syst.} = 5 mg/m ³	0.2, 1.0, 5.0 mg/m ³	2	Procter & Gamble, 1991
No data	<i>Rat</i>	4 weeks	Inhalation	NOAEC = 4 mg/m ³ LOAEC = 21 mg/m ³	1.75, 4, 21 mg/m ³	4	Tansy, 1988
No data	<i>Rat</i>	4-13 weeks	Inhalation	NOAEC = 14 mg/m ³ LOAEC = 56 mg/m ³	14, 56, 134, or 275 mg/m ³	4	Baldwin, 1986

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Table 29: Summary table of the repeated dose toxicity tests with P-AA/MA

Molecular Weight	Test species	Duration	Route	Estimated NO(A)EL	Doses	Reliability	Reference
70,000	<i>Rat</i>	90 days	Oral drinking water	NOAEL > 16,000 ppm	1,000; 4,000; 16,000 ppm	2	BASF, 1987 f
70,000	<i>Rabbit</i>	28 days	dermal	NOEL = 2000 mg/kg bw/d	2000 mg/kg bw/d	2	BASF, 1983
70,000	<i>Rat</i>	91 days	Inhalation	NOEC _{lung} = 1 mg/m ³ NOEC _{syst.} = 5 mg/m ³	0.2, 1.0 and 5.0 mg/m ³	2	Procter & Gamble, 1991

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

5.2.1.5.1 Inhalation route

P-AA4,500 and P-AA/MA70,000 have been tested separately in a 91 d inhalation study. The studies were conducted in compliance with the guidelines for the EPA's Toxic Substances Control Act and in compliance with the EPA GLP Regulations (40CR, Part 792). 25 male and 25 female rats were exposed to 0.2, 1.0 and 5.0 mg/m³ of each polymer for 6h/d, 5 d/wk for 13 weeks. The substance was administered as a dust aerosol. Ten animals/group were allowed to recover for a period of a further 91 days. Body and organ weights, food and water consumption, clinical observation and blood chemistry were all within the normal range. Histopathology of lung tissues from the animals necropsied after the last exposure revealed signs of mild pulmonary irritation based on at least one of the following local lung effects: increase in polymorphonuclear granulocytes or alveolar macrophages, pneumocyte hyperplasia, alveolar wall thickening and focal alveolitis in the animals exposed to 1 and 5 mg/m³ of P-AA4,500 and to 5 mg/m³ P-AA/MA70,000. Histopathological examination of the animals in the recovery group showed no lasting or residual microscopic lesions, which could be considered treatment-related. From these studies it was concluded that the NOEC is 1 mg/m³ for respirable dust of P-AA/MA70,000 and 0.2 mg/m³ P-AA4,500 for local lung effects typical of insoluble respirable polymer dust (Procter & Gamble, 1991) whereas the NOEC for systemic effects was above 5 mg/m³ with both substances.

Supporting data on local lung effects with respirable dust of P-AA with unknown molecular weight are reported. The only evidence of toxicity in rats exposed to powdered P-AA at atmospheric concentrations of 1.75, 4 or 21 mg/m³ for 6 h/d, 5 days/wk for 4 weeks, was a reversible effect on lung function in the top-dose females. Growth, organ weights and blood biochemistry were all normal, and microscopic examination of the tissues of the lungs, livers, kidneys, reproductive organs and blood system revealed no abnormalities (Tansy, 1988).

Rats exposed for 6 h/d, 5 days/wk, for 4 or 13 weeks to a test substance described as "non-ionic acrylic polymer dust" at concentrations of 14, 56, 134 or 275 mg/m³ developed cellular changes in the lungs and increased lung weights at 56 mg/m³ and at the higher concentrations. The investigators concluded that the responses were those expected from the inhalation of an excessive amount of an insoluble respirable dust (Baldwin, 1986).

5.2.1.5.2 Oral route

P-AA2,500 has been tested in a Non-Guideline study with substance application via oral feed for 28 days to examine the effect of the test substance on mineral homeostasis (Unilever, 1993). Six male rats were fed 2.5% of the test substance in the diet (about 1136 mg/kg bw/d). Growth, weight and appearance of the animals were normal throughout the study. In the last week, a small but significant decrease in the total weight of bone minerals was detected and confirmed by radiographic and histological examination. The concentration of magnesium in the bones and the plasma of the treated animals was significantly decreased. Calcium loss was slight and not statistically significant. Urinary excretion of sodium and phosphorus was markedly increased. Excretion of calcium was slightly increased. The result was interpreted by the authors to be due to a metabolic or nutritional imbalance rather than to a systemic toxicity. The excretion of sodium might have been increased by the high uptake of the sodium-neutralized test substance. The applied dose was therefore interpreted as a NOAEL.

P-AA/MA70,000 has been tested according to OECD Guideline 408 under GLP conditions. The test substance was administered to 10 male and 10 female Wistar rats for 90 d in drinking water at dose levels of 1,000; 4,000 and 16,000 ppm, the top dose being equivalent to 1,871 mg/kg bw/day for male rats and 2,216 mg/kg bw/day for female rats. At the beginning of the study the low-dose males consumed about 119 mg/kg bw/d and the mid-dose males about 445 mg/kg bw/d. The females with the low dose showed a substance intake of about 126 mg/kg bw/d and those with the mid dose about 499 mg/kg bw/d. Ophthalmoscopic investigations were performed on control and high-dose animals prior to and at the end of test substance administration. Clinical chemistry and

urinalysis were performed in week 6 of the study and at the end. Furthermore, macroscopic and histopathological examinations were conducted. With the exception of increased water consumption in both sexes (more pronounced in the females) of the high-dose group, no other test substance related findings were reported. Especially, no adverse effects to the gonads were reported.

The NOAEL determined in this study was 16,000 ppm, which is equivalent to 1,871 mg/kg bw/d for male rats and 2,216 mg/kg bw/d for female rats (BASF, 1987 f).

5.2.1.5.3 Dermal route

P-AA/MA70,000 has been examined in a 28-day rabbit dermal study. Groups of 15 male and 15 female rabbits received 10, 25 and 50% aq. solutions of the test material at a dosage of 2 g/kg bw on to shaved and abraded skin (open application). For comparison, a group of 5 animals per sex was used as control and treated with aqua dest. All test sites were washed with lukewarm water approx. 7 h after treatment and gently dried with disposable paper towels. Examinations of the body weight, for clinical signs and skin irritation as well as haematological, gross pathological and histopathological examinations were carried out. The concentrations selected for the present investigation were determined in a pre-test with 16 rabbits, which received the neat test substance, 50, 25, 10, 5, 2.5 and 1% aqueous solutions of the test substance applied topically on the shaved and abraded skin 5d/wk for two weeks. At the beginning of the test substance application mean weights of the rabbits were 2.68 kg for male and 2.78 kg for female animals. Statistical evaluation of the data was performed.

In all high-concentration animals slight erythema was seen commencing in the third week and persisting until the end of the study. No effects on the skin were observed in the low concentration group animals and in the control animals. There were no changes in the remaining investigated parameters of the treatment groups when compared with the concurrent control animals. The minimum slightly irritant concentration was 25%. In the 50% concentration group the irritation was also reported to be slight. In view of the test substance to the abraded skin and taking into account that the treatment was repeated work daily for 4 weeks, the observation of slight skin irritation is in accord with the study results obtained for short term skin irritation (BASF, 1983).

The NOAEL for systemic toxicity upon short term repeat dose dermal exposure to the abraded skin was 2,000 mg/kg bw/d.

For repeat dose dermal exposure no data are available for homopolymers.

Conclusion:

Table 30

Test Substance	Duration	Route of Exposure	Species	NOAE(L)C _s <small>yst</small>	NOAE(L)C _{local}
P-AA2,500	4 wks	Oral feed	Rat	1,136 mg/kg bw/d	
P-AA/MA70,000	13 wks	Oral drinking water	Rat	1,871-2,216 mg/kg bw/d	
P-AA/MA70,000	4 wks	Dermal (abraded skin)	Rabbit	2,000 mg/kg bw/d (limit dose)	
P-AA4,500	13 wks	Inhalation	Rat	5 mg/m ³	0.2 mg/m ³
P-AA/MA70,000	13 wks	Inhalation	Rat	5 mg/m ³	1 mg/m ³

As the acute oral and dermal toxicities of P-AA/MA are of similar magnitude and this observation is corroborated by the similar toxicities upon repeated exposure, the similar acute oral and dermal toxicities of P-AA are suggestive that, for an approximate risk assessment, the repeat dose oral toxicity of P-AA can serve as a substitute – even as a worst case – for a potential dermal toxicity of P-AA upon repeated exposure.

5.2.1.6 Genotoxicity

5.2.1.6.1 In vitro

Table 31: Summary table of the genotoxicity *in vitro* of P-AA

Mean MW	Test system	Test Substance	Metabolic Activation	Result	Reliability	Reference
1,500-2,500	Cytogenetic Assay	No further data	No further data	positive ¹	4	Medvedev A. I., 1980
2,000	Ames	54% aq. solution	With and without	negative	2	Thompson, 1989
2,000	Mouse Lymphoma Assay	54% aq. solution	With and without	negative	2	Thompson, 1989
2,000	Unscheduled DNA synthesis	54% aq. solution	Without	negative	2	Thompson, 1989
4,500	Ames	48% aq. solution	With and without	negative	2	Thompson, 1989

¹ Due to inadequate data reporting this result is not assignable with respect to its reliability

Mean MW	Test system	Test Substance	Metabolic Activation	Result	Reliability	Reference
4,500	Mouse Lymphoma Assay	48% aq. solution	With and without	negative	2	Thompson, 1989
4,500	Unscheduled DNA synthesis	48% aq. solution	Without	negative	2	Thompson, 1989
4,500	Cytogenetic assay (CHO)	48% aq. solution	With and without	negative	2	Thompson, 1989
4,500	Ames	No data	No data	negative ¹	4	Freeman et al., 1993
4,500	Mammalian cell gene mutation assay	No data	No data	negative ¹	4	Freeman et al., 1993
4,500	Unscheduled DNA synthesis	No data	No data	negative ¹	4	Freeman et al., 1993

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Table 32: Summary table of the genotoxicity *in vitro* of P-AA/MA

Mean MW	Test system	Test Substance	Metabolic Activation	Result	Reliability	Reference
12,000	Ames Test	45% aq. solution	With and without	negative	2	Thompson, 1983
12,000	Mouse lymphoma assay	45% aq. solution	With and without	negative	2	Thompson, 1983
12,000	Cytogenetic Assay (CHO)	45% aq. solution	With and without	negative	2	Thompson, 1983
12,000	Unscheduled DNA synthesis	45% aq. solution	Without	negative	2	Thompson, 1983
70,000	Ames Test	No data	With and without	negative	2	BASF, 1984
70,000	Cytogenetic Assay (CHO)	No data	With and without	negative	2	BASF, 1985
70,000	Unscheduled DNA synthesis	No data	Without	negative	2	BASF, 1984

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Ames Tests

The results obtained in studies with adequate validity do not suggest a genotoxic potential of the polymers tested.

Chromosome aberrations in cultured mammalian cells

Preliminary range finding cytotoxicity tests were performed to determine the effect of the test material on cell survival. In an HGPRT assay with Chinese hamster ovary (CHO) cells the test substance (P-AA/MA65,000) was applied to the cells at 0, 1.0, 4.64, 6.81, 10.0, 21.5 and 46.4 mg/ml with and without metabolic activation. Toxicity to CHO cells was observed at approximately 10 mg/ml in the absence of S-9 mix and > 46.6 mg/ml in the presence of S-9 mix. An increase of mutants at certain toxic dose levels was observed, but this was not clearly dose related and was considered due to other effects, e. g. calcium chelation, cytotoxicity and precipitation out of solution of the test substance (BASF, 1985) .

Neutralised test substances of aqueous solutions containing 45-54% P-AA2,000 and P-AA/MA12,000 have been tested for clastogenic activity using CHO cells. Cells were treated for 4 h in the presence and absence of S9 mix followed by 16 hrs in compound medium free of test substance. Both test substances were tested at concentrations up to 77 µl/ml in the presence and absence of S9 mix. Single cultures were used. No increases in chromosome aberrations were detected with either substance. More pronounced toxicity was observed at higher concentrations with the copolymer than with P-AA4,500 (Thompson et al., 1989).

Unscheduled DNA Synthesis

Neutralised test substances of aqueous solutions containing 45-54% P-AA2,000, P-AA4,500 and P-AA/MA12,000 have been tested for induction of UDS (Unscheduled DNA Synthesis) in primary rat hepatocytes following the methods described by Williams et al. (1977). P-AA2,000 was tested to a maximum concentration of 5 µl/ml, P(AA)4500 to a maximum of 20 µl/ml and P-AA/MA12,000 to a maximum of 4 µl/ml. All 3 test substances showed appreciable toxicity at the highest concentrations tested. No evidence of UDS was observed (Thompson et al, 1989).

Under GLP conditions, a study with P-AA/MA70,000 did not induce significant changes in the nuclear labelling of primary rat hepatocytes for the concentration range 25 to 5,000 µg/ml (0.025 - 5.0 -µl/ml). 8 treatments in this range resulted in a cell survival range of 102% to 73.8 %. Treatment with 10,000 µg/ml (10µl/ml) was excessively toxic (BASF, 1984) .

Conclusion *in-vitro*:

Tests performed to determine the potential of these polymers to induce DNA damage *in-vitro* (Ames test and Induction of Unscheduled DNA Synthesis) were negative.

Similarly, a negative result was obtained when testing for the potential to induce chromosomal aberrations *in-vitro*.

5.2.1.6.2 *In vivo*

Micronucleus assay

P-AA2,000 has been tested in a mouse micronucleus assay using groups of 5 male and 5 female mice. The test substance or sterile distilled water (control vehicle) was administered by gavage at a volume of 20 ml/kg. Animals were dosed by gavage with the maximum tolerated dose (13,850 mg/kg bw) and observed over a 3-day period. Positive control animals were *i.p.* injected with mitomycin C that was prepared in sterile 0.9% saline at a concentration of 0.2 mg/ml. Animals were killed at 24, 48 and 72 h after dosing, bone marrow cells were harvested and 1,000 cells per

animal were examined for micronuclei in polychromatic erythrocytes and also for the ratio for polychromatic to normochromatic erythrocytes. During the experiment 3 female mice died, 1 at each of the harvest times. Clinical signs of piloerection, hunched posture and lethargy were observed following dosing.

No increase in micronucleus induction was observed in the groups administered the test substance at any of the harvest times, when compared with the controls.(Thompson et al., 1989)

Cytogenetic Assay

P-AA/MA70,000 has been tested for chromosome aberrations in the bone marrow of male and female Chinese hamsters following a single i.p. injection of 200; 600 and 1,780 mg/kg bw. The doses were applied in a volume of 10 ml/ kg bw.

For control purposes, a solvent control group and a positive control group (cyclophosphamide) were used. 20 animals (10 animals of each sex) were used for the solvent control, 10 animals (5 of each sex) for the positive control and the low- and mid-dose groups, respectively, and 30 animals (15 of each sex) for the high dose group . High-dose animals were killed and bone marrow was examined at 6, 24 and 48 h after dosing (10 animals at each time point). The animals (10 per group, 5 of each sex) from the other two dose groups and the solvent and positive control groups were killed 24 h after dosing.

No increase in aberrant metaphases and no significant differences in the types and frequency of aberrations between the dose groups and the solvent control group were observed. No chromosome-damaging effects were seen under the present study conditions (BASF, 1985a).

Conclusion *in-vivo*:

The negative test results obtained *in-vitro* for induction of DNA damage and chromosomal aberrations were corroborated with two tests for chromosomal aberrations *in-vivo*. As no positive *in-vitro* evidence for a DNA damaging potential exists no further testing for induction of DNA damage *in-vivo* was performed.

5.2.1.7 Carcinogenicity

No studies on carcinogenicity are available for these substance classes. P-AA and P-AA/MA are, however, devoid of any genotoxic potential *in-vitro* and *in-vivo*. Apart from some indication of cellular pneumocyte hyperplasia in a 90 d inhalation study of P-AA/MA, these polymers did not show other cellular hyperplasias upon other routes of exposure. As acrylic homo- and copolymers for detergent applications are manufactured to rigorous specification of particle size and exclusion of inhalable particles and as no long high dose inhalative exposure is anticipated from handling and use patterns in detergent application, especially in the absence of spray applications, a carcinogenic risk appears to be negligible.

Furthermore, the monomers are devoid of alerting groups for a genotoxic or carcinogenic potential.

5.2.1.8 Reproduction, Embryotoxicity, Developmental Toxicity

Table 33: Summary table of developmental toxicity data for P-AA

Mean MW	Test Species	Route	Test Substance	Doses [mg/kg]	NO(A)EL (mg/kg)	Reliability	Reference
4,500	<i>Rat</i>	Gavage	43.3 % aq. solution	500 ; 1,000 ; 3,000	M: >= 3,000 T: >= 3,000	2	Nolen, 1989
90,000	<i>Rat</i>	Gavage	77.5 % aq. solution	125; 375; 1,125	M: >= 375 T: >= 1,125	2	Nolen, 1989

M= Maternal toxicity, T= Teratogenicity

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

Table 34: Summary table of developmental toxicity data for P-AA/MA

Mean MW	Test Species	Route	Test Substance	Doses [mg/kg]	NOAEL (mg/kg)	Reliability	Reference
12,000	<i>Rat</i>	Gavage	44.9 % aq. solution	67 ; 667 ; 6,670	M: >= 6,670 T: >= 6,670	2	Nolen, 1989

M= Maternal toxicity, T= Teratogenicity

MW Molecular Weight (g/mol)

Reliability criteria of IUCLID acc. to Klimisch et al. (1997) are used:

1 valid without restriction 2 valid with restriction 3 not valid 4 validity is not assignable

P-AA4,500 was tested in a rat developmental toxicity study in which the compound was administered by gavage on day 6-15 of pregnancy at dose levels of 500; 1,000; and 3,000 mg/kg bw/day. No treatment related effects on foetal development or on pregnancy were noted. There were no significant differences in the body weight changes or feed intakes during pregnancy, the rats treated with 3,000 mg/kg of the test substance had soft or liquid stools during the treatment period. The NOEL was 3,000 mg/kg bw/day (Nolen, 1989).

P-AA90,000 was administered during the period of organogenesis. Groups of 28 or 29 rats were administered the test substance (77.5% aq. solution) at dose levels of 125; 375 and 1,125 mg/kg/d or vehicle (distilled water) by gavage. An additional group served as untreated control group. Conception was considered day 0 of pregnancy. 8 females/group were treated from day 6 to 13 of gestation and were killed on day 13 of gestation; the remaining animals in each group were sacrificed on day 19. Two-thirds of the foetuses were examined for visceral findings by the Wilson (1965) method and one-third was cleared and stained for skeletal examinations according to Dawson (1926). One mid-dose dam and 6 high dose dams died during the study, however four of these deaths were due to a technical error (malintubation), while 3 high-dose deaths were interpreted to be treatment-related. No data have been reported, however, as to significant pathological or clinical findings in these animals. No statistically significant differences were seen in maternal body weights, body weight gains or overall food intake. The only substance-related effect was a transient decrease in food consumption in high-dose dams during days 7-9 of

gestation. The test substance administration had no effect on embryo or foetal viability. Examination of the fetuses revealed no significant embryotoxic effects or differences in the incidence of soft-tissue and/or skeletal abnormalities between treated and control groups. The NOEL for maternal toxicity was 375 mg/kg bw/d and that for developmental toxicity was 1,125 mg/kg bw (Nolen, 1989).

P-AA/MA12,000 was administered to four groups of 25 female rats each by gavage at dose levels of 67; 667 and 6,670 mg/kg bw/day during days 6-15 of gestation. On day 20 of gestation the dams were killed. One half of each litter was examined for visceral findings by the Wilson (1965) method and the other half by the Dawson (1926) method for skeletal findings. Conception was considered day 0. There were no deaths in the high-dose group but in the low-dose group there were 8 malformed fetuses all from 1 litter and all with short thickened bodies with numerous malformations. Animals from the other 23 litters in this test group showed no developmental toxic effects (no foetotoxicity and no teratogenicity). This singular finding was therefore considered to be incidental and not to be treatment-related. All other findings with respect to malformations or variations were scattered randomly throughout the groups with no pattern or increased incidence. Therefore the NOEL for maternal toxicity and developmental toxicity was determined to be 6,670 mg/kg bw/d (Nolen, 1989).

Conclusion

None of the P-AAs or P-AA/MA tested showed developmental toxicity or embryotoxic effects in rats.

In a ninety days repeat dose study with substance application via drinking water no effects on the reproductive organs of the test animals were reported for P-AA/MA.

From these observation a reprotoxic potential of the two polymer classes appears negligible.

5.2.1.9 Additional Endpoints

No data on toxicokinetics are available.

5.2.2 Critical Endpoints

5.2.2.1 Overview on hazard identification

Polyacrylates and polyacrylates/polycarboxylates are of low acute oral toxicity. No mortalities were seen even when testing to the highest attainable doses. Typically the LD50 values in rats are above 5,000 to 10,000 mg/kg bw for molecular weights ranging from 1,000 to 78,000 g/mol.

The acute dermal toxicity determined for polyacrylates in the rabbit was likewise very low with an LD50 of > 5,000 mg/kg bw for substances with a molecular weight of 1,000 to 4,500. Data for acute dermal toxicity for polyacrylates/polycarboxylates are not available.

Due to the typical high molecular weights of P-AA and P-AA/MA it can be safely assumed, however, that percutaneous penetration is very low to non-existent so that low dermal toxicity can be expected also for other species and for the polycarboxylates (P-AA/MA).

The results obtained for a P-AA/MA70,000 with a 4 weeks repeat dose exposure to the abraded skin of rabbits at 2,000 mg/kg bw/d which did not show any signs of systemic toxicity support this argument.

Data on acute inhalative toxicity are not available. In the absence of any spray application products with P-AA and P-AA/MA, inhalative exposure with these products is confined to the handling of fabric washing powders which have a very low level of respirable dust particles due to

rigorous product specification (see chapter 5.1.3.5). Hence, no human health issues are to be expected.

Skin irritation studies in rabbits with P-AA and P-AA/MA, respectively, in the molecular weight range from 1,000 to 78,000 at high concentrations have shown that these substances are essentially not irritating.

Eye irritation studies in rabbits have revealed, at most, slight irritation which, however, was reversible within the observation period. Therefore the effects were assessed as being not classifiable as irritating.

P-AA and P-AA/MA have been demonstrated to be not skin sensitising on the basis of several independent studies performed with P-AA4,500, P-AA78,000 and with P-AA/MA70,000 in the guinea pig maximization test (GPMT).

Two P-AA with molecular weight of 2,500 and 4,500 and two P-AA/MA of 70,000 molecular weight have been tested in repeat dose studies via oral feed, drinking water and inhalation as dust aerosols. Exposure times were from 4 – 13 weeks.

Oral exposure of rats via feed of P-AA2,500 in a non-guideline study led to a NOAEL of about 1136 mg/kg bw/day. In this study an increased excretion of bone minerals (Magnesium, phosphorus, some Calcium) was observed and interpreted as metabolic or nutritional imbalance. In view of the proven metal ion binding capacity of P-AA and P-AA/MA this result comes not unexpected. It can, however, be interpreted as a unrealistic high dose exposure scenario.

In a subchronic drinking water study in rats, performed according to the OECD test guideline 408. Apart from an increase of water consumption in the high dose group, no other test substance related effects were identified. The NOAEL identified in this study was approx. 2,000 mg/kg bw/d for both genders.

In a 28 d non-guideline study in rabbits with substance application to the abraded skin of rabbits, a systemic NOEL of 2,000 mg/kg bw/ d was determined.

All three studies confirm a low repeat dose toxicity by the oral and dermal route.

P-AA and P-AA/MA of molecular weight between 2,500 and 70,000 tested by inhalative exposure for 4 to 13 weeks with dust aerosols have shown some local effects in the lung which can be attributed, however, to the typical nuisance dust effects observed which are also observed with other inert respirable dusts. Available data show that these effects have been reversible in the post exposure period.

Systemic toxicity in these studies was not observed up to the maximal concentration of 5 mg/m³ tested in these studies.

P-AA and P-AA/MA are not considered to be mutagenic or genotoxic. They do not possess structural elements alerting to genotoxicity and carcinogenicity. A number of studies have been performed in-vitro in the Ames test and with mammalian cell cultures and in-vivo and have excluded the potential to induce DNA damage and chromosomal aberrations.

Though there are no carcinogenicity studies available there are no alerts which would lead to suspect a carcinogenic potential.

P-AA and P-AA/MA with molecular weights of 4,500 to 90,000 have been tested for developmental toxicity in rats. No significant embryotoxicity or developmental toxicity were

detected in these studies. Furthermore, in a subchronic oral study in rats no substance related impairment of the reproductive organs was detected. Therefore, though results on guideline compliant reprotoxicity studies are not available reprotoxic effects are not expected for these two polymer classes.

5.2.2.2 Rationale for identification of critical endpoints

Dermal exposure is the main exposure route for consumers and subsequently, dermal effects such as skin irritation and sensitisation as well as long term dermal toxicity must be considered for the human health risk assessment. Pertinent data are available addressing skin irritation and skin sensitisation potential of P-AA and P-AA/MA containing consumer product formulations. As high molecular weight polymers these substances are expected to have a low to non-existing potential to penetrate the intact skin to become systemically available. The available oral studies involving repeated exposures have shown a similar toxicity profile as compared to dermal exposure and therefore can be used to assess potential human exposure via the dermal route.

5.3 Risk Assessment

5.3.1 Margin of Exposure Calculation

The Margin Of Exposure (MOE) is the ratio of the No Observed Adverse Effect Level (NOAEL) or an appropriate substitute (e.g. NOEL) to the estimated or actual level of human exposure to a substance. For P-AA, a NOAEL of 1136 mg/kg bw/day from a 28-d oral feed study (Unilever 1993) was determined in rats. For P-AA/MA a NOEL of 2000 mg/kg bw/d for dermal exposure during 28 days has been shown in rabbits (BASF 1983) and a NOAEL of 1,871 to 2,216 mg/kg bw/day has been determined on the basis of a 90 d oral drinking water study in rats (BASF, 1987f).

NO(A)ELs for MOE Calculations:

- NOAEL rat, oral feed, 28 d study: **1,136 mg/kg bw/d for P-AA**
- NOEL rabbit, dermal, 28 d study: **2,000 mg/kg bw/d for P-AA/MA**
- NOAEL rat, oral drinking water, 90 d study: **1,871 mg/kg bw/d for P-AA/MA**

5.3.1.1 Exposure scenario: direct skin contact by hand-washed laundry

For calculation of the MOE for P-AA/, the NOEL of **1,136** mg/ kg bw/d from the 28 day rat oral feed study was divided by the daily systemic dose of 4.4 µg/kg bw/d, taking into account an aggregate worst case scenario of skin contact with laundry detergent, including garment manual pretreatment (cf. section 5.1.3.1 & 5.1.3.2).

A similar calculation for P-AA/MA was performed taking the 28 day repeat dose dermal study in rabbits as a substitute.

P-AA:

$$\text{MOE}_{\text{direct skin hand-washed laundry}} = 1136,000/4.4 = 2.5 \times 10^5$$

P-AA/MA:

$$\text{MOE}_{\text{direct skin hand-washed laundry}} = 2000,000/26 = 7.7 \times 10^4$$

5.3.1.2 Exposure scenario: indirect skin contact wearing clothes

For calculation of the MOE for P-AA, the NOAEL of 1,136 mg/ kg bw/d from the 28 day rat oral feed study was taken as a worst case substitute and divided by the daily systemic dose of 0,0147 µg/kg bw/d.

A similar calculation for P-AA/MA was performed taking the NOEL from the 28 d repeat dose dermal exposure in rabbits. The daily systemic dose of 0.088 µg/kg bw/d was used.

P-AA:

$$\text{MOE}_{\text{indirect skin contact wearing clothes}} = 1136,000/0.0147 = 7.7 \times 10^7$$

P-AA/MA:

$$\text{MOE}_{\text{indirect skin contact wearing clothes}} = 2000,000/0.088 = 2.2 \times 10^7$$

5.3.1.3 Exposure scenario: oral route from residues on dishes and eating utensils

For calculation of the MOE, the NOAEL of 1,136 and 1,871 mg/ kg bw/ day of PAA and PAA-MA, respectively, were divided by the daily systemic dose of 1.2×10^{-2} and 7.3×10^{-2} µg/kg bw/ day, respectively (cf. section 5.1.3.5) .

P-AA: MOE oral route from residues on dishes and eating utensils
= 1136,000/0.012 = **9.5×10^7**

P-AA/MA: MOE oral route from residues on dishes and eating utensils
= 1,871,000 /0.073 = **2.6×10^7**

5.3.1.4 Exposure scenario: oral route via drinking water containing P-AA or P-AA/MA

For calculation of the MOE, the NOEL of 1136 mg/ kg bw/ day was divided by the daily systemic dose of 4.4 µg/kg bw/ day for the uptake of P-AA from drinking water. Accordingly, the MOE for P-AA/MA is the NOAEL of 1,871 mg/ kg bw/ day divided by the daily systemic dose of 2.27 µg/kg.

$$\text{P-AA: MOE}_{\text{oral route via drinking water}} = 1,136,000/4.4 = 2.5 \times 10^5$$

$$\text{P-AA/MA: MOE}_{\text{oral route via drinking water}} = 1,871,000/2.27 = 8.2 \times 10^5$$

5.3.1.5 Exposure scenario: inhalation of dust during washing process

The systemic dose of P-AA and P-AA/MA via inhalation of detergent dust during the washing process was estimated to amount to 2.3×10^{-5} µg/ kg bw/ day for P-AA and 1.4×10^{-4} µg/ kg bw/ day for P-AA/MA.

In rats the adverse effect after repeated inhalation dosing (91-d/rat) was a mild, reversible pulmonary irritation. This effect was considered as not substance-related owing to the physical property of the respirable dust, which caused local and not systemic lung effects. Nevertheless, in a worst case scenario, the NOECs of 0.2 mg/m³ for P-AA and 1.0 mg/m³ for P-AA/MA are taken forward into a Margin of Exposure calculation under the assumption of a ten percent deposition into the lung and a 100% absorption of the deposited material.

For P-AA a daily exposure to the NOEC of 0.2 mg/m³ would lead to a hypothetical systemic dose of 0.2 [NOEC; mg/m³] x 10⁻³ [Conversion m³ to Litre] x 0.2 [Litre/min; Respiratory Minute Volume] x 60 [min] x 6 [hours/d; exposure duration per day] x 0.1 [10% deposition in the lung] / 0.3 [kg bw; rat] = 0.0048 mg / kg bw/ day (basic data according to Snipes et al, 1989). For the calculation of the MOE this value is divided by the estimated daily consumer exposure to laundry detergent dust (cf. section 5.1.3.6).

For P-AA/MA the NOEC of 1 mg/m³ would be equivalent to a hypothetical systemic dose of 0.024 mg/ kg bw/ day based upon the same calculation but based upon a higher NOEC. Under these assumptions the resulting MOEs for inhalative exposure are calculated as follows:

$$\text{P-AA: MOE}_{\text{dust inhalation}} = 0.0048 \times 10^3 / 2.3 \times 10^{-5} = 2 \times 10^5$$

$$\text{P-AA/MA: MOE}_{\text{dust inhalation}} = 0.024 \times 10^3 / 1.4 \times 10^{-4} = 1.7 \times 10^5$$

5.3.1.6 Exposure scenario: oral ingestion via case of poisoning and accidental contact with the eyes

Accidental ingestion of milligrams of polycarboxylates as a consequence of accidental ingestion of laundry and cleaning products is not expected to result in any significant adverse health effects, given the low toxicity profile of laundry and cleaning products in general. Furthermore, the poison centres in Germany have not reported a case of lethal poisoning with detergents containing polycarboxylates.

Accidental contact of polycarboxylates with the eyes is not expected to cause more than a slight irritation on the basis of the experimental data.

5.3.1.7 Total Consumer Exposure

The consumer exposure via direct and indirect skin contact and via the oral route from residues on dishes and eating utensils and in drinking water are discussed separately:

Exposure by skin contact:

$$\begin{aligned} \text{P-AA: } & (0.165_{\text{Hand washed laundry}} + 4.2_{\text{pretreatment laundry}} + 0.0147_{\text{wearing clothes}}) \text{ } [\mu\text{g} / \text{kg bw/day}] \\ & = 4.4 \text{ } \mu\text{g} / \text{kg bw/ day} \end{aligned}$$

$$\begin{aligned} \text{P-AA/MA: } & (0.99_{\text{Hand washed laundry}} + 25_{\text{pretreatment laundry}} + 0.088_{\text{wearing clothes}}) \text{ } [\mu\text{g} / \text{kg bw/day}] \\ & = 26 \text{ } \mu\text{g} / \text{kg bw/ day} \end{aligned}$$

$$\text{P-AA: MOE}_{\text{skin contact}} = 1136,000 / 4.4 = 2.5 \times 10^5$$

$$\text{P-AA/MA: MOE}_{\text{skin contact}} = 1,871,000 / 26 = 7.2 \times 10^4$$

Exposure by ingestion:

$$\begin{aligned} \text{P-AA: } & (0.012_{\text{residues on dishes}} + 4.4_{\text{drinking water}}) \text{ } [\mu\text{g} / \text{kg bw/day}] \\ & = 4.41 \text{ } \mu\text{g} / \text{kg bw/ day} \end{aligned}$$

$$\begin{aligned} \text{P-AA/MA: } & (0.073_{\text{residues on dishes}} + 2.27_{\text{drinking water}}) \text{ } [\mu\text{g} / \text{kg bw/day}] \\ & = 2.34 \text{ } \mu\text{g} / \text{kg bw/ day} \end{aligned}$$

$$\text{P-AA: MOE}_{\text{ingestion}} = 1136,000 / 4.41 = 2.6 \times 10^5$$

$$\text{P-AA/MA: MOE}_{\text{ingestion}} = 1,871,000 / 2.34 = 8 \times 10^5$$

Inhalative dust exposure was not included in the calculation as due to the specifications of particle size during manufacture no inhalable dusts are expected. Furthermore, due to the very low exposure to (non-inhalable) dust per application (see chapter 5.1.3.5) the change in the Total Consumer Exposure would not be numerically significant.

5.3.2 Risk Characterisation

Assessment of the contact scenarios revealed only remote consumer exposure to homo- and copolymers via intended use of polycarboxylate-containing products. As a result, the MOEs for the total estimated systemic dose of homo- and copolymers are very high

PAA: $MOE_{\text{skin contact}} = 2.5 \times 10^5$; $MOE_{\text{ingestion}} = 2.6 \times 10^5$; $MOE_{\text{inhal}} = 2 \times 10^5$;

P-AA/MA: $MOE_{\text{skin contact}} = 7.2 \times 10^4$; $MOE_{\text{ingestion}} = 8 \times 10^5$; $MOE_{\text{inhal}} = 1.7 \times 10^5$), and thus of no concern to human health. Furthermore, accidental exposure or intentional overexposure does not imply risk owing to the very low acute toxicity of both substances.

It can be concluded that P-AA and P-AA/MA in consumer washing and automatic dishwashing detergents are not considered to cause any risk to human health.

5.3.3 Summary and Conclusion

The polycarboxylates P-AA and P-AA/MA are widely used in laundry detergents (regular and compact powder) and dishwashing tablets. Thus, consumers are exposed to P-AA and P-AA/MA mainly via the dermal route by direct contact via hand-washed laundry and indirect contact via wearing clothes. Furthermore consumers are orally exposed to P-AA and P-AA/MA through residues remaining on eating utensils and dishes after running a typical dishwashing programme.

P-AA and P-AA/MA have a very low toxicity after oral or dermal application. In both routes of exposure, the LD_{50} is greater than 2,000 mg/kg bw/day in experimental animals. P-AA/MA demonstrates no irritating potential on rabbits' skin and eyes, whereas P-AA shows no skin-irritating potential on the one hand, but has a non- to slight eye-irritating potential on the other hand. Beyond that, there is no indication that P-AA and P-AA/MA are skin sensitising. Local dermal effects due to direct skin or indirect skin contact with P-AA- and P-AA/MA- containing solutions in hand-washed laundry are not of concern because P-AA and P-AA/MA are not a contact sensitiser and are not expected to be irritating to the skin.

The adverse effect after repeated inhalation dosing (91d/rat) was a mild, reversible pulmonary irritation. This effect is considered as not substance-related owing to the physical property of the respirable dust created for this kind of study which caused local lung effects. Nevertheless, in a worst case scenario, the local NOECs of 0.2 mg/m^3 for P-AA and 1.0 mg/m^3 for P-AA/MA were taken forward into a Margin of Exposure calculation under the assumption of a ten percent deposition into the lung and a 100% absorption of the deposited material.

No studies are available on carcinogenicity. However, in the absence of genotoxicity, the lack of exposure to inhalable dust due to the manufacturing process and with no cellular hyperplasia being reported in other studies as the 90 days drinking water study with rats for P-AA/MA at exposure levels well beyond the limit dose, no carcinogenic potential is expected for this substance group. On the grounds of the close similarity of the toxicological potential of P-AA as compared to P-AA/MA it appears appropriate to extend this conclusion also to the P-AA substance family taking into account the lack of exposure to inhalable dusts created by P-AA in detergent application.

Data on developmental toxicity demonstrate that polycarboxylates are not developmentally toxic in rats.

Evidence from a subchronic study in rats where no effects on the reproductive organs and tissues were detected would further argue against a reprotoxic potential of these polymers.

In summary, based on the available data, the human risk assessment considers the use of polycarboxylates in household laundry products and automatic dishwashing detergents as safe and of no concern with regard to consumer use.

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7. CONTRIBUTORS

This report was developed by experts from BASF AG and Rohm & Haas with the assistance of members of the HERA Environmental Task Force and the HERA Human Health Task Force.