ASCEND

PERFORMANCE MATERIALS

Adipic Acid
Product Stewardship Summary
April 12, 2017

Ascend Performance Materials is a United States based chemical company with global focus. We are focused more than ever before on our customers – to understanding their unique challenges in the market, to developing product solutions that address their market needs, and to providing excellent customer and technical service. For more information on our products please visit www.ascendmaterials.com.

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RESPONSIBLE CARE®
OUR COMMITMENT TO SUSTAINABILITY

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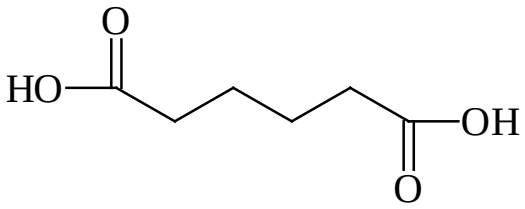
Adipic Acid
Product Stewardship Summary

Chemical Family: Organic dicarboxylic acid
Chemical Name: Hexanedioic acid
Synonyms: Adipic
CAS. Number: 124-04-9
EC Number: 204-673-3
Formula: $HOOC(CH_2)_4COOH$



Introduction

Adipic Acid is a high production volume chemical, with more than 5.7 billion pounds produced annually around the world. Ascend Performance Materials LLC is the world's leading producer of Adipic Acid. Ascend produces this material in our Cantonment, FL, USA facility, for distribution to our customers worldwide. Ascend provides high purity Adipic Acid in a variety of package sizes (50 pound and 25 kg bags, flexible intermediate bulk containers, truck, shipping container and rail), and in several grades, including food grade. Ascend is the only large scale producer of Food Grade Adipic Acid in the World.

Conclusion of Safety for Use

Adipic Acid is safe for industrial, food and cosmetic use, when used with proper care and responsibly. This includes adherence to Safety Data Sheet and labeling guidance, along with good industrial hygiene, process safety and waste disposal practices. It is up to the customer to determine fitness for use in their facility, handling systems, reaction processes and in their formulated products.

Uses for Adipic Acid

Adipic is used in a variety of ways, to make industrial and consumer products. Typical uses include:

Use as an industrial intermediate:

Adipic is reacted with other chemicals to form solvents, lubricants, plasticizers and other chemical products. These include:

- Dimethyl Adipate – Solvent used in industrial reactions, and in consumer paint and caulk strippers
- Bis(2-ethylhexyl) Adipate (Dioctyl Adipate) – Plasticizer used in PVC films, and a component of hydraulic fluids
- 1,6-Hexanediol – A monomer in the manufacture of polyurethanes and polyesters

Use as a monomer:

Adipic's largest use is a monomer in formation of various polymers. These include

- Nylon 6,6 – The reaction product of Adipic and 1,6-Hexamethylenediamine (Such as Ascend's Vydyne® and Ascend® resins)

- Polyesters – Such as Poly(1,4-Butylene Adipate) – The reaction products between Adipic and various Di-Alcohols
- Other polymers, such as Nylon copolymers, and Wet Strength Resins for paper manufacture

Use as a formulation ingredient:

- Solder Flux – Adipic is used for flux activation and its weak acid properties help with metal cleaning
- Dishwashing Tablets – Adipic is used as a binder in tablet dishwashing detergents
- Glass Interleaving Powders – Adipic is used to protect flat glass products from damaging corrosive reactions in humid storage and transport environments

Use as a food, medication or cosmetic ingredient:

- Flavoring – Food Grade Adipic is used to provide tartness to baked and blended foodstuffs
- Gelling Aid – Food Grade Adipic is used to form gels in food products such as gelatin
- Excipient in Medications – Food Grade Adipic is used to help control delivery of medicines within the body.

Properties of Adipic Acid

Commercially, Adipic is a white crystalline solid. It is available as a powder or granular material.

Chemical Properties

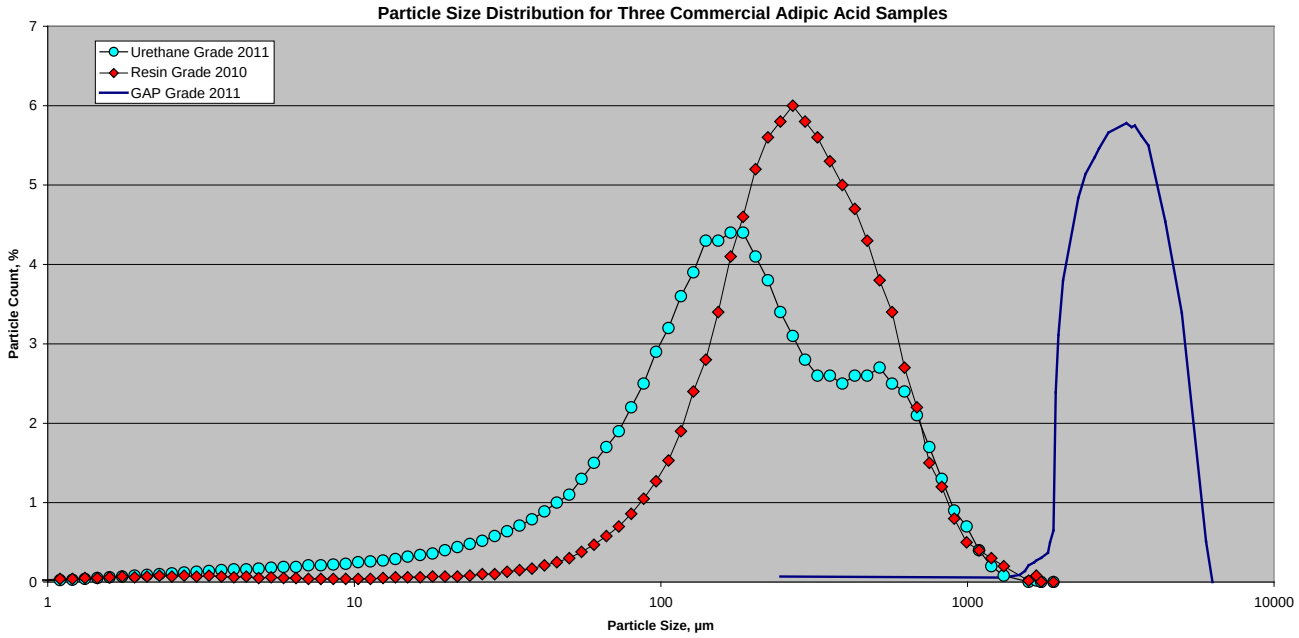
Available chemical information is below. This data is a combination of Ascend historical data, and data submitted as a part of the joint REACh registration. The REACh data may differ slightly, and is the result of consensus among many producers of Adipic Acid. Differences may be due to crystal properties, particle size or measurement methods.

Parameter	**Ascend Data**	**REACh Consortium Data**
Appearance:	White Crystalline Solid	White Crystalline Solid
Crystalline Density	1.366 g/cm3	1.36 at 25°C
Bulk Density	40 - 45 lb/ft3 (0.65-0.72 g/cm^3)	
pH:	wt% 0.1 0.6 1.2 pH 3.45 2.86 2.69 (25°C)	3.2, 0.1% Solution in Water, 25°C
Melting Point:	151°C	150.85 °C at 1013 hPa EU Method A.1
Boiling Point:	337.5°C @ 760 mmHg (Decomp) 265.0°C @ 100 mmHg 244.5°C @ 50 mmHg 205.5°C @ 10 mmHg	337.5 °C at 1013 hPa
Flash point:	210°C Cleveland open cup	196°C Closed Cup
Flammability:		Non flammable
Explosive limits:		Non explosive; However dust explosivity can be an issue
Vapor Pressure:		0.097 hPa at 18.5°C
Relative Density:		1.36 at 25°C (crystalline)
Solubilities:	2.0 g / 100 g water at 25°C 9.2 g / 100 g water at 50°C 72 g / 100 g water at 80°C 30 g / 100 g methanol at 25°C	Water - 23000 mg/L at 25 °C (2.3%) very soluble in methanol and ethanol; soluble in acetone and ethyl acetate; slightly soluble in cyclohexane and benzene
Partition Coefficient:		Log Kow (Pow): 0,09 at 20 °C
Autoignition temperature	420°C (literature value)	>400°C

Dissociation constant	K1 3.7 x 10-5 at 25°C K2 2.9 x 10-6 at 25°C	pK1 4,43 and pK2 5,42 at 20 °C
Henry's Law constant		0.0616 Pa m³/mol in water at 25° C (Calculated)
Heat of Combustion	669 kcal/g-mole	

Particle Size

As with any other crystalline material, Adipic Acid has a range of particle sizes. When crystals form in a chemical process, and these crystals are dried, conveyed and packaged, a variety of particle sizes are formed. The graph below shows particle size for three samples of different grades of Ascend Adipic Acid. This data should be considered typical of our products, but does not represent a product specification.



Dust Explosivity Properties

As mentioned above, under certain conditions it is possible for Adipic Acid to form an explosive mixture in air. These conditions have been investigated by several manufacturers. Monsanto investigated these, and found that this hazard was present in atmospheres which contain greater than 11% oxygen. Other available explosivity data are below. The wide range of values is due to differences in measurement methods and sample particle size. The Ascend data below was generated Resin Grade/Urethane Grade material, and should not be representative of GAP grades of Adipic Acid.

Parameter	**Ascend Data**		**REACh Consortium Data**
minimum explosive concentration	10-15 mg dust / liter air		35 g/m3
Minimum Ignition Energy	480 mJ	270 mJ	10 to 30 mJ
Maximum Explosion Pressure	8.8 Bar gauge	8.0 Bar gauge	8.3 Bar Gauge
Kst Value	116 m.bar/sec	121	130-220 m.bar/sec
ST Class	1	1	2

Equipment design for Adipic bulk handling should include measures to minimize dust generation and to provide pressure relief, explosion suppression or inert atmospheres. All equipment, including trucks, railcars, unloading lines, etc., should be electrically grounded to prevent static charge buildup. In addition, electrical equipment exposed to Adipic dust should be rated Class II, Group G, Division II.

For more details on this subject, please see the Ascend Product Safety Focus "Adipic Acid Dust – Management of Dust Combustion and Explosion Risk", available at www.ascendmaterials.com.

Combustion Products

When Adipic Acid is burned in an excess oxygen environment, typical combustion products should include Carbon Dioxide, Carbon Monoxide, and Water. In limited oxygen or fires involving other chemicals, combustion products could include low weight aldehydes (Formaldehyde, Acetaldehyde).

Health Affects Overview

Adipic Acid has been extensively studied by manufacturers, governmental agencies and researchers around the world. Hundreds of studies have been conducted, and these studies have shown that:

- Adipic Acid is safe for worker and consumer exposure when used responsibly in the manner intended
- Adipic Acid does not pose occupational risks when properly controlled through engineering and protective equipment
- Like most acidic materials, if Adipic Acid gets into the eyes, it can cause severe irritation. If left untreated, eye damage may occur. Opportunity for these effects can be minimized through good industrial practice and personal protective equipment. The severity of these effects can be reduced through eye washing and proper medical follow-up
- Adipic Acid is very biodegradable, and poses no risks to the environment from consumer and industrial use.

Established Occupational Exposure Limits

In many jurisdictions, occupational exposure limits have been established. These are limits above which it is deemed necessary to have employees protected from inhalation exposure. The current established limits are:

ACGIH TLV:	5 mg/m3	8-hr TWA
Belgium: GRENSWAARDE / VALEUR LIMITE (8h):	5 mg/m3	8-hr TWA
Denmark : Grænseværdier for Stoffer og Materialer (TWA):	5 mg/m3 ;	8-hr TWA
Ireland : OEL (Occupational Exposure Limit)	5 mg/m3	8-hr TWA
Italy : Occupational Exposure Limits (OEL)	5 mg/m3	8-hr TWA
Latvia - Occupational Exposure Limits - TWAs (AERs)	4 mg/m3	8-hr TWA
Netherlands : MAC (Maximum concentration on workplace)	5 mg/m3	8-hr TWA
Poland : Occupational Exposure Limits	5 mg/m3	8-hr TWA
Poland : Occupational Exposure Limits	10 mg/m3	15-min STEL
Portugal : Occupational Exposure Limits (OEL)	5 mg/m3	8-hr TWA
Spain : Occupational Exposure Limits (VLA-ED)	5 mg/m3	8-hr TWA

Details on Health Effects

Acute Effects

In the workplace, acute effects from Adipic Acid exposure may occur via dust exposure to the eyes, or inhalation of Adipic Acid dust. While Adipic on the skin could lead to irritation, the likelihood is low and effects can be eliminated through removal of the product from the skin.

Oral Toxicity – Adipic Acid is classified as practically non-toxic by mouth. In animal studies, the LD_{50}(rat) value for Adipic is 5560 mg Adipic/kg of body weight.

Inhalation Toxicity – Adipic Acid is classified as non-toxic by inhalation. In animal studies, the LC_{50} (rat) value for Adipic is 7700 mg Adipic/m^3 of air. This level is far above relevant occupation exposure limits (please see table above). While it is non-toxic by inhalation, the inhalation of any powder can be irritating to the nasal and bronchial tracts, and to the lungs.

Dermal Toxicity – Adipic Acid is considered non-toxic by dermal exposure. When Adipic Acid was applied to rabbit skin at up to 7940 mg Adipic/kg of body weight, no deaths occurred in tested animals.

Dermal Irritation – Adipic Acid should not be irritating to intact skin, in short exposure situations. If left on skin, some slight irritation can occur. An animal study with 24 and 72 hour skin exposure to rabbits has shown Adipic Acid to be slightly irritating.

Eye Irritation – Adipic acid is severely irritating to the eyes – it will cause redness, pain and tearing. If left in the eyes for an extended period of time, if can cause damage to the cornea. This is based on both animal studies and on occupational experience.

Adipic acid is soluble in water; if dust from Adipic lands on the surface of the eye, it will dissolve into the tear film present on the surface of the eye, and will lower the pH of the film. The phenomenon occurs with almost any acidic material. When this pH is lowered changes occur in proteins present on the cornea, and in the skin inside the eyelids. This results in the effects mentioned above – redness and pain. The human body produces tears in a defensive effort to remove the material from the eye. If Adipic (or any acid) is removed quickly and thoroughly, irritation or damage is minimized, and the effects are easily reversed.

Chronic Effects

Just as for acute exposures, chronic effects from Adipic Acid exposure primarily occur via dust exposure to the eyes, or inhalation of Adipic Acid dust.

Sensitization – In animal studies, Adipic Acid has been shown to not be a sensitizer. No occupational evidence for sensitization has been found.

Oral Exposure – Long term animal feeding studies have shown that after 2 years of daily ingestion of Adipic Acid, no effects were seen at dosages of 1% in food (NOAEL = 750 mg Adipic/kg of body weight per day). At levels higher than this (3 and 5% in food) the primary effects seen were in reduced body weight as compared to control. Reduced bodyweight is primarily due to loss of appetite in the test animals. Such high dose levels are not representative of any occupational or environmental exposure.

A human volunteer test showed no effects with daily ingestion of 7 grams of Adipic Acid for 10 days.

Inhalation Exposure – In a 4 month study of mice to Adipic Acid dust, no effects were seen at the only tested concentration (126 mg of Adipic Acid/ m^3 of air, exposure for 6 hours/day).

Cancer – Several studies have shown that Adipic Acid does not cause cancer in lab animals, and does not cause genetic mutations in bacteria or animal cells.

Reproductive/Developmental Effects – Available animal studies show no effects to reproductive organs or ability for rats, and also no effects to offspring from multiple species of animals.

REACh Registration

In 2010, Adipic Acid was registered for continued, large scale use in Europe. Ascend was part of the consortium which helped assemble the registration dossier. This comprehensive review contained hundreds of studies, and narrowed the available dataset down to the most scientifically valid studies. The following data was used for regulatory assessment:

Acute Animal Toxicity, Sensitization and Corrosion Data

Exposure Route	Type of Test	Species	Value
Oral	LD50 oral gavage	Sprague-Dawley rat	5560 mg/kg bw (male/female)
Inhalation	LC50, 4 hour exposure dust/aerosol (nose/head only)	Sprague-Dawley rat	7700 mg/m³ air (male/female)
Dermal	LD0: occlusive	New Zealand White rabbit	7940 mL/kg bw (male/female)
Skin Irritation	occlusive Time point: 24 and 72 h	Vienna white rabbit	slightly irritating
Eye Irritation	OECD Guideline 405 Time point: 24, 48, 72 h	Himalayan rabbit	moderately irritating
Respiratory Irritation	no valid animal data available		not sensitizing
Skin Sensitization	Guinea pig maximization test Induction: intradermal Challenge: epicutaneous, open	guinea pig (albino) male	not sensitizing

Repeat Dose/Chronic Toxicity Data

Exposure Route	Type of Test	Species	Value
Repeat dose Oral:	chronic (oral: feed)	rat (Carworth Farm strain)	NOAEL: 1 % in diet (approx. 750 mg/kg/day) (male/female)
Repeat dose Dermal:	No data available		
Repeat dose Inhalation:	subacute (inhalation) (whole body), dust 126 mg/m3 Exposure: 6 h (15 applications)	rat (Alderley Park)	NOAEC: 126 (male/female) based on: test mat.

Carcinogenicity/ Mutagenicity Data

Exposure Route	Type of Test	Species	Value
Mutagenicity – In Vitro	bacterial reverse mutation assay (e.g. Ames test) (gene mutation)	S. typhimurium TA 1535, TA 1537, TA 1538, TA 98, TA 100, and Escherichia coli WP2	negative
Mutagenicity – In Vivo	chromosome aberration assay (chromosome aberration) oral: gavage	rat male	negative
Carcinogenicity	Exposure: 2 years (diet ad libitum) oral: feed	Carworth Farm rat male/female	NOAEL: 750 mg/kg bw/day
Reproductive and developmental toxicity	chronic two-year study oral: feed	Carworth Farm rat male/female	No Effects Noted
Developmental toxicity (Teratogenicity)	oral: gavage	Wistar rat	NOAEL: >= 288 mg/kg bw/day (No Effects at Highest Dose Tested)

Specific Target Organ Toxicity (STOT)
Not Classified

The REACh Risk Assessment process requires that Derived No Effect Levels (DNEL's) be calculated for likely exposure routes. These values represent a concentration at which no effect is expected in any human system. These values were derived from the available best data, and by using ECHA's methodology for risk assessment.

Exposure pattern	DNEL	
	Workers	**General population**
Acute – inhalation, systemic effects	264 mg/m³	65 mg/m³
Acute – dermal, systemic effects	38 mg/kg bw/day	19 mg/kg bw/day
Acute – oral, systemic effects	n.a.	19 mg/kg bw/day
Acute – inhalation, local effects	2 mg/m³	No information available
Acute – dermal, local effects	no information available	
Long-term – dermal, systemic effects	38 mg/kg bw/day	19 mg/kg bw/day
Long-term – inhalation, systemic effects	264 mg/m³	65 mg/m³
Long-term – oral, systemic effects	n.a.	19 mg/kg bw/day
Long-term – dermal, local effects	no information available	
Long-term – inhalation, local effects	1 mg/m³	No information available

Use of this data for Risk Assessment should be performed by qualified risk management professionals.

In addition to basic physical, chemical and toxicological data, REACh registration requires that the registrant proves the Adipic is safe when used properly, in the types of end uses seen within Europe. Since all major uses of Adipic Acid occur in Europe, this health assessment has relevance for the rest of the world. It was successfully shown that for 6 different types of Exposure patterns, the risk to human health and the environment was sufficiently controlled, and Adipic Acid may continue to be used in current applications. The typical end uses for Adipic Acid were covered, with the exception of food, drug and cosmetic use; these are not within the scope of REACh. Please see Ascend's Extended Safety Data Sheet for registration details[1].

Food, Drug and Cosmetic End Uses

As mentioned previously, in many parts of the world Adipic acid may be used as a direct food ingredient, in both human and animal feeds. National or State/Provincial regulations must be consulted to determine the legality and suitability for such purposes. More detailed information may be obtained from Ascend's Product Stewardship Group's Adipic Food Citations letter, which may be found at www.ascendmaterials.com. Known citations and limitations for such use are:

> **USA** – Adipic Acid may be used as a GRAS flavoring, leavening or pH control agent. Adipic Acid may also be used as a monomer/starting material or ingredient for many food contact substances, including adhesives, polymers and paperboard.
>
> **Canada** – In Canada, there are no positive lists for food packaging materials; however nylon polymers, made from Adipic Acid, are in common and legally accepted use. Adipic Acid is allowed as both a human food and animal feed ingredient. In human foods it is allowed as a pH adjustment or starch modifying agent; in animal feeds it is allowed as a Class 8 feed additive on Schedule IV of the Canada's Feed Regulation.
>
> **Europe** – Adipic Acid is allowed as a direct food ingredient as well as an authorized monomer/starting substance for food contact plastics.
>
> **Japan** – Adipic Acid is allowed as direct food additive under Japan's Food Sanitation Law. Adipic Acid is also allowed as a monomer for food contact substances

In pharmaceuticals and cosmetics, Adipic Acid has been used to control pH and to control the delivery of certain medications. For such end uses, national and local laws should be consulted.

Environmental Affects Overview

Adipic Acid has been extensively studied by manufacturers, governmental agencies and researchers around the world. Hundreds of studies have been conducted, and these studies have shown that:

- Adipic Acid is not Persistent, Bioaccumulative or Toxic in the environment.
- Adipic Acid is readily and inherently biodegradable in water and soil environments.
- Adipic Acid is readily broken down in both aerobic and septic waste disposal systems
- While Adipic Acid is shows low or moderate toxicity to aquatic in laboratory studies, these are not reflective of real world conditions. Adipic is a weak acid, and lowers the pH of water. These toxic effects seen are negated when the pH of the test medium is adjusted back to an environmentally relevant level. Further explanation is below.
- Adipic Acid undergoes photo and chemical degradation.
- Ultimate chemical and biodegradation products are carbon dioxide and water.

Details on Environmental Effects

Adipic Acid's primary uses do not result in substantial releases into the environment. In most cases Adipic is an intermediate, used within a chemical facility, and converted to another chemical substance. Other cases which involve the use of Adipic Acid in formulations typically have Adipic as a minor ingredient. Proper use and disposal practices will minimize releases to the environment from all uses of Adipic Acid.

Biodegradation

Adipic Acid has been shown to be rapidly biodegradable in aerobic and freshwater conditions in the environment. While no specific studies exist concerning biodegradation in anaerobic and marine environments, the results of a 1980 inherent biodegradation study show high inherent biodegradation, indicating that all typical uses should result in no appreciable environmental effects[2]. Adipic Acid can also undergo both photo- and chemical- degradation. When broken down, Adipic Acid is converted into carbon dioxide and water by microorganisms present in the environment. Microbial degradation is complete meaning that Adipic Acid and intermediate compounds which are formed during the Adipic Acid degradation reaction do not persist in the environment.

Aquatic Toxicity

The acute and chronic toxicity of Adipic Acid to aquatic organisms has been extensively studied. It has been concluded that through normal use, disposal and waste treatment, Adipic Acid should not adversely affect freshwater or marine organisms. As with any acid, if Adipic Acid is placed in a pure water environment, it will lower the pH of the water. Any organisms which are in the water will be affected by such a pH change. Studies have shown that a pH change of 3-4 units will be fatal to 50% or more of organisms which are present in the water.[3] Aquatic toxicity data for Adipic Acid is shown below. This data includes both ph controlled and not controlled studies, and the difference between the two is obvious. pH controlled data is more relevant to waste treatment and small releases, while pH not controlled studies are more relevant to immediate. local effects from large spills and uncontrolled releases.

If a large spill of Adipic Acid was to occur, and this spilled material would enter surface water, clearly there would be acute toxic effects. It is for this reason that in the Unites States, any spill of Adipic Acid in excess of 5000 pounds requires a 24 hour notice to the National Response Center. Adipic Acid, when properly controlled and treated, poses no hazard to the aquatic environment.

Wastewater Treatment Facilities

Based on the inherent biodegradation of Adipic Acid, no negative effects on wastewater treatment processes are expected from normal use and disposal. If a large quantity were to be released to a waste treatment system within a short period of time, some temporary upset to the system may occur.

REACh Dossier for Adipic Acid – Environmental Health Effects

In 2010, Adipic Acid was registered for continued, large scale use in Europe. Ascend was part of the consortium which helped assemble the registration dossier. In addition to basic physical, chemical and toxicological data, REACh registration requires that the registrant proves the Adipic is safe when used properly, in the types of end uses seen within Europe. Since all major uses of Adipic Acid occur in Europe, this health assessment has relevance for the rest of the world. In preparation of the dossier for Adipic Acid's REACh registration, all available data (through June 2010) was reviewed[4]. This comprehensive review contained hundreds of studies, and narrowed the available dataset down to the most scientifically valid studies. The following data was used for regulatory assessment:

Aquatic Toxicity Values for Adipic Acid

Fish, Short Term	96 h LC50 Fish	Danio rerio (Zebrafish)	>1000 mg/L, pH controlled to neutral
	96 h LC50 Fish	Pimephales promelas (Fathead Minnow)	97 mg/L, not pH controlled
	96 h LC50 Fish	Leuciscus idus (Ide)	230 mg/L, Not pH controlled – Range 3.8 to 7.0
	48 h LC50 Fish	Oncorhynchus mykiss (Rainbow Trout)	> 100 mg/L, unknown pH control
Aquatic Invertebrates, Short Term	48 h EC50	Daphnia magna (Waterflea)	85.6 mg/L, Not pH controlled – Range 4.0 to 7.0
	40h-IC50 Growth Inhibition Test	Tetrahymena pyriformis	591 mg/l
Aquatic Invertebrates, Long Term	21 day NOEC, Reproductive Effects	Daphnia magna (Waterflea)	6.3 mg/l, not pH controlled
Algae and Aquatic Plants, Short Term	96 h EC50 Algae Growth Inhibition	Desmodesmus subspicatus	26.6 mg/L
	72 h EC50 Algae Growth Inhibition	Pseudokirchnerella subcapitata	59 mg/l, unknown pH control
	72 h EC50 Algae Growth Inhibition	Desmodesmus subspicatus	31.3 mg/L
Biodegradation	Multiple valid studies show degradation of 75-100% within 7-28 days. Classified as "Readily biodegradable", in all environmental compartments, even at low environmental temperatures.		
Bioaccumulative potential	Not expected to bioaccumulate.		

The REACh Risk Assessment process requires that Predicted No Effect Concentrations (PNEC's) be calculated for likely exposure routes. These values were derived from the available best data, and by using ECHA's methodology for risk assessment.

Exposure pattern	PNEC
PNEC aqua (freshwater)	0.126 mg/L
PNEC aqua (marine water)	0.0126 mg/L
PNEC aqua (intermittent releases)	0.46 mg/L
Freshwater Sediment	0.484 mg/kg sediment dw
Marine Sediment	0.0484 mg/kg sediment dw
Soil	0.0228 mg/kg soil dw
PNEC STP	59.1 mg/L
PNEC (oral, secondary poisoning)	No potential for bioaccumulation

Use of this data for Risk Assessment should be performed by qualified risk management professionals.

REACh Exposure Scenarios and Proof of Safe Use

Within REACh, once the PNEC's are calculated, a registrant must prove that the uses of the substance result in exposures which are less than the PNEC. In 6 different exposure scenarios, using data provided by downstream users, safe use was proven for each condition. The typical REACh regulated end uses for Adipic Acid were covered; please see Ascend's Extended Safety Data Sheet for details[5].

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Adipic Acid
Hazard Communication

GHS Classification and Labeling

Under the Global Harmonized Standard for Hazard Communication (GHS), Version 4, Adipic Acid is classified as follows:

Category	Sub-Category	Classification
Physical Hazards		Not classified for any physical hazard
Acute Health Hazards	Serious Eye Irritation/ Eye Damage	Category 1, Causes Serious Eye Damage
Chronic Health Hazards		Not classified for any Chronic Health hazard
Specific Target Organ Toxicity (STOT), Acute Exposure	Respiratory Tract Irritation	Category 3, May Cause Respiratory Irritation
Acute Environmental Hazards	Toxicity to Algae	Category 3, Harmful to Aquatic Life
Long-term Environmental Hazards		Not classified for any long term environmental hazard
Signal Word	Danger	
Pictogram		

While the above information is consistent with GHS, in Europe, the European Commission's Harmonized Classification and Labeling only includes classification for eye damage/irritation as Category 2, and in the European Union, Adipic Acid is labeled as "Warning", and the corrosive pictogram is not allowed.[6]

HMIS and NFPA

Under the 3rd revision of the HMIS[7] and the 2012 NFPA 704 standard[8], NTA is rated as follows:

HMIS III	Rating	Basis for Classification
Health	2	Severe Eye Irritation/ Eye Damage (GHS Category 1), Respiratory Irritation
Flammability	3 (Dust); 2 (Other forms)	Combustible Dust; Both process fines and standard product are combustible
Physical Hazard	0	No known effects
Personal Protection	Dependent on engineering controls. In most circumstances – B In situations of insufficient dust control – E or E (Dust Goggles instead of safety glasses)	

NFPA Standard 704 (2012)	Rating (Degree of Hazard)	Basis for Classification
Health	2	Severe Eye Irritation/ Eye Damage (GHS Category 1), Inhalation Toxicity, Respiratory Irritation
Flammability	2(Dust); 1 (Other forms)	Combustible Dust; Both process fines and standard product are combustible
Instability Hazards	0	No known effects
Special Hazards	None	

Application of Available Data to NFPA and HMIS

The emphasis on a critical review of toxicology and physical hazard information for European regulatory requirements necessarily led to reevaluation of Adipic Acid's classification in other hazard communication systems. Two of the most widely used non-governmental systems for chemical classification are the NFPA Standard 704[9] and the American Coatings Association's Hazardous Materials Identification System (HMIS®III)[10]. These systems rank certain hazards of chemicals on similar scales, but have different purposes.

The HMIS III system is designed to provide employees information on workplace chemical hazards. The three categories, health, flammability and physical hazard, are rated on a 0 to 4 scale, with 4 representing the highest risk. Additionally the HMIS system includes single letter codes for Personal Protective Equipment (PPE) which would be appropriate for the chemical's routine use. The PPE codes do not take into account the details of a work area or tasks performed (such as engineering controls or other chemicals present) which may result in different PPE requirements.

The NFPA Standard 704 system is designed to provide first responders with information on the health, flammability, instability, and related hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies. These hazard categories are also rated on a 0 to 4 scale, with 4 representing the highest risk.

The best available physical property and toxicology data for Adipic Acid is presented on our Safety Data Sheet. The hazards which are applicable to classification in both standards are:

1. Eye Irritation/Eye Damage
2. Skin Irritation
3. Inhalation Toxicity
4. Respiratory Irritation
5. Dust combustibility

Within a criteria (Health, Flammability, etc.) the highest score is used as the final classification for Adipic.

HMIS III Standard

By the criteria in this standard, Adipic Acid has the following classifications:

HMIS III	Toxic Effect	Rating	Basis for Classification
Health	Skin Irritation	1	Slightly Irritating based on animal studies and human occupational exposure. Rating 1 is 0< Draize < 5
	Eye Irritation	2	Severe Eye Irritation/ Eye Damage (GHS Rating 1), based on test of rabbits. Corneal damage was reversible within 13 days. Draize values not available. Rating 2 is 26< Draize <110. Adipic would be within this range.
	Oral Toxicity	0	Oral toxicity to rats LD_{50} = 5560 mg/kg bw. Rating 0 is LD_{50} > 5000 mg/kg
	Dermal Toxicity	0	Dermal toxicity to rabbits LD_{50} = 7940 mg/kg bw. Rating 0 is LD_{50} > 2000 mg/kg
	Inhalation Toxicity	1	Inhalation toxicity to rats LC_{50} = 7700 mg/m^3; Converts to 7.7 mg/L. Rating 1 is 2.0< LC_{50} ≥20 mg/L
	Long Term Health	0	Not carcinogenic, mutagenic or a reproductive toxicant, based on in vivo and in vitro studies.
	Respiratory irritation	Not Rated	This endpoint is not addressed in the standard. Adipic is irritating to the respiratory tract based on animal studies and human occupational exposure
Flammability	Combustible Dust Fraction	3	Multiple dust explosion studies show that Adipic dust is a moderate combustible dust. Smaller particle sizes are more explosive. A Rating of 3 is applicable for dust collectors and other locations where accumulation of dust may occur. Rating 3 includes "Materials that on account of their physical form or environmental conditions can form explosive mixtures with air and that are readily dispersed in air, such as dusts of combustible solids
	Standard Product	2	Adipic Acid will burn. Tests at 815°F have not been conducted. Flashpoint is 196°C. The only reliable autoignition study did not produce an ignition at the top range to instrument (> 400°C) Dust explosion studies have been run on standard product, and it will combust under appropriate circumstances. Rating 2 includes "Solid materials in the form of course dusts that may burn rapidly but that generally do not form explosive atmospheres."
Physical Hazard		0	No known effects. Adipic is a stable compound, and will not react with water. It is not an organic peroxide, explosive, compressed gas, a pyrophoric material or an oxidizer. Adipic does not self-polymerize or self-react.
Personal Protection	Dependent on engineering controls. In most circumstances – B – Safety glasses, gloves should be sufficient. In situations of insufficient dust control – E or E (Dust Goggles instead of safety glasses) should be considered. PPE decisions should be made by appropriately trained and experienced safety professionals, should be suitable for the task being performed, and should be made in consideration of other hazards which exist in the area.		

Ascend understands that the flammability rating differs from the information provided by ACA in their HMIS Chemical Ratings Guide[11], but feels that this is a more appropriate classification. The dust explosion data was not considered by ACA. Adipic Acid's dust explosive properties are discussed in detail in Ascend's dust explosion safety focus for Adipic Acid.[12]

NFPA Standard 704

By the criteria in this standard, Adipic Acid has the following classifications:

NFPA 704	Toxic Effect	Rating	Basis for Classification
Health	Skin Irritation	1	Slightly Irritating based on animal studies and human occupational exposure. Rating 1 is "Materials that cause slight to moderate irritation to the…skin"
	Eye Irritation	2	Severe Eye Irritation/ Eye Damage (GHS Rating 1), based on Draize test of rabbits. Corneal damage was reversible within 13 days. Rating 2 is "Materials that cause severe but reversible irritation to the eyes."
	Oral Toxicity	0	Oral toxicity to rats LD_{50} = 5560 mg/kg bw. Rating 0 is LD_{50} > 2000 mg/kg
	Dermal Toxicity	0	Dermal toxicity to rabbits LD_{50} = 7940 mg/kg bw; Rating 0 is LD_{50} > 2000 mg/kg.
	Inhalation Toxicity	2	Inhalation toxicity to rats LC_{50} = 7700 mg/m^3; Converts to 7.7 mg/L. Rating 2 is 2.0< LC_{50} ≥10 mg/l
	Respiratory irritation	2	Irritating to the respiratory tract based on animal studies and human occupational exposure. Rating 2 is materials which are respiratory irritants.
Flammability	Combustible Dust Fraction	2	Multiple dust explosion studies show that Adipic dust is a moderate combustible dust. Smaller particle sizes are more explosive. A rating of 2 is applicable for dust collectors and other locations where accumulation of dust may occur. Rating 2 includes "Finely divided solids less than 420 µm (40 mesh) that present an ordinary risk of forming an ignitable dust cloud."
	Standard Product	1 to 2	Adipic Acid will burn. Tests at 815°F have not been conducted. Flashpoint is 196°C. The only reliable autoignition study did not produce an ignition at the top range to instrument (> 400°C) Dust explosion studies have been run on standard product, and it will combust under appropriate circumstances. The particle size of Adipic straddles the 40 µm limit between these categories. Rating 1 includes "Combustible pellets, powders, or granules greater than 420 µm (40 mesh)."
Instability		0	No known effects. Adipic is a stable compound and should not exhibit an exotherm under fire conditions
Special Hazards	Adipic is not classified for any NFPA Special Hazard. It is not an oxidizer, does not react with water and is not a simple asphyxiant.		

References

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[6] EU Regulation 1272/2008 (Classification, Labeling and Packaging Regulation), December 2008. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2008R1272:20110419:EN:PDF (Last accessed January 17, 2013)
[7] HMIS Chemical Ratings Guide, Appendix A. March, 2002. Available online at http://www.jjkeller.com/wcsstore/CVCatalogAssetStore/references/miscellaneous/hmis-downloads/9M-2.pdf (Accessed August 13, 2013)

[8] The NFPA Standard is available online for purchase at http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=704 (Accessed August 13, 2013)
[9] The NFPA Standard is available online for purchase at http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=704 (Accessed August 13, 2013)
[10] The HMIS III Ratings Instruction Guide is available on-line for download at http://www.jjkeller.com/webapp/wcs/stores/servlet/content____hmis-downloads_10151_-1_10551 (Accessed August 13, 2013)
[11] HMIS Chemical Ratings Guide, Appendix A. March, 2002. Available online at http://www.jjkeller.com/wcsstore/CVCatalogAssetStore/references/miscellaneous/hmis-downloads/9M-2.pdf (Accessed August 13, 2013)
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