Safety Assessment of Phosphoric Acid and Simple Salts as Used in Cosmetics

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All interested persons are provided 60 days from the above date to comment on this safety assessment and to identify additional published data that should be included or provide unpublished data which can be made public and included. Information may be submitted without identifying the source or the trade name of the cosmetic product containing the ingredient. All unpublished data submitted to CIR will be discussed in open meetings, will be available at the CIR office for review by any interested party and may be cited in a peer-reviewed scientific journal. Please submit data, comments, or requests to the CIR Director, Dr. Lillian J. Gill.

The 2015 Cosmetic Ingredient Review Expert Panel members are: Chair, Wilma F. Bergfeld, M.D., F.A.C.P.; Donald V. Belsito, M.D.; Ronald A. Hill, Ph.D.; Curtis D. Klaassen, Ph.D.; Daniel C. Liebler, Ph.D.; James G. Marks, Jr., M.D.; Ronald C. Shank, Ph.D.; Thomas J. Slaga, Ph.D.; and Paul W. Snyder, D.V.M., Ph.D. The CIR Director is Lillian J. Gill, D.P.A. This report was prepared by Wilbur Johnson, Jr., M.S., Senior Scientific Analyst and Bart Heldreth, Ph.D., Chemist.

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INTRODUCTION

The safety of the following 31 ingredients, phosphoric acid and its salts, as used in cosmetics is reviewed in this safety assessment:

Phosphoric Acid
Ammonium Phosphate
Dicalcium Phosphate
Calcium Dihydrogen Phosphate
Calcium Phosphate
Calcium Potassium Sodium Phosphate
Calcium Pyrophosphate
Diammonium Phosphate
Dicalcium Phosphate Dihydrate
Dipotassium Phosphate
Disodium Phosphate
Disodium Pyrophosphate
Magnesium Hydrogen Phosphate
Magnesium Phosphate
Metaphosphoric Acid
Pentapotassium Triphosphate
Pentasodium Triphosphate
Phosphate Buffered Saline
Potassium Metaphosphate
Potassium Phosphate
Potassium Polyphosphate
Sodium Hexametaphosphate
Sodium Metaphosphate
Sodium Polyphosphate
Sodium Phosphate
Sodium Trimetaphosphate
Tetrapotassium Pyrophosphate
Tetrasodium Pyrophosphate
Tricalcium Phosphate
Trimagnesium Phosphate
Trisodium Phosphate

According to the *International Cosmetic Ingredient Dictionary and Handbook*, the functions of these ingredients in cosmetic products frequently include buffering agents, corrosion inhibitors, chelating agents, and pH adjusters.[1]

Three of the ingredients included in this safety assessment, sodium metaphosphate, sodium trimetaphosphate, and sodium hexametaphosphate, have been reviewed by the Cosmetic Ingredient Review (CIR) Expert Panel (Panel).[2] Each ingredient is a salt of phosphoric acid. In 2001, the Panel concluded that these ingredients are safe for use in cosmetics when formulated to avoid skin irritation.

CHEMISTRY

Definition and Structure

The definitions, structures, and functions in cosmetics of phosphoric acid and its salts are presented in Table 1.

Phosphoric acid and its simple salts are all related in that they have the same phosphate core. Except for phosphoric acid and metaphosphoric acid, the ingredients in this report are either alkaline earth metals (column I or II) or ammonium salts of phosphoric acid. These ingredients are all related as inorganic phosphates, with varying degrees of protonation and cation. This group is comprised of simple phosphate salts, wherein any property differences due to the variable cation(s) can be contrasted herein. Contrasting these differences in one report is more informative and more efficient than assessing the safety of each salt in separate reports.

Phosphoric acid is a polyprotic acid which is deprotonated to mono-, di-, and tri-phosphates with rising pH. In aqueous solutions (and likely in water containing formulations) there will be a pH dependent equilibrium of phosphoric acid and phosphates, regardless of which ingredient was added. For example, a solution wherein phosphoric acid was added will also contain phosphates, unless the pH is kept extremely low (which is not likely for cosmetic formulation or use).

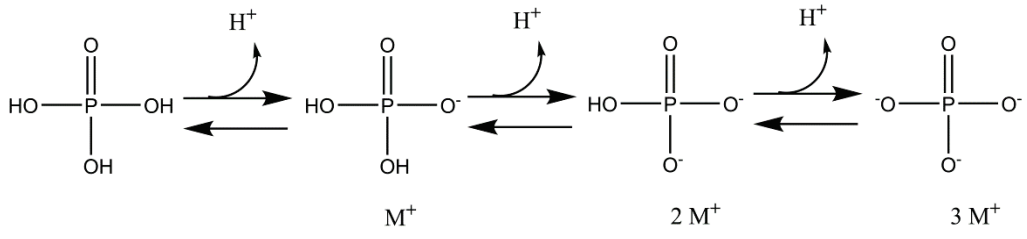


Figure1. Phosphoric Acid and the Phosphates

Chemical and Physical Properties

Properties of phosphoric acid and its simple salts are included in Table 2.

Method of Manufacture

Acids

Phosphoric Acid

Phosphoric acid is manufactured by the wet process or the furnace (thermal) process. In the wet process, phosphoric acid is produced directly from phosphate ores and is said to be of low purity.[3] This process is used mostly for the production of fertilizers. In the thermal or furnace process, phosphoric acid is produced from elemental phosphorus. This process is used in the production of phosphoric acid for other uses, such as metal treatment, refractories, catalysts, and use in food and beverages.

Ammonium Salts

Ammonium Phosphate

In the process for manufacturing ammonium phosphate, a one-to-one ratio of ammonia (NH_3) and phosphoric acid (H_3PO_4) is reacted, and the resulting slurry of ammonium phosphate is solidified in a granulator.[4]

Diammonium Phosphate

In the manufacture of diammonium phosphate, each mole of phosphoric acid is neutralized by approximately 2 moles of ammonia.[5]

Sodium Salts

Disodium Phosphate

Disodium phosphate is prepared by the ignition of dicalcium phosphate.[6]

Sodium Metaphosphate

Sodium metaphosphate is prepared by dehydration of sodium orthophosphates.[6]

Sodium Polyphosphate

Sodium phosphate monobasic hydrate was used to prepare sodium polyphosphate with a degree of polymerization (D_p) lower than ≈ 500.[7] Sodium phosphate monobasic hydrate was heated (from 25˚C to 700˚C), the melt maintained at 700˚C for 1, 3, or 9 h, and quenched on a copper plate. To fraction the sodium polyphosphate glass, the frit was ground and dissolved in deionized water to yield a 10% (w/v) sodium polyphosphate solution. The solution was stirred, fractioned by serial dilution with acetone, and then centrifuged to collect the precipitate. Sodium polyphosphate with a $D_p > 500$ was obtained from an ion-exchange process on a potassium polyphosphate crystalline phase.

Tetrasodium Pyrophosphate

Tetrasodium pyrophosphate is produced by molecular dehydration of dibasic sodium phosphate at 500˚C.[6]

Pentasodium Triphosphate

Pentasodium triphosphate is prepared by the molecular dehydration of mono- and disodium phosphates.[6]

Potassium Salts

Potassium Metaphosphate

Potassium metaphosphate is obtained by the fusion of monopotassium phosphates.[8] It is also prepared by dehydration of potassium phosphate potassium phosphate.[6]

Potassium Phosphate

Food-grade potassium phosphates have been prepared by the neutralization of phosphoric acid with potassium hydroxide at 50 to 60°C.[9]

Potassium Polyphosphate

Potassium polyphosphate can be obtained by heating monopotassium orthophosphate to any temperature above 150°C.[10]

Calcium Salts

Calcium Pyrophosphate

Calcium pyrophosphate can be obtained by a solid state reaction (870˚C and normal atmosphere) from a mixture of tricalcium phosphate and orthophosphoric acid solution.[11] It can also be prepared by ignition of dicalcium phosphate.[6]

Dicalcium Phosphate

Dicalcium phosphate results from rock phosphate acidulation (frequently with sulfuric acid), yielding phosphoric acid that is neutralized, after purification, with calcium carbonate.[12] According to another source, it is prepared from calcium chloride and disodium phosphate.[6]

Trialcium Phosphate

Tricalcium phosphate has been produced by a calcination process (at high temperature of 1500˚C to 1600˚C) that is preceded by the grinding and mixing of phosphate rock and sodium carbonate and the addition of phosphoric acid to the reaction mixture.[13]

Magnesium Salts

Magnesium Phosphate

Magnesium phosphates have been prepared by adding a magnesium nitrate solution into mixed solutions of potassium hydroxide and phosphoric acid at temperatures of 29°C to 95°C.[14]

Composition/Impurities

Ammonium Salts

Ammonium Phosphate

Iron and aluminum have been mentioned as ammonium phosphate impurities.[15]

Diammonium Phosphate

Diammonium phosphate is a complex fertilizer that contains 2 major nutrients, nitrogen (in the form of ammonium radical) and phosphorus (in the form of phosphate radical).[16] Specifications for these fertilizers are: moisture (1%), total nitrogen (18%), ammonical nitrogen (18%), total phosphate (46%), and water soluble phosphate (41%).

Sodium Salts

Sodium Hexametaphosphate

Sodium Hexametaphosphate (a polymer) contains 10 to 12 repeating pyrophosphate subunits.[17]

Potassium Salts

Dipotassium phosphate

Heavy metal (as lead, 0.6 x 10^{-3} %) and arsenic (0.5 x 10^{-4} %) impurities have been reported for dipotassium phosphate.[18]

Calcium Salts

Calcium Dihydrogen Phosphate

Calcium dihydrogen phosphate may contain a trace amount of phosphoric acid as an impurity.[6]

Calcium Phosphate

Calcium Phosphate is approximately 96% pure, usually containing an excess of calcium oxide calcium oxide.[6]

Dicalcium Phosphate

Commercial dicalcium phosphate is not a chemically-defined entity, but is a mixture of varying amounts of dicalcium and monocalcium phosphates, phosphoric acid, calcium carbonate, and impurities, depending on the origin of the raw material and procedures employed in its industrial production.[12]

USE

Cosmetic

The safety of phosphoric acid and its simple salts included in this safety assessment is evaluated based on data received from the U.S. Food and Drug Administration (FDA) and the cosmetic industry on the expected use of these ingredients in cosmetics. Use frequencies of individual ingredients in cosmetics are collected from manufacturers and reported by cosmetic product category in FDA's Voluntary Cosmetic Registration Program (VCRP) database. Use concentration data are submitted by Industry in response to surveys conducted by the Personal Care Products Council (Council) of maximum reported use concentrations, by product category. Collectively, the use frequency and use concentration data indicate that 22 of the 31 ingredients in this safety assessment are currently being used in cosmetic products (See Table 3). According to these data, the following 9 ingredients are not being used in cosmetics:

Calcium Potassium Sodium Phosphate
Magnesium Hydrogen Phosphate
Magnesium Phosphate
Metaphosphoric Acid
Pentapotassium Triphosphate
Phosphate Buffered Saline
Potassium Polyphosphate
Sodium Polyphosphate
Sodium Trimetaphosphate

According to the 2015 VCRP data, the greatest reported use frequency is for phosphoric acid (446 formulations, mostly rinse-off products), followed by dicalcium phosphate (314 formulations, mostly leave-on products) (Table 3).[19] The results of a concentration of use survey provided in 2015 indicate that disodium phosphate has the highest maximum concentration of use; it is used at concentrations up to 58% in leave-on products (face and neck products [not spray]) (Table 3).[20] In some cases, reported uses appear in the VCRP database, but concentrations of use data were not provided. For example,

according to the VCRP, tetrapotassium pyrophosphate and calcium pyrophosphate are being used in 85 and 31 cosmetic products, respectively; however, use concentration data on these ingredients were not provided in the concentration of use survey.

Cosmetic products containing phosphoric acid and simple salts may be applied to the skin and hair or, incidentally, may come in contact with the eyes (e.g., dicalcium phosphate at maximum use concentrations up to 10% in eye area cosmetics) and mucous membranes (e.g., pentasodium triphosphate at maximum use concentrations up to 9% in bath preparations). Additionally, some of these ingredients are being used in products that may result in incidental ingestion. For example, dicalcium phosphate dehydrate is being used in dentifrices at maximum use concentrations up to 48%, and dicalcium phosphate is being used in lipstick at maximum use concentrations up to 10%. Products containing these ingredients may be applied as frequently as several times per day and may come in contact with the skin or hair for variable periods following application. Daily or occasional use may extend over many years.

Phosphoric acid is used in used in aerosol hair sprays at concentrations of < 0.01% and in pump hair sprays at concentrations up to 0.26%. The following other ingredients are also used in hair sprays: potassium phosphate (in pump hair sprays [up to 0.09%]) and sodium phosphate (in pump hair sprays [up to 0.000014%]). The following ingredients are used in face powders: dicalcium phosphate (up to 2.2%), diammonium phosphate (up to 0.00046%), dicalcium phosphate dihydrate (up to 2.2%), sodium metaphosphate (up to 0.25%), and sodium phosphate (up to 0.086%). Additionally, phosphoric acid is used in dusting and talcum powders at concentrations up to 0.00001%, and tricalcium phosphate is used in dusting and talcum powders at concentrations up to 10%. In practice, 95% to 99% of the droplets/particles released from cosmetic sprays have aerodynamic equivalent diameters >10 μm, with propellant sprays yielding a greater fraction of droplets/particles below 10 μm, compared with pump sprays.[21,22,23,24] Therefore, most droplets/particles incidentally inhaled from cosmetic sprays would be deposited in the nasopharyngeal and bronchial regions and would not be respirable (i.e., they would not enter the lungs) to any appreciable amount.[21,22]

Noncosmetic

Phosphoric Acid and Phosphates

The U.S. FDA has determined that the following 20 ingredients included in this report are direct food additives that are generally recognized as safe (GRAS):[25]

Phosphoric Acid
Ammonium Phosphate
Calcium Dihydrogen Phosphate
Calcium Phosphate
Calcum Pyrophosphate
Diammonium Phosphate
Dicalcium Phosphate
Dipotassium Phosphate
Disodium Phosphate
Magnesium Hydrogen Phosphate
Pentasodium Triphosphate
Potassium Phosphate
Potassium Pyrophosphate
Sodium Hexametaphosphate
Sodium Metaphosphate
Sodium Phosphate
Sodium Trimetaphosphate
Tetrasodium Pyrophosphate
Trimagnesium Phosphate
Trisodium Phosphate

Additionally, FDA has determined that potassium polymetaphosphate, chemically similar to one or more ingredients on the preceeding list, is a GRAS direct food additive.

Phosphates, diphosphates, and polyphosphates were evaluated by the Joint FAO/WHO Expert Committee on Food Additives at a number of their meetings.[26] A maximum tolerable daily intake (MTDI) of 70 mg/kg body weight was determined, based on the lowest concentration of phosphorus (6600 mg/day) that caused nephrocalcinosis in rats. "The MTDI is expressed as phosphorus and applies to the sum of phosphates naturally present in food and the phosphates derived from use of these food additives." It was considered inappropriate to establish an average daily intake (ADI) because phosphorus (as phosphates) is an essential nutrient and an unavoidable constituent of food.

Acids

Phosphoric Acid

Phosphoric acid is used in the manufacture of the following: phosphate salts, superphosphate fertilizers, detergents, activated carbon, animal feed, ceramics, dental cement, pharmaceuticals, soft drinks, gelatin, rust inhibitors, wax, and rubber

latex.[3] Use in the following other processes has also been reported: electropolishing, engraving, photoengraving, lithograving, metal cleaning, sugar refining, and water treatment.

Metaphosphoric Acid

In dentistry, metaphosphoric acid is used in the process of making zinc oxyphosphate cement.[6] It is also used as a reagent in chemical analysis.

Ammonium Salts

Ammonium Phosphate

In agriculture, ammonium phosphate has been an important granular fertilizer for many years.[27] Ammonium phosphate is also used in dry chemical fire extinguishers that are commonly found in offices, schools, and homes. The extinguisher spray disperses finely powdered ammonium phosphate, which coats the fuel and rapidly smothers the flame.

Diammonium Phosphate

Diammonium phosphate is used in fireproofing textiles, paper, wood, vegetable fibers, and dentifrices.[6]

Sodium Salts

Disodium Phosphate

Disodium phosphate is used as an emulsifier and buffer in foods, and in the manufacture of enamels, ceramics, detergents, and boiler compounds.[6]

Disodium Pyrophosphate

Disodium pyrophosphate is used chiefly in baking powders.[6]

Pentasodium Triphosphate

Pentasodium triphosphate is used as a preservative, sequestrant, and texturizer in foods, as a whitening agent in toothpaste, and is also used in water softeners and detergents.[6]

Sodium Hexametaphosphate

Sodium Hexametaphosphate is an anti-tartar ingredient in toothpaste that is known to remove existing stains.[17]

Sodium Phosphate

The FDA has stated its awareness of reports of acute phosphate nephropathy associated with the use of oral sodium phosphate products for bowel cleansing prior to colonoscopy or other procedures.[28] Acute phosphate nephropathy is a form of acute kidney injury that is associated with deposits of calcium phosphate crystals in the renal tubules that may result in permanent renal function impairment. As a result of the safety information received, FDA requires that the manufacturer of 2 oral sodium phosphate products (prescription only) for bowel cleansing add a Boxed Warning to the labeling for these products. The FDA has also stated that, in light of the risk of acute phosphate nephropathy, over-the-counter laxative oral sodium phosphate products should not be used for bowel cleansing.

Sodium phosphate is also used in baking powders and as dry acidulant and sequestrant for foods.[6]

Sodium Polyphosphate, Sodium Trimetaphosphate, and Tetrasodium Pyrophosphate

Blended phosphates (usually ortho and glassy polyphosphates) are used in municipal water treatment as part of scale control and corrosion control programs in the United States, as these compounds bind calcium carbonate, iron, magnesium, and manganese.[29] Sodium polyphosphate**,** sodium trimetaphosphate, and tetrasodium pyrophosphate are some of the chemicals that are found in the phosphate blends. Sodium trimetaphosphate is also used in detergent processing, and as a crosslinking agent for starch in foods and pharmaceuticals.[6]

Tetrasodium pyrophosphate is also used in processed meat products, as an emulsifier in cheese, and as a color preservative in soybean paste.[30] Other uses include: sequestrant, dispersant, deflocculant, detergent builder, and component of solid or liquid fertilizers.[31] Tetrasodium pyrophosphate is one of the anti-calculus components of most tartar control dentifrices that are marketed.[32]

The EPA has established an exemption from the requirement of a tolerance for residues of tetrasodium pyrophosphate when used as an inert ingredient in pesticide formulations applied to growing crops only.[33]

Trisodium Phosphate

Trisodium phosphate is used in photographic developers, in detergent mixtures, and in the manufacture of paper.[6]

Potassium Salts

Dipotassium Phosphate

Dipotassium phosphate is used as a buffering agent in antifreeze, nutrient in the culturing of antibiotics, ingredient of instant fertilizers, and as a sequestrant in the preparation of non-dairy powdered coffee creams.[6]

Potassium Phosphate

Potassium phosphate is used as a pharmaceutical aid (buffering agent).[6]

Tetrapotassium Pyrophosphate

Blended phosphates (usually ortho and glassy polyphosphates) are used in municipal water treatment as part of scale control and corrosion control programs in the United States, as these compounds bind calcium carbonate, iron, magnesium, and manganese.[29] Tetrapotassium pyrophosphate is one of the chemicals in phosphate blends for water treatment. Tetrapotassium pyrophosphate is also one of the anticalculus components of most tartar control dentifrices that are marketed.[32]

The EPA has established an exemption from the requirement of a tolerance for residues of tetrapotassium pyrophosphate when used as an inert ingredient in pesticide formulations applied to growing crops only.[33]

Calcium Salts

Calcium Phosphate

Calcium phosphate has been used as an adjuvant (any material that can increase the humoral or cellular immune response to an antigen) for simultaneous immunizations with diphtheria, tetanus, polio, Bacillus Calmette-Guerin (BCG), yellow fever, measles and hepatitis B vaccines, with hepatitis B and DTP-polio vaccines, and with allergens.[34] It has also been used in the manufacture of fertilizers, phosphoric acid, P compounds, milk-glass, polishing and dental powders, porcelains, and pottery.[6]

Calcium phosphate is an active ingredient in antacid over-the-counter (OTC) drug products that are generally recognized as safe and effective.[35]

Calcium Pyrophosphate

ß-Calcium pyrophosphate has been used clinically as a bone-graft extender, in that it adequately bonds with host bone.[36] It is also used in dentifrices and in the production of ceramic ware and glass.[6]

Dicalcium Phosphate

Dicalcium phosphate is used chiefly in animal feeds, and is also used as a mineral supplement in cereals and other foods.[6]

Dicalcium Phosphate Dihydrate

Dicalcium phosphate dehydrate is a cleaning and polishing agent that is specifically used in dentifrices that contain monoflourophosphate.[37] As an abrasive, this ingredient assists in the removal of dental stains and deposits that form on tooth surfaces.

FDA has determined that there are inadequate data to establish general recognition of the safety and effectiveness of dicalcium phosphate dihydrate as an active ingredient in anticaries OTC drug products.[35]

Tricalcium Phosphate

Tricalcium phosphate, described as a porous ceramic material, is used in bone transplantation surgery.[38] It acts as a scaffold for bone ingrowth, undergoing progressive degradation and replacement by bone. Most often, it is used in granule or powder form during surgery.

FDA has determined that there are inadequate data to establish general recognition of the safety and effectiveness of dicalcium phosphate dihydrate as an active ingredient in weight control OTC drug products.[35] Tricalcium phosphate is also an active ingredient in antacid OTC drug products, and FDA has established a maximum daily dosage limit of 24 grams for tricalcium phosphate in these products.[39]

Magnesium Salts

Magnesium Phosphate

The FDA has determined that magnesium phosphate (including magnesium phosphate, dibasic and magnesium phosphate, tribasic) is generally recognized as safe (GRAS) as a direct human food ingredient.[40]

TOXICOKINETICS

Phosphorus (as phosphate) is an essential constituent of all known protoplasm, and its content is uniform across most plant and animal tissue.[41] According to the1994 United States Department of Agriculture (USDA) survey of food intake of individuals, values for the mean daily phosphorus intake from food were 1,495 mg (males, $\geq$ 9 years) and 1,024 mg (females, $\geq$ 9 years). In both sexes, intakes decreased at ages $\geq$ 51 years.

Structurally, phosphorus occurs as phospholipids, which constitute a major component of most biological membranes, and as nucleotides and nucleic acids. The total phosphorus concentration in whole blood is 13 mmol/liter (40 mg/dl), most of which is in the phospholipids of red blood cells and plasma lipoproteins. Approximately 1 mmol/liter (3.1 mg/dl) is present as inorganic phosphate (P_i), which is a tiny fraction of body phosphorus (< 0.1 %). In adults, P_i makes up approximately 15 mmol (465 mg) of body phosphorus, and is located mainly in the blood and extracellular fluid. Phosphate enters this P_i compartment during absorption from the diet and resorption from bone, and is the primary source from which cells of all tissues derive both structural and high-energy phosphate.[41] Furthermore, most of the urinary phosphorus and hydroxyapatite mineral phosphorus are derived from the P_i compartment.

Phosphates are absorbed from the gastrointestinal tract, and the transport of phosphate from the lumen is an active, energy-dependent process; vitamin D stimulates phosphate absorption.[42] At physiologic pH (7.4), extracellular phosphate is present primarily as the disodium phosphate and sodium phosphate salts (4:1). Once absorbed, phosphate combines with calcium to form dicalcium phosphate in bones and teeth.[29] Free orthophosphate is the primary form by which dietary P_i is absorbed. When phosphate ion in very large amounts is ingested, most of the phosphate ion uptake from the gut is eliminated in the feces.[43] According to another source, in general, approximately two thirds of the ingested phosphate is absorbed from the gastrointestinal tract in adults, and absorbed phosphate is almost entirely excreted in the urine.[42] Toxicokinetic data relating to phosphoric acid and its salts are included below.

Non-human

Acids

Phosphoric Acid

Phosphoric acid can become dissociated and then absorbed as phosphate and hydronium ions through mucous membranes.[44] Some of the phosphate and hydronium ions are conjugated in the liver and then excreted in the urine. Study details were not included.

Sodium Salts

Sodium Hexametaphosphate

Sodium hexametaphosphate is metabolized to sodium phosphate in the stomach.[45] Details relating to this study were not included.

After hexametaphosphate was administered to rats and rabbits by stomach tube, no more than trace amounts of labile phosphate were found in the urine.[8,46] Study details were not included.

Sodium Polyphosphate

Ingested polyphosphates are degraded by phosphatase enzymes to monophosphates.[29] The short- and long-chain polyphosphates are absorbed intact only to a very limited extent, if at all, and the larger molecules are hydrolyzed by phosphatases (present in the gut) to monophosphates.[47]

In an animal study (number and strain not stated), 10% to 30% of administered sodium polyphosphate was absorbed as monophosphate, and small amounts of oligophosphates were found in the urine.[8] In another experiment in which labeled sodium polyphosphate was administered to rats, the chemical was not absorbed as such, but was taken up, after hydrolysis, as monophosphate and diphosphate. In 18 h, 40% of the dose was hydrolyzed and absorbed.[8,48] Study details were not included.

Potassium Salts

Potassium Metaphosphate

In an animal study (number and strain not stated), 10% to 30% of administered potassium metaphosphate was absorbed as monophosphate, and small amounts of oligophosphates were found in the urine.[8,49] Study details were not included.

When radiolabeled potassium metaphosphate was administered orally to rats, approximately half of the radioactivity was recovered from the feces, mainly as polymeric phosphate. Only a small percentage of the dose was found in the urine, in the form of monophosphate.[8] Study details were not included.

Human

The Federation of American Societies for Experimental Biology (FASEB) estimate of maximum tolerable daily intake of phosphates in man = 70 mg/kg body weight.[50]

Sodium Salts

Sodium Phosphate

In a pharmacokinetic analysis, 45 ml of a laxative containing 30 g of sodium phosphate was administered to 13 normal volunteers.[51,52,53] The subjects were divided into the following 2 groups: Group 1 (median weight = 60 kg) and Group 2 (median weight = 119.2 kg). Serum and urine electrolytes were measured for 12 h. Hydration was maintained by monitoring the weight, fluid intake, and total body water. Markedly elevated serum phosphate levels were observed in Group 1, compared to Group 2. The normalized area under the phosphate vs. time curve was much higher in Group 1 (1120 ± 190

mg/dl per minute) than in Group 2 (685 ± 136 mg/dl per minute); $P < 0.001$was reported for this comparison. The urinary excretion of calcium was significantly lower in Group 1 (mean =16.4 ± 7.6 mg), compared to Group 2 (mean = 39.2 ± 7.8 mg); $P < 0.001$ was reported for this comparison. The results of this study demonstrated that lower body-weight individuals develop high serum phosphate levels for prolonged periods of time after ingesting sodium phosphate, even under the idealized condition of continuous monitoring of fluids and weight. The authors noted that individuals of lower body weight are a newly described group at risk for acute phosphate nephropathy when they use colonoscopy preparations containing sodium phosphate.

Calcium Salts

Tricalcium Phosphate

The absorption of ingested tricalcium phosphate was evaluated using 10 women. The subjects ingested tricalcium phosphate (1200 mg) after fasting for 12 h.[54,55] Calcium and phosphorus absorption were determined by the postload rise in urinary calcium and phosphate, respectively, above baseline. A significant increase in urinary calcium excretion ($P < 0.001$) was observed during the 2-4 h post-load period, and a significant increase in serum calcium ($P < 0.02$) was observed at 4 h post-load. Significant increases in urinary phosphate excretion ($P < 0.001$) and serum phosphorus ($P < 0.001$) were also reported.

TOXICOLOGY

Calcium Phosphate

A publication (in Japanese; not translated [English abstract]) on the safety of a calcium phosphate bone paste is available.[56] The following series of tests was performed: acute toxicity, pyrogenicity, hemolysis, intracutaneous reactivity, sensitization, genotoxicity, and cytotoxicity. The authors noted that there was no evidence of abnormal or toxic effects in any of these tests. The abstract does not include pertinent details relating to study results.

Single Dose (Acute) Toxicity

Non-Human

Inhalation

Acute inhalation toxicity data on phosphoric acid and its sodium, potassium, and calcium salts are presented in Table 4. At the highest lethal concentrations tested, phosphoric acid caused tracheal lesions in rabbits, rats, and mice, but not in guinea pigs. It should be noted that, due to its hygroscopic nature, phosphoric acid aerosols will combine with water molecules within the human tracheobronchial tree, which increases the aerodynamic diameter of the particles of the aerosol to greater than 0.5 µm. This effect is known as hygroscopic growth. As a result, the deposition characteristics of these aerosols change as they pass through the respiratory tract, which will affect the total deliverable dose in the lungs after inhalation.[44] Overall, the data suggest that the sodium, potassium, and calcium salts of phosphoric acid exhibit a low potential for inhalation toxicity.

According to an additional information source, phosphoric acid caused moderate to acute inhalation toxicity in mice.[57]

Oral

Acute oral LD_{50} values for phosphoric acid and its salts are presented in Table 5. In studies involving rats, LD_{50s} for phosphoric acid ranged from 1530 mg/kg to 4400 mg/kg. The LD_{50} for phosphoric acid in rabbits was 2740 mg/kg. Oral LD_{50s} for the ammonium salts of phosphoric acid in studies involving rats ranged from 5750 mg/kg (ammonium phosphate) to > 25,100 mg/kg (diammonium phosphate). Sodium salts of phosphoric acid were administered to rats, mice, hamsters and guinea pigs in acute oral toxicity studies, and LD_{50} values ranged from 1300 mg/kg (tetrasodium pyrophosphate [mice]) to 10,600 mg/kg (sodium trimetaphosphate [rats]). For potassium salts of phosphoric acid administered orally in studies involving rats or mice, acute oral LD_{50} values ranged from 1,000 mg/kg (tetrapotassium pyrophosphate [mice]) to 7,100 mg/kg (potassium phosphate [rats]). In acute oral toxicity studies on calcium salts of phosphoric acid involving rats or mice, LD_{50} values ranged from 2,170 mg/kg (calcium phosphate [rats]) to > 10,000 mg/kg (calcium pyrophosphate [rats]). LD_{50} values for magnesium phosphate in studies involving rats ranged from > 1,000 mg/kg (magnesium phosphate) to > 10,000 mg/kg (trimagnesium phosphate).

Dermal

Acute dermal LD_{50} values for phosphoric acid and its salts are presented in Table 6. In studies involving rabbits, an LD_{50} = 2740 mg/kg and an LD_{50} of > 3160 mg/kg were reported for phosphoric acid. For ammonium salts of phosphoric acid, LD_{50s} were > 5000 mg/kg (rats) and ranged from > 7940 mg/kg to > 10,000 mg/kg (rabbits). LD_{50} values ranging from > 300 mg/kg to > 7940 mg/kg (rabbits) were reported for sodium salts of phosphoric acid. The oral administration of potassium salts of phosphoric acid to rabbits resulted in LD_{50} values ranging from > 300 mg/kg to > 10,000 mg/kg. LD_{50} values ranging from > 300 mg/kg to > 7940 mg/kg were reported for calcium salts of phosphoric acid. LD_{50} values ranging from > 2000 mg/kg to > 7940 mg/kg were reported for magnesium salts of phosphoric acid.

Repeated Dose Toxicity

Inhalation

Phosphoric Acid

The EPA calculated an inhalation reference concentration (RfC) of 1 x 10^{-2} mg/cu.m. for phosphoric acid (critical effect = bronchiolar fibrosis).[58] Developing an inhalation RfC involves evaluating toxic effects inside the respiratory system (port-of-entry effects) and outside the respiratory system (extrarespiratory effects). In general, the RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects over a lifetime of exposure. The calculated RfC for phosphoric acid is based on inhalation toxicity data from the studies summarized below.

In two parallel 13-week inhalation studies, groups of Sprague-Dawley rats were exposed (2.25 h/day, 4 consecutive days/week) to either filtered air (controls) or an aerosol of the combustion products of burning 95% red phosphorus and 50.8% % butyl rubber.[59] In the first study, male Sprague-Dawley rats were exposed to filtered air (control) or air containing 300, 750, or 1200 mg/m^3 of the combustion products. The number of rats in the control and high- and mid-exposure groups was 176 (i.e., 176 in each group), and 84 rats were in the group exposed to 300 mg/m^3. The combustion products were mixed and diluted with filtered air and introduced into 1-cu.m exposure chambers. Aerosol particle size was determined once a day, with mass mean aerodynamic diameters (MMADs) ranging from 0.49-0.65 μm. The percentages of phosphorus acids in the aerosols ranged from 71%-79% (based on gravimetric analysis). All major organs and respiratory tract tissues were examined histologically in selected animals (n = 12) from each exposure group. Test substance-related mortality was observed among the animals exposed to the two highest concentrations in the first study, 19/176 at 1200 mg/m^3 and 1/176 at 750 mg/m^3. The target organ was the respiratory tract; specifically, the terminal bronchioles. Pathological examination of some of the animals that died revealed extensive involvement of bronchiolar and laryngeal mucosa. Terminal bronchiolar fibrosis (minimal to severe) with no or minimal involvement of pulmonary tissues was the only concentration-dependent lesion noted in the respiratory tract of animals surviving repeated exposures. This lesion was present in all examined animals that had been exposed to 750 or 1200 mg/m^3, including those necropsied after an 8-week recovery period, and was judged predominately as moderate to severe.

In the second study, male Sprague-Dawley rats (40/group) were exposed to filtered air (control) or 50, 180, or 300 mg/m^3 of the same combustion products. The duration-adjusted values for the second study were 2.7, 9.6, and 16.7 mg/m^3. The focus of this study was the respiratory tract, and the tissues examined included the turbinates (two sections), trachea, and five lobes of the lung from 20 animals in each exposure group and controls. None of the animals died. Terminal bronchiolar fibrosis (minimal to severe) with no or minimal involvement of pulmonary tissues was the only concentration-dependent lesion noted in the respiratory tract of animals surviving repeated exposures. This lesion was present, with minimal severity, in 9/20 animals exposed to 300 mg/m^3, 4/20 animals exposed to 180 mg/m^3, and 0/20 animals exposed to 50 mg/m^3. Based on the histologic lesions in the tracheobronchiolar region, 180 mg/m^3 was the LOAEL, and 50 mg/m^3 was the NOAEL in this study.[59]

Oral

The results of repeated dose oral toxicity studies on phosphoric acid and its salts are summarized in Table 7. In the longest duration feeding study on phosphoric acid, a no-observed-effect level (NOEL) of 338 mg/kg/day was reported for rats that received concentrations up to 0.75% in the diet for one year. The average weight of the parathyroid glands (only parameter assessed) was 235% of control values in rabbits that received oral doses of diammonium phosphate up to 700 mg/kg/day for up to 16 months. Kidney damage (nephrocalcinosis) was a common pathological finding in repeated dose oral

toxicity studies involving sodium and potassium salts of phosphoric acid. There were basically no adverse effects in rats/monkeys fed calcium salts of phosphoric acid in the diet.

Cytotoxicity

Calcium Phosphate and Dicalcium Phosphate Dihydrate

The cytotoxicity of the following mixture was evaluated using a mouse L-929 cell suspension: α-tricalcium phosphate (90%) and dicalcium phosphate dihydrate (10%) in a solution containing chondroitin sulfate (5%) and sodium succinate (12%).[60] Cell morphology was evaluated at 24 h; the affected area of the cell layer was determined using microscopy. Contracted cells, rounded cells with dark nuclei, and broken cells were considered damaged cells. A very low degree of cytotoxicity (mild cytotoxicity) was observed.

Calcium Pyrophosphate

The cytotoxicity of calcium pyrophosphate was studied using Chinese hamster ovary K-1 cells.[11] Cytotoxicity potential was determined quantitatively by cytolethality (expressed as the cytotoxicity index [$IC_{50\%}$]) using a colony suppression assay. The $IC_{50\%}$ is defined as the concentration that is necessary to kill half of the cell population or the concentration that suppresses colony formation to 50% of the control value. Phenol solution (0.02%) and alumina extracts served as positive and negative controls, respectively. Calcium pyrophosphate was not cytotoxic ($IC_{50\%}$ = 100). The positive and negative controls performed as expected.

REPRODUCTIVE AND DEVELOPMENTAL TOXICITY

Reproductive and developmental toxicity data on ammonium, sodium, potassium, and calcium salts of phosphoric acid are presented in Table 8. Teratogenicity was assessed primarily using rats and mice; however, rabbits and hamsters were also used. These salts did not produce teratogenic effects *in vivo*, and the highest dose tested was diammonium phosphate at 1500 mg/kg/day for 35 days. However, the following salts of phosphoric acid were teratogenic to chick embryos: tetrasodium pyrophosphate (injection of 5 mg/egg), sodium hexametaphosphate (injection of 0.5 to 10 mg/egg), sodium phosphate (injection of 0.5 to 10 mg/egg), potassium phosphate (injection of 10 mg/egg), calcium phosphate (injection of 2.5 mg/egg), and tricalcium phosphate (injection of 2.5 mg/egg).

GENOTOXICITY

In vitro and *in vivo* genotoxicity data on phosphoric acid and its ammonium, sodium, potassium, and calcium salts are presented in Table 9. The *in vitro* tests included the Ames/*Salmonella* mutagenicity assay (with and without metabolic activation), the *Saccharomyces cerevisiae* mutagenicity assay (with and without metabolic activation), the chromosome aberrations assay (Chinese hamster fibroblasts), and the *in vitro* cytogenetics assay (human lung cells). The *in vivo* tests included the dominant lethal test (rats), host-mediated assay (mice), and the mouse translocation test. Phosphoric acid and its ammonium, sodium, potassium, and calcium salts did not produce positive responses in *in vitro* or *in vivo* genotoxicity assays.

CARCINOGENICITY

Non-Human

Acids

Phosphoric Acid

According to one source, no carcinogenic potential was demonstrated in limited feeding studies involving rats treated with phosphoric acid or several of its salts. However, in rodents treated orally, several phosphates have been shown to promote the effects of known carcinogenicity.[57]

Sodium Salts

Disodium Phosphate and Tetrasodium Pyrophosphate

An oral feeding study involving groups of 10 male and 10 female rats fed various concentrations of a mixed preparation (33% potassium metaphosphate + 67% tetrasodium pyrophosphate [in Sherman diet]) was conducted.[8,61] The following diets were fed:

- 0.5% commercial preparation (effective concentration [potassium metaphosphate] = 0.5% x 33% = 0.17%; effective concentration [tetrasodium pyrophosphate] = 0.5% x 67% = 0.34%)
- 1% commercial preparation (effective concentration [potassium metaphosphate] = 1% x 33% = 0.33%; effective concentration [tetrasodium pyrophosphate] = 1% x 67% = 0.67%)
- 5% commercial preparation (effective concentration [potassium metaphosphate] = 5% x 33% = 1.7%; effective concentration [tetrasodium pyrophosphate] = 5% x 67% = 3.4%)

From each dietary group, a second and third generation were produced and feeding was continued. For all dietary groups, the tumor incidence was not greater than that observed in control animals. Additional study details were not included.

Pentasodium Triphosphate

Groups of weanling rats of the Rochester strain (number not stated) were maintained on a diet supplemented with 0.05%, 0.5%, or 5% pentasodium triphosphate for 2 years.[62] The carcinogenesis index was similar to the frequencies expected for aging rats, and did not vary among dietary groups.

Sodium Hexametaphosphate

Groups of weanling rats (males and females; number not stated) were fed a diet containing 0.05%, 0.5%, or 5% sodium hexametaphosphate for 2 years.[62] There was no correlation between the dietary level of sodium heametaphosphate and tumor incidence.

Sodium Trimetaphosphate

A diet containing 0.1%, 1%, or 10% sodium trimetaphosphate was fed to groups of weanling rats (number and strain not stated) for 2 years. There was no correlation between the dietary level of sodium trimetaphosphate and tumor incidence.[62]

Sodium Metaphosphate

Calcium sodium metaphosphate (CSM) fiber is a manmade inorganic fiber composed of condensed polyphosphate chains in a specific crystal lattice.[63] Male and female Fischer 344 rats (80/sex/group) were exposed to CSM fiber 6 hr/day, 5 days/week at target-exposure levels of 0, 1, 5, or 25 mg/m^3 (corresponding to 0, 27, 80, and 513 fibers/cc, respectively) for 24 months. At 3 and 12 months, 10 rats/sex/group were killed and, at 18 and 24 months, 5 rats/sex/group were killed. Additionally, 5 rats/sex/group were removed from exposure at 18 months and maintained for a 6-month recovery period. No increase in tumors (benign or malignant) was observed in this study.

Phosphates

A study was performed to elucidate the potential effects of high dietary phosphate (Pi) on the development of lung cancer.[64] The first experiment involved two groups of male K-*ras*^{LA1} mice (9 per group). One group received an AIN93-based diet containing 0.5% P_i (normal P_i), and the other group received the same diet fortified with 1% Pi (high P_i). Both diets were fed for 4 weeks, after which the animals were killed. Blood samples were obtained and necropsy was performed. Tumor lesions of lung surfaces were counted and the diameter of each lesion was measured. A lobe of the left lung was prepared for histopathological examination and immunohistochemistry. The diet containing 1% P_i increased lung tumor progression and growth, when compared with the diet containing 0.5% P_i. Histopathological examination results showed that pulmonary tumor progression was markedly stimulated by 1% P_i in the diet. The number and size (at least 1.5 mm in diameter) of lung surface tumor lesions (adenomas) increased significantly ($P < 0.05$). P_i (1%) in the diet also had the following effects: (1) increased the sodium-dependent inorganic phosphate transporter-2b protein levels in the lungs; (2)

stimulated pulmonary Akt (known to regulate cell cycle progression) activity, while suppressing the protein levels of tumor suppressor phosphatase and tensin homolog deleted on chromosome 10 as well as Akt binding partner carboxyl-terminal modulator protein, resulting in facilitated cap-dependent protein translation; and (3) significantly ($P < 0.05$) stimulated cell proliferation in the lungs of K-*ras*^{LA1}mice.

In a second study (urethane-induced lung cancer model), A/J mice were injected intraperitoneally with urethane (1 mg/g body weight) in saline. At 4 weeks, post-injection, the mice were divided into 2 groups (7 mice per group) and fed, 1% P_i and 0.5% P_i in the diet, respectively, for 4 weeks. The effect of high dietary P_i on lung tumorigenesis was confirmed in this experiment. P_i (1%) in the diet significantly increased ($P < 0.05$) tumor development. Both the mean number of tumors and the mean tumor diameter (at least 1 mm in diameter) increased significantly ($P < 0.05$). Histopathological examination results also showed that pulmonary tumor progression was stimulated.[64]

The authors noted that the results of this study indicate that high dietary P_i strongly activated Akt signaling and increased lung tumorigenesis.[64]

Tumor Promotion

Potassium Salts

Dipotassium Phosphate

In a tumor promotion study involving groups of 20 nephrectomized male rats, the following diets were fed:[18,65]

- Group I: 1,000 ppm N-ethyl-N-hydroxyethylnitrosamine (EHEN) diet (2 weeks) + 50,000 ppm dipotassium phosphate diet (18 weeks)
- Group II: The basal diet (2 weeks) + 50,000 ppm dipotassium phosphate (18 weeks)
- Group III: 1,000 ppm EHEN diet (2 weeks) + the basal diet (18 weeks)
- Group IV: The basal diet (20 weeks)

The rats were fed EHEN (1,000 ppm) in the diet for 2 weeks, and the left kidney was removed at week 3. Next, the rats were fed dipotassium phosphate (50,000 ppm) in the diet for 18 weeks (from weeks 3 to week 20). A control group of 20 rats received basal diet only after EHEN administration and nephrectomy. The mean relative kidney weight per body weight in group I was significantly greater when compared to group III. Additionally, the mean kidney weight in group II was significantly greater when compared to group IV. The numbers of simple hyperplastic foci and adenomatous hyperplastic foci in group I animals were significantly greater ($p < 0.05$) when compared to group III. The incidence of renal cell tumors was 30% in group I. Nephropathy, lymphocyte accumulation, hyaline droplets in proximal convoluted tubular cells, and dilatation of the proximal convoluted tubular cells were observed in the cortex of group I and group II animals. Calcification was observed in the renal medulla and cortex of groups I and II. It was concluded that dipotassium phosphate promoted the development of renal tubular cell tumors.

In a medium-term bioassay for renal tumorigenesis, the feeding of male Wistar rats with 5% potassium dibasic phosphate in the diet promoted the development of preneoplastic lesions.[66] These study results were obtained from a Japanese publication with few details in the English abstract.

IRRITATION AND SENSITIZATION

Dermal

Non-Human

Skin irritation and sensitization data on phosphoric acid and its ammonium, sodium, potassium, calcium, and magnesium salts are presented in Table 10. A broad range of reactions (non-irritating to corrosive) is reported. Phosphoric acid was classified as non-irritating or corrosive, the sodium salts were non-irritating to moderately irritating, and the potassium and calcium salts were non-irritating to mildly irritating to rabbit skin. The magnesium salts of phosphoric acid were non-irritating to the skin of rabbits. Pentasodium triphosphate and sodium metaphosphate were mildly irritating to the

skin of human subjects. Phosphoric acid was a non-sensitizer in human subjects, and sodium phosphate was a non-sensitizer in the local lymph node assay.

Case Reports

Calcium Pyrophosphate

The articular deposition of calcium pyrophosphate (calcium pyrophosphate deposition disease [CPPD]) is a common age-related phenomenon. Frequently, this disease is asymptomatic and unassociated with structural joint damage.[67,68] Acute attacks of synovitis, resulting in pseudogout, are observed occasionally.[69] These attacks are often provoked by local trauma or surgery and commonly involve the knee, and, less often, the wrist, hip, shoulder, and elbow.

Sodium Phosphate

A systematic review of adverse event reports relating to oral sodium phosphate (used for bowel cleansing prior to colonoscopy) was performed.[70] Fifty-eight publications of significant events in 109 patients who used sodium phosphate were identified. Between January of 2006 and December of 2007, the most commonly reported findings were electrolyte disturbances, renal failure, and colonic ulceration. The number of cases of renal failure reported to FDA during this period was 171.

A retrospective study was performed using the FDA Adverse Event Reporting System, a voluntary reporting system available for public access, and renal adverse events were identified.[71] A total of 2,097,223 files (years 2004–2008 and the first 9 months of 2009) was extracted from FDA's website. Of these, 178 patients (71% women) on sodium phosphate tablets were identified, with increasing numbers of renal adverse drug reactions from tablet preparations reported each year. In 2006, nine of 74 (12%) renal adverse drug reactions (ADRs) were from tablets and results (tablets ingested) for subsequent years were as follows: 40 of 181 (22%) [2007], 46 of 148 (31%) [2008], and 60 of 795 (7.55%) [2009]. The mean weight for women with renal complications from tablet preparations was 68.57 ± 1.78 kg, significantly lower than the national average weight of 74 ± 0.5 kg for the same age group ($P = 0.003$) in the National Health and Nutrition Examination Survey. It was concluded that renal adverse drug reactions from sodium phosphate tablets were more common in women with a mean body weight lower than the national average weight.

In more recent studies, 10 adult cases of acute phosphate nephropathy, associated with acute renal failure, following administration of a sodium phosphate preparation before colonoscopy, were reported, as well as a case series of 3 children with severe hyperphosphatemia and hypocalcemia after the use of sodium phosphate-containing laxatives.[72,73] Acute renal failure due to phosphate nephropathy following bowel cleansing with an oral sodium phosphate solution was reported in another patient.[74] Electron microscopy of a kidney biopsy sample revealed membranous glomerulonephritis, and calcium phosphate deposits were observed in tubular cells and in tubules. Phosphate remained elevated for 11 days; other electrolyte levels were normal. A biopsy taken only 2 months before the acute kidney disease showed no sign of the calcium phosphate deposits found in the second biopsy. It was concluded that the phosphate load given to the patient was responsible for the biopsy findings.

Ocular Irritation

Non-Human

Ocular irritation data on phosphoric acid and its ammonium, sodium, potassium, calcium, and magnesium salts are presented in Table 11. A broad range of reactions (non-irritating to corrosive) is reported, non-irritating to moderately irritating (rinsed eyes) and mildly irritating to extremely irritating (unrinsed eyes).

Mucosal Irritation

Human

Phosphoric Acid

Phosphoric Acid (50%) was applied to the gingival tissue and teeth of 26 orthodontic patients.[3] The 90-second contact period for the acid was followed by rinsing. No demonstrable test substance-related effect on treated tissues was observed during the 7-day observation period.

Tetrasodium Pyrophosphate
Tetrapotassium Pyrophosphate

Some non-prescription dentifrices, particularly pyrophosphate-based tartar control toothpastes, may be irritating to oral tissues.[32] The following clinical observations were made in patients (number not stated) at a dental clinic that frequently uses tartar control toothpastes containing tetrasodium pyrophosphate and/or tetrapotassium pyrophosphate: pale gingival tissues, mucosal sloughing, small blisters, dryness of oral tissues, and/or free-gingival-margin erythema. Subjective symptoms included a painful, burning sensation of oral tissues (most commonly gingival mucosa); a generalized, non-specific sensitivity or odd feeling to teeth and/or soft tissues; and sensations of "itchy" oral tissues. Patient complaints averaged approximately 5 per week over a 2-year period. Amelioration of the patients' chief complaint symptoms occurred rapidly upon switching to a non-tartar control toothpaste.

EPIDEMIOLOGY

Acids

Phosphoric Acid

In the 1980s, a large population-based case-control study in Montreal was performed to explore the possible associations between hundreds of occupational substances and multiple cancer sites,[75] and an analysis of the occupational information collected in this study (focusing on renal cell cancer) was subsequently performed.[75] In this study, the following individuals were interviewed: 142 male patients with pathologically confirmed renal carcinoma; 1900 controls with cancer at other sites; and 533 population-based controls. Logistic regression results for exposure to selected substances were presented, including the following 2 sets of odds ratios: (1) OR_1 (95% confidence interval [CI]): Odds ratios (adjusted for respondent status, age, smoking and body mass index [BMI]) and 95% CI; (2) OR_2 (95%CI):Odds ratios (adjusted for respondent status, age,smoking,BMIand occupational confounders) and 95% CI. There was evidence of excess risk for renal cell carcinoma following workplace exposure to phosphoric acid, as indicated by the following odds ratios (considered high): The OR_1 value reported for phosphoric acid was 3.4 (1.3-9.2), and an OR_2 value of 2.4 (0.8-7.0) was reported. [75] Notwithstanding the low precision of many of the odds ratio estimates, the following workplace exposures also showed some evidence of excess risk of renal cell carcinoma: chromium compounds, chromium (VI) compounds, inorganic acid solutions, styrene-butadiene rubber, ozone, hydrogen sulfide, ultraviolet radiation, hair dust, felt dust, jet fuel engine emissions, jet fuel, aviation gasoline, and inks.

In the International Agency for Research on Cancer (IARC) monograph on occupational exposures to mists and vapors from sulfuric acid and other inorganic acids (phosphoric acid included), several questionable epidemiological studies in the phosphate fertilizer manufacturing industry showed excess lung cancer; but, IARC did not classify phosphoric acid as carcinogenic.[76] However, IARC did conclude that occupational exposure to strong-inorganic-acid mists containing sulfuric acid is carcinogenic to humans.

Phosphates

Cancer morbidity and mortality were studied in a population of employees of phosphate ore mining and processing operations in Central Florida.[77] The workers involved in the study were employed by participating phosphates companies between 1950 and 1979, and the study population consisted of 3541 male employees who had worked for 6 months or more. Based upon an industrial hygiene analysis, only drying/shipping, chemical/fertilizer, and maintenance job categories were found to have the potential for exposure to high levels of dust, chemical fumes, or radiation. Cancer incidence was traced using questionnaires confirmed by medical records, and by tumor registry searches. Standardized incidence ratios (SIRs) were calculated. In order to estimate the study population's risk in relation to general rates in the United States, standardized mortality ratios (SMRs) adjusted for age and calendar time were calculated. The SMRs were tested for statistical significance at the 0.05 level using the Poisson distribution. Statistically significant elevations in lung cancer (standardized mortality ratio = 1.62) and emphysema were observed when compared to rates in the United States. For workers employed over a period of 20 years, there was a dose-response trend of increasing lung cancer risk with increasing duration of employment (standardized mortality ratio = 2.48, with 20 years of employment). There was no evidence of excess lung cancer risk among employees who were hired after 1960. The authors noted that multivariate analyses and internal comparisons of risk by job type were consistent with a hypothesis of occupationally-related lung cancer, but that the small numbers prevented firm conclusions.

MISCELLANEOUS INFORMATION

Calcium Phosphate and
Calcium Pyrophosphate

Calcium pyrophosphate dihydrate and basic calcium phosphate crystals are common components of synovial fluids.[78] Calcium pyrophosphate dihydrate deposition disease involves the calcification of tendons and ligaments, accompanied by involvement of hyaline and fibro-cartilage.

SUMMARY

The safety of 31 ingredients, phosphoric acid and its salts, as used in cosmetics is reviewed in this safety assessment. The functions of these ingredients in cosmetic products frequently include buffering agents, corrosion inhibitors, chelating agents, and pH adjusters.

According to the 2015 VCRP data, the greatest reported use frequency is for phosphoric acid (446 formulations, mostly rinse-off), followed by disodium phosphate (268 formulations, mostly rinse-off). Lower use frequencies are being reported for the remaining simple salts. The results of a concentration of use survey provided in 2015 indicate that disodium phosphate has the highest maximum concentration of use; it is used at concentrations up to 58% in leave-on products (face and neck products [not spray]).

Phosphoric acid can become dissociated and then absorbed as phosphate and hydronium ions through mucous membranes. Some of the phosphate and hydronium ions are conjugated in the liver and then excreted in the urine. Following the absorption of phosphates from the gastrointestinal tract, phosphate combines with calcium to form $CaHPO_4$ in bones and teeth. Free orthophosphate is the primary form by which dietary P_i is absorbed. In general, approximately two thirds of the ingested phosphate is absorbed from the gastrointestinal tract in adults, and absorbed phosphate is almost entirely excreted in the urine.

In acute inhalation toxicity studies, at the highest lethal concentrations, phosphoric acid caused tracheal lesions in rabbits, rats, and mice, but not in guinea pigs. Overall, the data suggest that the sodium, potassium, and calcium salts exhibit a low potential for inhalation toxicity. The EPA has calculated an inhalation reference concentration (RfC) of 1×10^{-2} mg/m^3. for phosphoric acid, based of the results from two parallel 13-week inhalation toxicity studies involving rats. In general, the RfC is an estimate of a daily inhalation exposure of the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime.

In acute oral toxicity studies involving rats, LD_{50s} for phosphoric acid ranged from 1530 mg/kg to 4400 mg/kg. The oral LD_{50} for phosphoric acid in rabbits was 2740 mg/kg. Oral LD_{50s} for the ammonium salts of phosphoric acid in studies involving rats ranged from 5750 mg/kg (ammonium phosphate) to > 25,100 mg/kg (diammonium phosphate). Sodium salts of phosphoric acid were administered to rats, mice, hamsters and guinea pigs in acute oral toxicity studies, and LD_{50} values ranged from 1300 mg/kg (tetrasodium pyrophosphate [mice]) to 10,600 mg/kg (sodium trimetaphosphate [rats]). For potassium salts of phosphoric acid admistered orally in studies involving rats or mice, acute oral LD_{50} values ranged from 1,000 mg/kg (tetrapotassium pyrophosphate [mice]) to 7,100 mg/kg (potassium phosphate [rats]). In acute oral toxicity studies on calcium salts of phosphoric acid involving rats or mice, LD_{50} values ranged from 2,170 mg/kg (calcium phosphate [rats]) to > 10,000 mg/kg (calcium pyrophosphate [rats]). LD_{50} values for magnesium phosphate in studies involving rats ranged from > 1,000 mg/kg (magnesium phosphate) to > 10,000 mg/kg (trimagnesium phosphate).

The feeding of phosphoric acid at concentrations up to 0.75% in the diet of rats for 52 weeks yielded a NOEL of 338 mg/kg/day. A no-observed-adverse-effect level (NOAEL) of 105 mg/kg/day was reported in a study in which sheep received doses of phosphoric acid up to 211 mg/kg/day for 70 days. An NOAEL of 250 mg/kg/day was reported for groups of rats that received diammonium phosphate at doses up to 1500 mg/kg/day for 35 days. The average weight of the parathyroid glands (only parameter assessed) was 235% of control values in rabbits that received oral doses of diammonium phosphate up to 700 mg/kg/day for up to 16 months.

A study of rats fed disodium phosphate or disodium pyrophosphate (up to 5% in the diet) for 100 days resulted in an LOEL of < 2571 mg/kg/day (only dose tested - disodium phosphate) and an LOEL of < 514 mg/kg/day (disodium pyrophosphate). When disodium phosphate, pentasodium triphosphate, or tetrasodium pyrophosphate was administered to

rats at concentrations up to 5% in the diet for 39 weeks, an LOEL of 495 mg/kg/day was reported. Of the NOELs determined in rat studies, the lowest NOEL (90 mg/kg/day) was reported in a study in which rats were fed pentasodium triphosphate at concentrations up to 10% in the diet daily for 30 days. The lowest NOAEL (225 mg/kg/day) was reported in a study in which rats were fed sodium polyphosphate/sodium hexametaphosphate at concentrations up to 5% in the diet daily for 104 weeks. In studies involving dogs, an NOAEL of 100 mg/kg/day was reported for the following sodium salts, each of which was administered orally at a dose of 100 mg/kg/day for 30 days: pentasodium triphosphate, sodium polyphosphate/sodium hexametaphosphate, and sodium trimetaphosphate. Kidney damage (nephrocalcinosis) was a common pathological finding in repeated dose oral toxicity studies involving sodium salts of phosphoric acid. The feeding of rats with commercial preparations containing effective concentrations of up to 3.4% tetrasodium pyrophosphate and 1.7% potassium metaphosphate also resulted in nephrocalcinosis.

When potassium salts of phosphoric acid were fed in the diet of rats at concentrations ranging from 0.6% to 10%, nephrocalcinosis/nephrotoxicity was observed at concentrations of 5% (tetrapotassium pyrophosphate) and 10% (tetrapotassium pyrophosphate or dipotassium phosphate). Nephrocalcinosis was also observed in dogs that received a diet providing dipotassium phosphate at a dose of 800 mg/kg/day. There were basically no adverse effects in rats/monkeys fed calcium salts of phosphoric acid in the diet (up to 0.8% calcium and 1.30% phosphorus). The same was true for rats that received dicalcium phosphate or tricalcium phosphate at doses up to 1000 mg/kg/day.

In acute dermal toxicity studies involving rabbits, a dermal LD_{50} = 2740 mg/kg and an LD_{50} of > 3160 mg/kg were reported for phosphoric acid. For ammonium salts of phosphoric acid, dermal LD_{50s} were > 5000 mg/kg (rats) and ranged from > 7940 mg/kg to > 10,000 mg/kg (rabbits). Dermal LD_{50} values ranging from > 300 mg/kg to > 7940 mg/kg (rabbits) were reported for sodium salts of phosphoric acid. The oral administration of potassium salts of phosphoric acid to rabbits resulted in dermal LD_{50} values ranging from > 300 mg/kg to > 10,000 mg/kg. Dermal LD_{50} values ranging from > 300 mg/kg to > 7940 mg/kg were reported for calcium salts of phosphoric acid. LD_{50} values ranging from > 2000 mg/kg to > 7940 mg/kg were reported for magnesium salts of phosphoric acid.

The teratogenicity of ammonium, sodium, potassium, and calcium salts of phosphoric acid was assessed primarily using rats and mice; however, rabbits and hamsters were also used. These salts did not produce teratogenic effects *in vivo*, and the highest dose tested was diammonium phosphate at 1500 mg/kg/day for 35 days. However, the following salts of phosphoric acid were teratogenic to chick embryos: tetrasodium pyrophosphate (injection of 5 mg/egg), sodium hexametaphosphate (injection of 0.5 to 10 mg/egg), sodium phosphate (injection of 0.5 to 10 mg/egg), potassium phosphate (injection of 10 mg/egg), calcium phosphate (injection of 2.5 mg/egg), and tricalcium phosphate (injection of 2.5 mg/egg).

In vitro and *in vivo* genotoxicity data on phosphoric acid and its ammonium, sodium, potassium, and calcium salts are available. The *in vitro* tests included the Ames/*Salmonella* mutagenicity assay (with and without metabolic activation), the *Saccharomyces cerevisiae* mutagenicity assay (with and without metabolic activation), the chromosome aberrations assay (Chinese hamster fibroblasts), and the *in vitro* cytogenetics assay (human lung cells). The *in vivo* tests included the dominant lethal test (rats), host-mediated assay (mice), and the mouse translocation test. Phosphoric acid and its ammonium, sodium, potassium, and calcium salts did not produce positive responses in *in vitro* or *in vivo* genotoxicity assays.

In an oral carcinogenicity study, rats were fed mixtures containing up to 1.7% potassium metaphosphate and up to 5% tetrasodium pyrophosphate. Feeding was continued through the second and third generations produced. For all dietary groups, the tumor incidence was not greater than that observed in control animals. When groups of rats were fed pentasodium triphosphate or sodium hexametaphosphate at concentrations up to 5% in the diet for 2 years, there was no correlation between concentration in the diet and tumor incidence. The same was true for rats fed a diet containing up to 10% sodium trimetaphosphate.

The results of a study on high dietary P_i intake and the development of lung cancer in mice indicated that high dietary P_i strongly activated Akt signaling and increased lung tumorigenesis.

In a population-based case-control study, workplace exposure to phosphoric acid produced some evidence of excess risk of renal cell carcinoma. Furthermore, in an IARC monograph on occupational exposure to phosphoric acid and other inorganic acids, there were several questionable epidemiological studies of the phosphate fertilizer manufacturing industry that showed excess lung cancer. However, IARC did not classify phosphoric acid as carcinogenic. Dipotassium phosphate in the diet (containing the carcinogen, EHEN) of male rats promoted the development of renal tumors.

Skin irritation and sensitization data on phosphoric acid and its ammonium, sodium, potassium, calcium, and magnesium salts are available, and a broad range of reactions (non-irritating to corrosive) have been reported. Phosphoric acid was classified as non-irritating or corrosive, the sodium salts were non-irritating to moderately irritating, and the potassium and calcium salts were non-irritating to mildly irritating to rabbit skin. The magnesium salts of phosphoric acid

were non-irritating to the skin of rabbits. Pentasodium triphosphate and sodium metaphosphate were mildly irritating to the skin of human subjects. Phosphoric acid was a non-sensitizer in human subjects, and sodium phosphate was a non-sensitizer in the local lymph node assay.

Ocular irritation studies on phosphoric acid and its ammonium, sodium, potassium, calcium, and magnesium salts have been performed. A broad range of reactions (non-irritating to corrosive) is being reported, non-irritating to moderately irritating (rinsed eyes) and mildly irritating to extremely irritating (unrinsed eyes).

Renal failure has resulted from the use of sodium-phosphate-containing colonoscopy preparations. Other case reports have indicated that some non-prescription dentrifices, particularly pyrophosphate-based tartar control toothpastes, may be irritating (erythema, burning, and mucosal sloughing) to oral tissues. The clinical findings relate to tartar control toothpastes containing tetrasodium pyrophosphate and/or tetrapotassium pyrophosphate.

Table 1. Definitions, Structures, and functions of the ingredients in this safety assessment.[1,6]

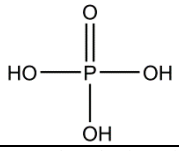
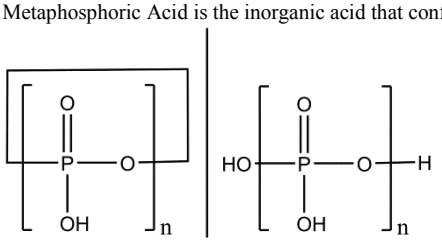
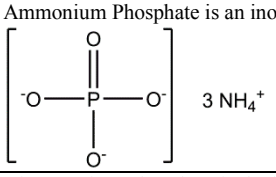
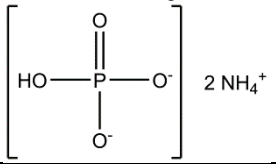
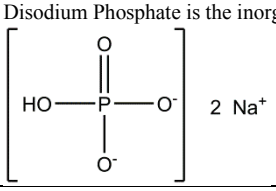
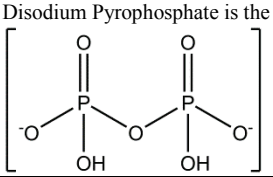
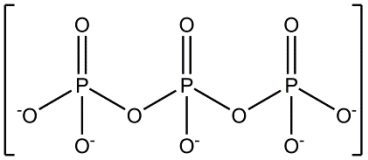
Ingredient/CAS No.	Definition & Structure	Function
Acids		
Phosphoric Acid 7664-38-2	Phosphoric Acid is the inorganic acid that conforms to the formula: 	Fragrance Ingredients; pH Adjusters
Metaphosphoric Acid 10343-62-1 37267-86-0	Metaphosphoric Acid is the inorganic acid that conforms to the formula:  ["Metaphosphoric" is a term used for a series of condensed protonated phosphates prepared by dehydration of orthophosphates; differing reaction conditions lead to various cyclic or linear polymeric structures. True metaphosphates, with the general formula, $(MHPO_3)n$, are cyclic polymers.]	pH Adjusters
Ammonium Salts		
Ammonium Phosphate 7722-76-1	Ammonium Phosphate is an inorganic salt that conforms to the formula: 	Buffering Agents; Oral Care Agents; pH Adjusters
Diammonium Phosphate 7783-28-0	Diammonium Phosphate is the inorganic salt that conforms to the formula: 	Buffering Agents; Corrosion Inhibitors; Oral Care Agents
Sodium Salts		
Disodium Phosphate 10140-65-5 7558-79-4 7782-85-6	Disodium Phosphate is the inorganic salt that conforms to the formula: 	Buffering Agents; Corrosion Inhibitors; Fragrance Ingredients; pH Adjusters
Disodium Pyrophosphate 7758-16-9	Disodium Pyrophosphate is the inorganic salt that conforms generally to the formula: 	Buffering Agents; Chelating Agents; Corrosion Inhibitors; pH Adjusters
Pentasodium Triphosphate 7758-29-4	Pentasodium Triphosphate is the inorganic salt that conforms to the formula: 	Chelating Agents; pH Adjusters

Table 1. Definitions, Structures, and functions of the ingredients in this safety assessment.[1,6]

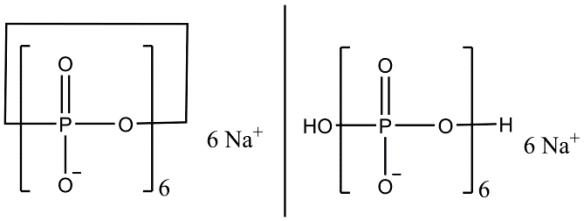
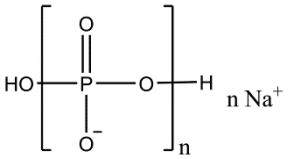
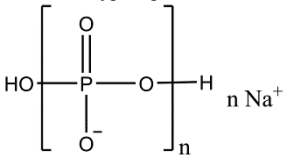
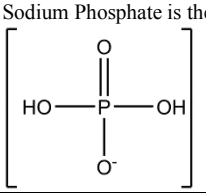
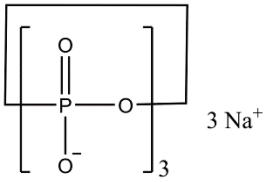
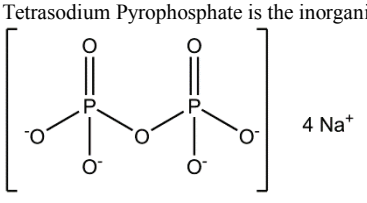
Ingredient/CAS No.	Definition & Structure	Function
Sodium Hexametaphosphate 10124-56-8 10361-03-2 68915-31-1	Sodium Hexametaphosphate is the inorganic salt that conforms generally to the formula:  [The name, sodium hexametaphosphate, has been used for both the cyclic hexamer and for a mixture of soluble sodium phosphate polymers also known as sodium polymetaphosphate.]	Chelating Agents; Corrosion Inhibitors; Fragrance Ingredients
Sodium Metaphosphate 10361-03-2 50813-16-6	Sodium Metaphosphate is a linear sodium polyphosphate that conforms generally to the formula:  ["Metaphosphate" is a term used for a series of condensed inorganic phosphates prepared by dehydration of orthophosphates; differing reaction conditions lead to various cyclic or linear polymeric structures. In contrast with the definition of this ingredient, true metaphosphates, with the general formula, $(MPO_3)n$, are cyclic polymers.]	Chelating Agents; Oral Care Agents
Sodium Polyphosphate 68915-31-1	Sodium Polyphosphate is a mixture of the sodium salts of polyphosphoric acid. 	Chelating Agents
Sodium Phosphate 7558-80-7 7632-05-5	Sodium Phosphate is the inorganic salt that conforms to the formula: 	Buffering Agents
Sodium Trimetaphosphate 7785-84-4	Sodium Trimetaphosphate is the inorganic salt that conforms to the formula:  ["Metaphosphate" is a term used for a series of condensed inorganic phosphates prepared by dehydration of orthophosphates; differing reaction conditions lead to various cyclic or linear polymeric structures. True metaphosphates, with the general formula, $(MPO_3)n$, are cyclic polymers.]	Buffering Agents; Chelating Agents; pH Adjusters
Tetrasodium Pyrophosphate 7722-88-5	Tetrasodium Pyrophosphate is the inorganic salt that conforms to the formula: 	Buffering Agents; Chelating Agents; Corrosion Inhibitors; Oral Care Agents; pH Adjusters

Table 1. Definitions, Structures, and functions of the ingredients in this safety assessment.[1,6]

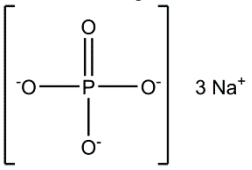
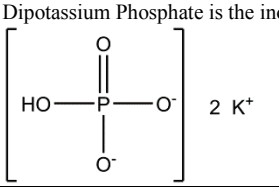
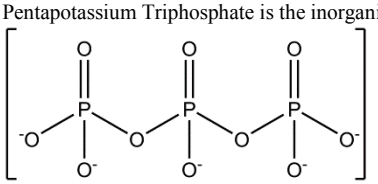
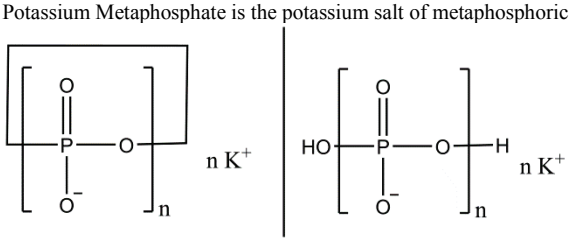
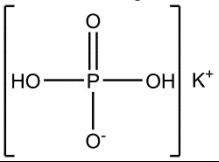
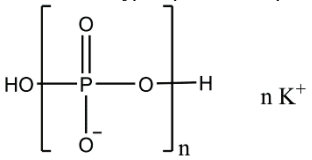
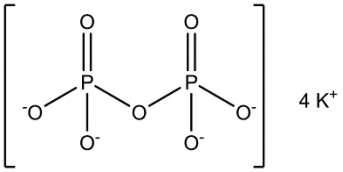
Ingredient/CAS No.	Definition & Structure	Function
Trisodium Phosphate 7601-54-9	Trisodium Phosphate is the inorganic salt that conforms to the formula: 	Chelating Agents; pH Adjusters
Potassium Salts		
Dipotassium Phosphate 7758-11-4	Dipotassium Phosphate is the inorganic salt that conforms generally to the formula: 	Corrosion Inhibitors; pH Adjusters
Pentapotassium Triphosphate 13845-36-8	Pentapotassium Triphosphate is the inorganic salt that conforms to the formula: 	Chelating Agents; pH Adjusters
Potassium Metaphosphate 7790-53-6	Potassium Metaphosphate is the potassium salt of metaphosphoric acid.  ["Metaphosphate" is a term used for a series of condensed inorganic phosphates prepared by dehydration of orthophosphates; differing reaction conditions lead to various cyclic or linear polymeric structures. True metaphosphates, with the general formula, $(MPO_3)n$, are cyclic polymers.]	Surfactants - Cleansing Agents
Potassium Phosphate 16068-46-5 7778-77-0	Potassium Phosphate is the inorganic salt that conforms generally to the formula: 	pH Adjusters
Potassium Polyphosphate 68956-75-2	Potassium Polyphosphate is the potassium salt of polyphosphoric acid. 	Chelating Agents
Tetrapotassium Pyrophosphate 7320-34-5	Tetrapotassium Pyrophosphate is the inorganic salt that conforms to the formula: 	Buffering Agents; Chelating Agents; Corrosion Inhibitors; Oral Care Agents; pH Adjusters

Table 1. Definitions, Structures, and functions of the ingredients in this safety assessment.[1,6]

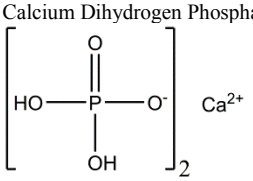
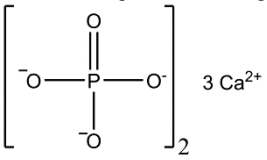
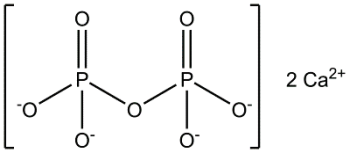
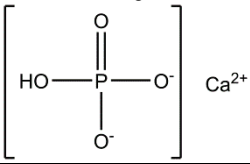
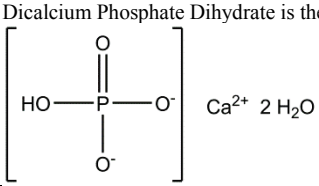
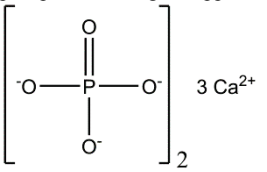
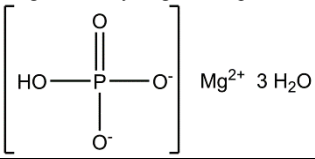
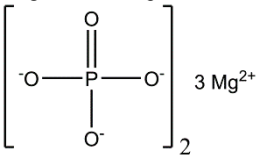
Ingredient/CAS No.	Definition & Structure	Function
Calcium Salts		
Calcium Dihydrogen Phosphate 7758-23-8	Calcium Dihydrogen Phosphate is the inorganic salt that conforms to the formula: 	pH Adjusters
Calcium Phosphate 10103-46-5	Calcium Phosphate is the inorganic salt that conforms to the formula: 	Abrasives; Buffering Agents; Bulking Agents; Oral Care Agents
Calcium Pyrophosphate 7790-76-3	Calcium Pyrophosphate is the inorganic salt that conforms to the formula: 	Abrasives; Buffering Agents; Bulking Agents; Oral Care Agents
Dicalcium Phosphate 7757-93-9	Dicalcium Phosphate is the inorganic salt that conforms to the formula: 	Abrasives; Opacifying Agents; Oral Care Agents
Dicalcium Phosphate Dihydrate 7789-77-7	Dicalcium Phosphate Dihydrate is the inorganic salt that conforms to the formula: 	Abrasives; Opacifying Agents; Oral Care Agents
Tricalcium Phosphate 7758-87-4	Tricalcium Phosphate is the inorganic salt that consists of a variable mixture of calcium phosphates having the approximate composition: 	Abrasives; Fragrance Ingredients; Opacifying Agents; Oral Care Agents
Magnesium Salts		
Magnesium Hydrogen Phosphate 7782-75-4	Magnesium Hydrogen Phosphate is the inorganic salt that conforms to the formula: 	Anticaking Agents
Magnesium Phosphate 10043-83-1	Magnesium Phosphate is the inorganic salt that conforms to the formula:  [Though a representative structure is drawn, the actual ratio of phosphate (with various degrees of protonation) to magnesium is variable for this ingredient]	Dispersing Agents - Nonsurfactant

Table 1. Definitions, Structures, and functions of the ingredients in this safety assessment.[1,6]

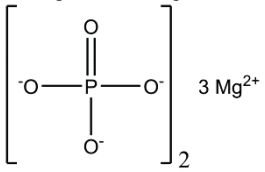
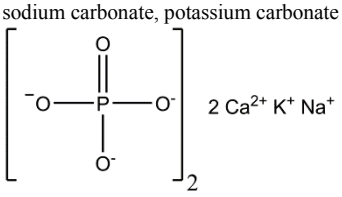
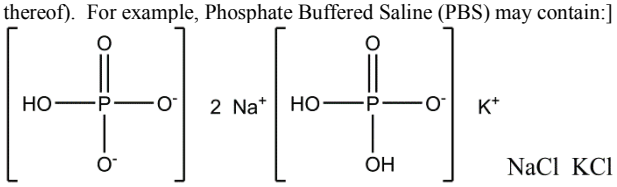
Ingredient/CAS No.	Definition & Structure	Function
Trimagnesium Phosphate 7757-87-1	Trimagnesium Phosphate is the inorganic salt that conforms to the formula:  	Bulking Agents; Opacifying Agents
Multi-cation Salts		
Calcium Potassium Sodium Phosphate 131862-42-5	Calcium Potassium Sodium Phosphate is the inorganic salt produced by the reaction of sodium carbonate, potassium carbonate and calcium hydrogen phosphate.  	Abrasives; Anticaries Agents; Antimicrobial Agents; Oral Care Agents
Phosphate Buffered Saline	Phosphate Buffered Saline is a phosphate buffered solution containing a physiological concentration of inorganic salt. [It is an aqueous solution containing phosphate and chloride salts of sodium, potassium, calcium, or magnesium (or some combination thereof). For example, Phosphate Buffered Saline (PBS) may contain:]  	Solvents

Table 2. Properties Phosphoric Acid and Simple Salts.[6]

Property	Value	Background Information
	Phosphoric Acid	
Form	Unstable orthorhombic crystals or clear, syrupy liquid	
% Composition	H (3.09%), O (65.31%), and P (31.61%)	
Molecular weight	97.99	
Density	1.8741 (100% solution)	
Solubility	Miscible with water and alcohol. Soluble in 8 vols of a 3:1 ether:alcohol mixture	
Melting point	42.35°C (orthorhombic crystals)	Becomes anhydrous at 150°. Changes to metaphosphoric acid when heated above 300°.
	Metaphosphoric Acid	
Form	Transparent, glass-like solid or soft silky masses; hygroscopic	Volatilizes at red heat
% Composition	H (1.26%), O (60.01%), and P (38.7%)	
Molecular weight	79.98	
Solubility	Very slowly soluble in cold water, slowly changing to H_3PO_4. Soluble in alcohol	
	Ammonium Phosphate	
Form	Odorless crystals or white crystalline powder	Stable in air
% Composition	H (5.26%), N (12.18%), O (55.64%), and P (26.93%)	
Density	1.80	
Molecular weight	115.02	
Solubility	1 g dissolves in ~ 2.5 ml water; slightly soluble in alcohol; practically insoluble in acetone	
Boiling point	376.1°C	
Melting point	193.3°C	
	Calcium Dihydrogen Phosphate	
Form	Monohydrate, large, shining, triclinic plates, crystalline powder, or granules	Non-hygroscopic when pure, but traces of impurities such as H_3PO_4 cause material to be deliquescent. Loses H_2O at 100°. Decomposes at 200°
% Composition	Ca (17.12%), H (1.72%), O (54.69%), and P (26.47%)	
Density	2.220	
Molecular weight	234.05	

Table 2. Properties Phosphoric Acid and Simple Salts.[6]

Property	Value	Background Information
	Calcium Dihydrogen Phosphate	
Solubility	Moderately soluble in water; soluble in dilute HCl or HNO_3 or acetic acid	
	Calcium Pyrophosphate	
Form	Polymorphous crystals or powder	
% Composition	Ca (31.55%), O (44.07%), and P (24.38%)	
Density	3.09	
Molecular weight	254.10	
Solubility	Practically insoluble in water; soluble in dilute HCl or HNO_3	
	Diammonium Phosphate	
Form	Odorless crystals or crystalline powder	Gradually loses approximately 8% NH_3 upon exposure to air
% Composition	H (6.87%), N (21.21%), O (48.46%), and P (23.45%)	
Molecular weight	132.06	
Solubility	1 g dissolves in 1.7 ml water; practically insoluble in alcohol and acetone	
	Dialcium Phosphate	
Form	Triclinic crystals	At red heat, dehydrated to calcium pyrophosphate
% Composition	Ca (29.46%), H (0.74%), O (47.04%), and P (22.76%)	
Molecular weight	136.06	
Solubility	Soluble in 3N HCl or 2N HNO_3; practically insoluble in water and alcohol	
	Dicalcium Phosphate Dihydrate	
Form	Monoclinic crystals	Loses water of crystallization slowly below 100°. Dehydration at red heat to calcium pyrophosphate
Density	2.31	
Solubility	Slightly soluble in dilute acetic acid; soluble in dilute HCl or HNO_3; practically insoluble in water and alcohol	
	Dipotassium Phosphate	
Form	White, hydroscopic granules	Converted into pyrophosphate by ignition
% Composition	H (0.58%), K (44.90%), O (36.74%), and P (17.78%)	
Molecular weight	174.17	

Table 2. Properties Phosphoric Acid and Simple Salts.[6]

Property	Value	Background Information
	Dipotassium Phosphate	
Solubility	Very soluble in water; slightly soluble in alcohol	
	Disodium Phosphate	
Form	Hygroscopic powder	On exposure to air, will absorb from 2 to 7 mols H_2O, depending on the humidity and temperature
% Composition	H (0.71%), Na (32.39%), O (45.08%), and P (21.82%)	
Molecular weight	141.96	
Solubility	Soluble in water; insoluble in alcohol	
	Disodium Pyrophosphate	
Form	White fused masses or powders	Decomposes at 220°
% Composition	H (0.91%), Na (20.72%), O (50.46%), and P (27.91%)	
Solubility	Soluble in water	
	Magnesium Hydrogen Phosphate	
Form	White crystalline powder	
% Composition	H (0.84%), Mg (20.21%), O (53.21%), and P (25.75%)	
Density	2.13	
Molecular weight	120.28	
Solubility	Soluble in dilute acids; slightly soluble in water	
	Magnesium Phosphate	
Form	White powder	
% Composition	H (1.85%), Mg (11.13%), O (58.64%), and P (28.38%)	
Molecular weight	218.28	
Solubility	Soluble in water	
	Pentasodium Triphosphate	
Form	Slightly hygroscopic granules	Reverts to the orthophosphate with prolonged heating
% Composition	Na (31.25%), O (43.49%), and P (25.26%)	
Molecular weight	367.86	
Solubility	Soluble in water	
	Potassium Metaphosphate	
Form	White, monoclinic crystals	
Density	2.45	
Solubility	Soluble in aqueous solutions of alkali metal (except potassium) salts; insoluble in water	

Table 2. Properties Phosphoric Acid and Simple Salts.[6]

Property	Value	Background Information
Potassium Phosphate		
Form	Colorless crystals or white, granular powder	At 400˚, loses H_2O, forming metaphosphate
% Composition	H (1.48%), K (28.73%), O (47.03%), and P (22.76%)	
Density	2.34	
Molecular weight	136.08	
Solubility	Soluble in water; practically insoluble in alcohol	
Potassium Polyphosphate		
Form	White, monoclinic crystals	
Density	2.45	
Solubility	Soluble in aqueous solutions of alkali metals (except potassium) salts; insoluble in water	
Sodium Hexametaphosphate		
		The name, sodium hexametaphosphate, has been used for both the cyclic hexamer and for a mixture of soluble sodium phosphate polymers
Sodium Metaphosphate		
		The name, sodium metaphosphate, is used for a series of condensed inorganic phosphates prepared by the dehydration of sodium orthophosphates
Sodium Phosphate		
% Composition	H (1.68%), Na (19.16%), O (53.34%), and P (25.82%)	
Molecular weight	119.98	
Sodium Polyphosphate		
Form	Clear, hygroscopic glass	Depolymerizes in aqueous solution to form sodium trimetaphosphate and sodium orthophosphates
Solubility	Soluble in water	
Melting point	628˚C	
Sodium Trimetaphosphate		
Form	White crystals or white, crystalline powder	Hydrolyzes to sodium tripolyphosphate (pentasodium triphosphate) in dilute alkaline solution
% Composition	Na (22.55%) O (47.07%), and P (30.38%)	
Density	2.49	
Solubility	Soluble in water	
Tetrapotassium Pyrophosphate		
% Composition	K (47.34%), O (33.90%), and P (18.75%)	
Molecular weight	330.33	
Solubility	Soluble in water; insoluble in alcohol	

Table 2. Properties Phosphoric Acid and Simple Salts.[6]

Property	Value	Background Information
Tetrasodium Pyrophosphate		
Form	Crystals	Hydrolyzes to orthophosphate in aqueous solution
% Composition	Na (34.58%), O (42.12%), and P (23.30%)	
Density	2.534	
Molecular weight	265.90	
Solubility	Soluble in water	
Tricalcium Phosphate		
Form	Amorphous powder	
% Composition	Ca (38.76%), O (41.27%), and P (19.97%)	
Density	3.14	
Molecular weight	310.17	
Solubility	Readily soluble in 3 N HCl and 2 $NHNO_3$; practically insoluble in water, alcohol, and acetic acid	
Trimagnesium Phosphate		
% Composition	Mg (27.74%), O (48.69%), and P (23.57%)	
Molecular weight	262.85	
Trisodium Phosphate		
% Composition	Na (42.07%), O (39.04%), and P (18.89%)	Crystallizes with 8 and 12 mols H_2O
Molecular weight	163.94	

Table 3. Current Frequency and Concentration of Use According to Duration and Type of Exposure.[19,20]

	Phosphoric Acid		Ammonium Phosphate		Diammonium Phosphate	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	446	0.000004-9	1	0.6	3	0.00046-5
Duration of Use						
Leave-On	126	0.000004-1.2	1	NR	NR	0.00046
Rinse off	310	0.00005-9	NR	0.6	3	5
Diluted for (bath) Use	10	0.34	NR	NR	NR	NR
Exposure Type						
Eye Area	7	NR	NR	NR	NR	NR
Incidental Ingestion	2	0.0003-0.21	NR	NR	NR	NR
Incidental Inhalation- Sprays	NR	0.001-0.26	NR	NR	NR	NR
Incidental Inhalation- Powders	NR	0.00001	NR	NR	NR	0.00046
Dermal Contact	132	0.000004-2.7	NR	NR	1	0.00046
Deodorant (underarm)	NR	0.068	NR	NR	NR	NR
Hair - Non-Coloring	122	0.00023-5.9	1	0.6	1	NR
Hair-Coloring	94	0.07-9	NR	NR	1	5
Nail	32	0.00049-0.1	NR	NR	NR	NR
Mucous Membrane	109	0.00005-0.34	NR	NR	NR	NR
Baby Products	NR	0.00001	NR	NR	NR	NR
	Disodium Phosphate		**Disodium Pyrophosphate**		**Pentasodium Triphosphate**	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	268	0.000054-58	15	0.05-0.3	43	0.25-9.3
Duration of Use						
Leave-On	79	0.000054-58	NR	NR	3	0.25-9.3
Rinse off	179	0.000055-2.9	15	0.05-0.3	23	1.1
Diluted for (bath) Use	10	0.04-0.2	NR	NR	17	6-9
Exposure Type						
Eye Area	15	0.00095-1	NR	NR	NR	NR
Incidental Ingestion	2	0.5	8	NR	22	1.1
Incidental Inhalation- Sprays	NR	0.02-0.3	NR	NR	NR	NR
Incidental Inhalation- Powders	NR	0.00095-58**	NR	NR	NR	1**
Dermal Contact	123	0.000054-58	NR	NR	17	1-9
Deodorant (underarm)	NR	0.03	NR	NR	NR	NR
Hair - Non-Coloring	21	0.000055-2	NR	NR	NR	NR
Hair-Coloring	71	0.0025-2.9	7	0.05-0.3	NR	NR
Nail	NR	NR	NR	NR	NR	0.25-9.3
Mucous Membrane	48	0.04-0.5	8	NR	39	1.1-9
Baby Products	NR	NR	NR	NR	NR	NR
	Sodium Hexametaphosphate		**Sodium Metaphosphate**		**Sodium Phosphate**	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	86	0.09-3	36	0.01-9.6	81	0.0000015-2.6
Duration of Use						
Leave-On	68	0.1-3	33	0.01-9.6	46	0.0000015-2
Rinse off	15	0.09-1.5	3	0.01-0.2	35	0.00007-2.6
Diluted for (bath) Use	3	NR	NR	0.03-0.5	NR	NR
Exposure Type						
Eye Area	18	NR	6	0.03-0.1	8	0.00007-0.5
Incidental Ingestion	1	NR	NR	0.14	7	0.25-0.55
Incidental Inhalation- Sprays	NR	NR	NR	0.04*	NR	0.000014
Incidental Inhalation- Powders	NR	0.1-3	NR	0.25	NR	0.00015-0.086
Dermal Contact	47	0.09-3	25	0.01-9.6	40	0.0000015-2.6
Deodorant (underarm)	NR	NR	NR	0.029	NR	0.099
Hair - Non-Coloring	NR	NR	NR	0.01-0.05	6	0.000014-2
Hair-Coloring	NR	NR	NR	0.15	1	NR
Nail	NR	NR	NR	0.03	NR	NR
Mucous Membrane	4	1.5	2	0.03-0.5	15	0.0032-2.6
Baby Products	NR	NR	NR	NR	NR	0.00015

Table 3. Current Frequency and Concentration of Use According to Duration and Type of Exposure.[19,20]

	Sodium Phosphate, Monobasic		**Tetrasodium Pyrophosphate**		**Trisodium Phosphate**	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	31	NR	113	0.0000014-6	24	0.00045
Duration of Use						
Leave-On	11	NR	17	0.03-3	12	0.00045-7
Rinse off	20	NR	96	0.0000014-6	12	0.05-1.7
Diluted for (bath) Use	NR	NR	NR	NR	NR	0.08
Exposure Type						
Eye Area	1	NR	2	NR	5	0.00045
Incidental Ingestion	NR	NR	8	0.4-2	5	NR
Incidental Inhalation- Sprays	NR	NR	NR	NR	NR	NR
Incidental Inhalation- Powders	NR	NR	NR	<0.1-1**	NR	7**
Dermal Contact	21	NR	40	0.0000014-3	8	0.00045-7
Deodorant (underarm)	NR	NR	NR	<0.01	NR	NR
Hair - Non-Coloring	1	NR	NR	0.000014-0.04	NR	0.25-0.5
Hair-Coloring	NR	NR	61	0.02-6	2	0.18-1.7
Nail	1	NR	NR	0.03	6	3.7
Mucous Membrane	16	NR	8	0.0000014-2	6	0.08
Baby Products	NR	NR	NR	NR	NR	NR
	Dipotassium Phosphate		**Potassium Metaphosphate**		**Potassium Phosphate**	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	31	0.002-1.8	NR	0.11	99	0.0000000014-0.9
Duration of Use						
Leave-On	10	0.002-0.3	NR	NR	39	0.0000000014-0.9
Rinse off	21	0.033-1.8	NR	0.11	59	0.00007-0.68
Diluted for (bath) Use	NR	NR	NR	NR	1	0.06
Exposure Type						
Eye Area	16	0.033-0.4	NR	NR	23	0.006-0.56
Incidental Ingestion	NR	NR	NR	NR	3	0.000007
Incidental Inhalation- Sprays	NR	NR	NR	NR	NR	0.00065-0.08
Incidental Inhalation- Powders	NR	0.002-0.3**	NR	NR	NR	0.0000000014-0.01**
Dermal Contact	27	0.002-0.47	NR	0.11	56	0.0000000014-0.9
Deodorant (underarm)	NR	NR	NR	NR	NR	0.07
Hair - Non-Coloring	1	NR	NR	NR	1	0.000003-0.6
Hair-Coloring	NR	1.8	NR	NR	4	0.2
Nail	NR	NR	NR	NR	1	NR
Mucous Membrane	1	0.05-0.066	NR	0.11	10	0.000007-0.06
Baby Products	NR	NR	NR	NR	NR	NR
	Tetrapotassium Pyrophosphate		**Calcium Dihydrogen Phosphate**		**Calcium Phosphate**	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	85	NR	4	NR	NR	0.0001
Duration of Use						
Leave-On	NR	NR	1	NR	NR	0.0001
Rinse off	85	NR	3	NR	NR	NR
Diluted for (bath) Use	NR	NR	NR	NR	NR	NR
Exposure Type						
Eye Area	NR	NR	NR	NR	NR	NR
Incidental Ingestion	23	NR	3	NR	NR	NR
Incidental Inhalation- Sprays	NR	NR	NR	NR	NR	NR
Incidental Inhalation- Powders	NR	NR	NR	NR	NR	NR
Dermal Contact	59	NR	NR	NR	NR	NR
Deodorant (underarm)	NR	NR	NR	NR	NR	NR
Hair - Non-Coloring	NR	NR	NR	NR	NR	NR
Hair-Coloring	NR	NR	NR	NR	NR	NR
Nail	NR	NR	1	NR	NR	0.0001
Mucous Membrane	23	NR	3	NR	NR	NR
Baby Products	NR	NR	NR	NR	NR	NR

Table 3. Current Frequency and Concentration of Use According to Duration and Type of Exposure.[19,20]

	Calcium Pyrophosphate		Dicalcium Phosphate		Dicalcium Phosphate Dihydrate	
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	# of Uses	Conc. (%)
Totals/Conc. Range	3	NR	314	0.000099-47.7	16	0.58-49
Duration of Use						
Leave-On	1	NR	309	0.04-10	11	0.58-6.8
Rinse off	2	NR	5	0.000099-47.7	5	49
Diluted for (bath) Use	NR	NR	NR	NR	NR	NR
Exposure Type						
Eye Area	NR	NR	22	0.042-10	6	0.58
Incidental Ingestion	2	NR	218	0.3-47.7	9	6.8-49
Incidental Inhalation- Sprays	NR	NR	NR	NR	NR	NR
Incidental Inhalation- Powders	NR	NR	NR	0.04-2.2	NR	2.2
Dermal Contact	NR	NR	84	0.04-10	6	0.58-2.2
Deodorant (underarm)	NR	NR	NR	0.49	NR	NR
Hair - Non-Coloring	1	NR	NR	0.000099	NR	NR
Hair-Coloring	NR	NR	NR	NR	NR	NR
Nail	NR	NR	NR	NR	NR	NR
Mucous Membrane	2	NR	218	0.3-47.7	9	6.8-49
Baby Products	NR	NR	NR	NR	NR	NR

	Tricalcium Phosphate		Trimagnesium Phosphate		
	# of Uses	Conc. (%)	# of Uses	Conc. (%)	
Totals/Conc. Range	31	NR	1	NR	
Duration of Use					
Leave-On	29	NR	NR	NR	
Rinse off	2	NR	1	NR	
Diluted for (bath) Use	NR	NR	NR	NR	
Exposure Type					
Eye Area	NR	NR	NR	NR	
Incidental Ingestion	2	NR	1	NR	
Incidental Inhalation- Sprays	NR	NR	NR	NR	
Incidental Inhalation- Powders	26	0.099**-10	NR	NR	
Dermal Contact	28	NR	NR	NR	
Deodorant (underarm)	NR	0.4	NR	NR	
Hair - Non-Coloring	NR	NR	NR	NR	
Hair-Coloring	NR	NR	NR	NR	
Nail	NR	NR	NR	NR	
Mucous Membrane	2	NR	1	NR	
Baby Products	7	0.12	NR	NR	

NR = Not Reported; Totals = Rinse-off + Leave-on + Diluted for (Bath) Use Product Uses.
*It is possible that these products may be sprays, but it is not specified whether the reported uses are sprays.
**It is possible that these products may be powders, but it is not specified whether the reported uses are powders.
***Not specified whether a powder or a spray, so this information is captured for both categories of incidental inhalation
Note: Because each ingredient may be used in cosmetics with multiple exposure types, the sum of all exposure type uses may not equal the sum total uses.

Table 4. Acute Inhalation Toxicity

Ingredient	Animals	Results
	Acids	
Phosphoric Acid (generated from pure red phosphorus ignited in an air stream). Target concentrations of smoke ranged from 111 to 6,731 mg/m^3 as phosphoric acid	New Zealand white rabbits (groups of 10), Porton strain rats (groups of 9 to 12), Porton strain mice (group of 20 or 50), and Dunkin-Hartley guinea pigs (groups of 10 or 20)	LC_{50}s (1-h exposure): 5337 mg/m^3 (rabbits), 3846 mg/m^3 (rats), 856 mg/m^3 (mice), and 193 mg/m^3 (guinea pigs). Lesions in larynx and trachea in all groups, except for guinea pigs.[79,80]
	Sodium Salts	
Disodium Pyrophosphate	Rats	LC_{50} (4-h exposure) > 0.58 mg/l air.[47]
Pentasodium Triphosphate	Rats	LC_{50} (4-h exposure) > 0.39 mg/l air.[47]
Sodium Polyphosphate/Sodium Hexametaphosphate	Rats	LC_{50} (4-h exposure) > 3.9 mg/l air.[47]
Sodium Phosphate	Rats	LC_{50} (4-h exposure) > 0.83 mg/l air.[47]
	Potassium Salts	
Tetrapotassium Pyrophosphate	Rats	LC_{50} (4-h exposure) > 1.1 mg/l air.[47]
	Calcium Salts	
Calcium Dihydrogen Phosphate	Rats (5 males and 5 females)	LC_{50} (4-h exposure) ≥ 2.6 mg/l air.[81,82]
Dicalcium Phosphate	Wistar rats (5 males and 5 females)	LC_{50} (4-h exposure) > 2.6 mg/l air.[83]

Table 5. Acute Oral Toxicity Studies

Ingredient	Test Concentration	Animals (number stated, if available from source)	Results
		Acids	
Phosphoric Acid	Not stated	Rats	LD_{50} = 1530 mg/kg.[3,80]
Phosphoric Acid	Not stated	Sprague-Dawley rats (12 females)	LD_{50} ≈ 2000 mg/kg.[80]
Phosphoric Acid	75%-85% solution	Rats	LD_{50} = 3160 mg/kg.[47]
Phosphoric Acid	85% solution	Rats	LD_{50} = 3380 mg/kg.[47]
Phosphoric Acid	85% solution	Sprague-Dawley albino rats (males and females)	LD_{50} = 3500 mg/kg.[80,84]
Phosphoric Acid	80% solution	Sprague-Dawley albino rats (males and females)	LD_{50} = 4200 mg/kg.[80,84]
Phosphoric Acid	75% solution	Sprague-Dawley albino rats (males and females)	LD_{50} = 4400 mg/kg.[80,84]
Phosphoric Acid		Rabbits	LD_{50} = 2740 mg/kg.[3]
		Ammonium Salts	
Ammonium Phosphate		Rats	LD_{50} >1000 mg/kg.[47]
Ammonium Phosphate		Rats	LD_{50} = 3250 mg/kg.[85]
Ammonium Phosphate		Rats	LD_{50} = 5750 mg/kg.[47]
Ammonium Phosphate		Rats	LD_{50} > 2000 mg/kg.[85]
Diammonium Phosphate		Rats	LD_{50} >1000 mg/kg.[47]
Diammonium Phosphate		Rats	LD_{50} > 2000 mg/kg.[85]
Diammonium Phosphate		Rats	LD_{50} = 6500 mg/kg.[47]
Diammonium Phosphate		Rats	LD_{50} > 25,100 mg/kg.[47]
		Sodium Salts	
Disodium Phosphate		Rats	LD_{50} = 5950 mg/kg.[47]
Disodium Pyrophosphate		Rats	LD_{50} >1000 mg/kg.[47]
Disodium Pyrophosphate		Rats	LD_{50} = 1690 mg/kg.[8]
Disodium Pyrophosphate		Rats	LD_{50} = 3600 mg/kg.[47]
Disodium Pyrophosphate		Rats	LD_{50} > 4000 mg/kg.[47,86]
Disodium Pyrophosphate		Mice	LD_{50} = 3350 mg/kg.[8]
Disodium Pyrophosphate		Hamsters	LD_{50} = 1660 mg/kg.[8]
Pentasodium Triphosphate		Rats	LD_{50} = 1700 mg/kg.[8]
Pentasodium Triphosphate		Rats	LD_{50} = 5010 mg/kg.[47]
Pentasodium Triphosphate		Mice	LD_{50} = 2380 mg/kg.[8]
Pentasodium Triphosphate		Rabbits	LD_{50} = 2500 mg/kg.[8]
Sodium Hexametaphosphate		Rats	LD_{50} = 2400 mg/kg.[8]
Sodium Hexametaphosphate		Mice	LD_{50} = 3700 mg/kg.[8]
Sodium Polyphosphate/Sodium Hexametaphosphate		Rats	LD_{50} = 2400 mg/kg.[47]
Sodium Polyphosphate/Sodium Hexametaphosphate		Rats	LD_{50} = 2900 mg/kg.[47,87]

Table 5. Acute Oral Toxicity Studies

Ingredient	Test Concentration	Animals (number stated, if available from source)	Results
Sodium Polyphosphate/Sodium Hexametaphosphate		Rats	LD_{50} >10,000 mg/kg.[47]
Sodium Polyphosphate/Sodium Hexametaphosphate		Mice	LD_{50} = 3700 mg/kg.[8]
Sodium Phosphate		Rats	LD_{50} = 4100 mg/kg.[8]
Sodium Phosphate		Rats	LD_{50} = 7100 mg/kg.[47]
Sodium Phosphate		Rats	LD_{50} = 8390 mg/kg.[47,88]
Sodium Phosphate		Mice	LD_{50} > 3700 mg/kg.[47,8]
Sodium Phosphate		Guinea pigs	LD_{50} > 2000 mg/kg.[47,86]
Sodium Trimetaphosphate		Rats	LD_{50} = 10600 mg/kg.[47]
Tetrasodium Pyrophosphate		Rats	LD_{50} = 1380 mg/kg.[8]
Tetrasodium Pyrophosphate		Rats (female)	LD_{50} = 1825 mg/kg.[47]
Tetrasodium Pyrophosphate		Rats (male)	LD_{50} = 2150 mg/kg.[47]
Tetrasodium Pyrophosphate		Rats	LD_{50} = 3770 mg/kg.[47]
Tetrasodium Pyrophosphate		Rats	LD_{50} = 1380 mg/kg.[8]
Tetrasodium Pyrophosphate (~ 67%) and potassium metaphosphate (~ 33%)		Rats	LD_{50} = 4000 mg/kg.[8]
Tetrasodium Pyrophosphate	200 mg/ml suspension in distilled water	Sprague-Dawley rats (females, groups of 5)	No clinical signs or necropsy findings. LD_{50} > 2000 mg/kg.[29,89]
Tetrasodium Pyrophosphate		Mice	LD_{50} = 1300 mg/kg.[8]
Trisodium Phosphate		Rats	LD_{50} > 2000 mg/kg.[47,90]
Trisosium Phosphate		Rats	LD_{50} = 4100 mg/kg.[47]
Trisodium Phosphate		Rats	LD_{50} = 4150 mg/kg.[47]
Trisodium Phosphate		Rats (female)	LD_{50} < 5000 mg/kg.[47]
Trisodium Phosphate	20% solution	Rats	LD_{50} = 6500 mg/kg.[47,91]
Trisodium Phosphate		Rats	LD_{50} = 7800 mg/kg.[47]
		Potassium Salts	
Dipotassium Phosphate		Rats	LD_{50} > 500 mg/kg.[47]
Dipotassium Phosphate		Rats	LD_{50} > 1000 mg/kg.[47]
Dipotassium Phosphate (liquid)		Rats	LD_{50} = 4810 mg/kg.[47]
Dipotassium Phosphate		Rats	LD_{50} = 5700 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rats (male)	LD_{50} > 1000 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rats	LD_{50} = 2980 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rats	LD_{50} = 3160 mg/kg.[47]

Table 5. Acute Oral Toxicity Studies

Ingredient	Test Concentration	Animals (number stated, if available from source)	Results
Tetrapotassium Pyrophosphate		Rats	LD_{50} = 3550 mg/kg.[47]
Tetrapotassium Pyrophosphate	Solution (concentration not stated)	Rats	LD_{50} = 2440 mg/kg.[47]
Tetrapotassium Pyrophosphate	Solution (concentration not stated)	Rats	LD_{50} < 5000 mg/kg.[47]
Tetrapotassium Pyrophosphate		Mice	LD_{50} = 1000 mg/kg.[47,92]
Dipotassium Phosphate		Mice	LD_{50} = 1700 mg/kg.[47,93]
Pentapotassium Triphosphate		Rats (male)	LD_{50} > 1000 mg/kg.[47]
Potassium Phosphate		Rats (male)	LD_{50} > 4640 mg/kg.[47]
Potassium Phosphate		Rats	LD_{50} = 7100 mg/kg.[47]
Potassium Phosphate		Rats	LD_{50} = 2820 mg/kg.[8]
Potassium Phosphate		Mice	LD_{50} = 1700 mg/kg.[47,94]
Potassium Phosphate		Mice	LD_{50} ≈ 3200 mg/kg.[8]
		Calcium Salts	
Calcium Dihydrogen Phosphate (in distilled water)		Female Sprague-Dawley rats (groups of 3)	LD_{50} > 2000 mg/kg.[81,82]
Calcium Dihydrogen Phosphate		Female Sprague-Dawley rats (groups of 5)	LD_{50} > 10000 mg/kg.[81,82]
Calcium Dihydrogen Phosphate		Albino rabbits (5 males and 5 females)	LD_{50} > 2000 mg/kg.[82]
Calcium Phosphate		Rats	LD_{50} > 1000 mg/kg.[47]
Calcium Phosphate		Rats	LD_{50} = 2170 mg/kg.[47]
Calcium Phosphate		Rats (female)	LD_{50} = 3986 mg/kg.[47]
Calcium Phosphate		Rats (male)	LD_{50} > 5000 mg/kg.[47]
Calcium Phosphate		Mice	LD_{50} = 4600 mg/kg.[8]
Dicalcium Phosphate		6 Sprague-Dawley rats (female)	LD_{50} ≥ 2000 mg/kg.[83]
Dicalcium Phosphate		Rats	LD_{50} = 7100 mg/kg.[47]
Dicalcium Phosphate		Rats	LD_{50} > 7940 mg/kg.[47]
Dicalcium Phosphate		10 Sprague-Dawley rats (female)	LD_{50} > 10000 mg/kg.[83]
Dicalcium Phosphate		Mice	LD_{50} ≈ 1700 mg/kg.[18]
Tricalcium Phosphate		Rats	LD_{50} > 5000 mg/kg.[47]
Tricalcium Phosphate		Sprague-Dawley rats (female, groups of 3)	LD_{50} > 2000 mg/kg.[55]
Calcium Pyrophosphate		Rats	LD_{50} > 10,000 mg/kg.[47]
		Magnesium Salts	
Magnesium Phosphate		Rats	LD_{50} > 1000 mg/kg.[47]

Table 5. Acute Oral Toxicity Studies

Ingredient	Test Concentration	Animals (number stated, if available from source)	Results
Magnesium Phosphate		Rats	LD_{50} > 4640 mg/kg.[47]
Magnesium Phosphate		Rats	LD_{50} > 5000 mg/kg.[47]
Trimagnesium Phosphate		Rats	LD_{50} > 10000 mg/kg.[47]
Magnesium Phosphate	Solution (concentration not stated)	Rabbits	LD_{50} > 2000 mg/kg.[47]

Table 6. Acute Dermal Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
		Acids	
Phosphoric Acid	85% solution	New Zealand white rabbits (males and females; groups of up to 2)	LD_{50} > 1260 mg/kg.[80]
Phosphoric Acid		Rabbits	LD_{50} = 2740 mg/kg.[47,88]
Phosphoric Acid	75% and 80% solutions	New Zealand white rabbits (males and females; groups of up to 2)	LD_{50} > 3160 mg/kg.[80]
Phosphoric Acid	85% solution	Rabbits	LD_{50} > 2000 mg/kg.[47]
		Ammonium Salts	
Ammonium Phosphate		Rats	LD_{50} > 5000 mg/kg.[85]
Ammonium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Diammonium Phosphate		Rats	LD_{50} > 5000 mg/kg.[85]
Diammonium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Diammonium Phosphate		Rabbits	LD_{50} > 10,000 mg/kg.[47]
Diammonium Phosphate		Rats	LD_{50} > 5000 mg/kg.[95]
		Sodium Salts	
Disodium Phosphate		Rabbits	LD_{50} >7940 mg/kg.[47]
Disodium Pyrophosphate		Rabbits	LD_{50} > 300 mg/kg.[96]
Disodium Pyrophosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Pentasodium Triphosphate		Rabbits	LD_{50} = 4640 mg/kg.[47]
Pentasodium Triphosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Sodium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Sodium Polyphosphate/Sodium hexametaphosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Tetrasodium Pyrophosphate		20 Sprague-Dawley rats	No clinical signs or necropsy findings. LD_{50} > 2000 mg/kg.[30]
Tetrasodium Pyrophosphate		Rabbits	LD_{50} > 2000 mg/kg.[47]
Tetrasodium Pyrophosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Trisodium Phosphate		Rabbits	LD_{50} > 300 mg/kg.[96]
Trisodium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
		Potassium Salts	
Dipotassium Phosphate		Rabbits	LD_{50} > 300 mg/kg.[47]
Dipotassium Phosphate (liquid)		Rabbits	LD_{50} > 5000 mg/kg.[47]
Dipotassium Phosphate		Rabbits	LD_{50} > 5000 mg/kg.[47]
Pentapotassium Triphosphate		Rabbits	LD_{50} > 4640 mg/kg.[47]
Potassium Phosphate		Rabbits	LD_{50} > 4640 mg/kg.[47]
Potassium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rabbits	LD_{50} > 2000 mg/kg.[47]
Tetrapotassium		Rabbits	LD_{50} > 4640 mg/kg.[47]

Table 6. Acute Dermal Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Pyrophosphate			
Tetrapotassium Pyrophosphate (liquid)		Rabbits	LD_{50} > 5000 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Tetrapotassium Pyrophosphate		Rabbits	LD_{50} > 10,000 mg/kg.[47]
Calcium Salts			
Calcium Dihydrogen Phosphate	2000 mg/kg	Rabbits (5 males and 5 females)	Severe erythema and mild edema. LD_{50} > 2000 mg/kg.[81]
Calcium Phosphate		Rabbits	LD_{50} > 300 mg/kg.[96]
Calcium Phosphate		Rabbits	LD_{50} > 2000 mg/kg.[47]
Calcium Pyrophosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Dicalcium Phosphate	2000 mg/kg	Stauffland albino rabbits (5 males and 5 females)	LD_{50} > 2000 mg/kg.[83]
Dicalcium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]
Tricalcium Phosphate		Rabbits	LD_{50} > 2000 mg/kg.[47]
Magnesium Salts			
Magnesium Phosphate	Solution (concentration not stated)	Rabbits	LD_{50} > 2000 mg/kg.[47]
Magnesium Phosphate		Rabbits	LD_{50} > 4640 mg/kg.[47]
Trimagnesium Phosphate		Rabbits	LD_{50} > 7940 mg/kg.[47]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
		Acids	
Phosphoric Acid	Oral doses of 0, 125, 250, or 500 mg/kg/day for 42 days (males) and 40 to 42 days (females)	Sprague-Dawley rats (13/sex/dose)	2 females of 500 mg/kg/day group died. NOAEL = 250 mg/kg/day.[79,80]
Phosphoric Acid	up to 0.75% in diet for > 52 weeks	Rats	NOEL = 338 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][47,86]
Phosphoric Acid	0, 35, 105, or 211 mg/kg/day for 70 days	Sheep	NOAEL = 105 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][97]
		Ammonium Salts	
Diammonium Phosphate	Oral doses (by gavage) of 0, 250, 750, or 1500 mg/kg/day (7 days/week) for 35 days	Rats (groups of 10 [5 males and 5 females/group])	Histological examination of stomach revealed submucosal inflammation (not dose-dependent) at all doses. NOAEL = 250 mg/kg/day.[85,98]
Diammonium Phosphate	Increasing oral doses (in drinking water) of 300 to 700 mg/kg/day for 5 to 16 months	10 Rabbits (females)	Average weight of parathyroid glands (only parameter assessed) was 235% of control values.[95]
		Sodium Salts	
Disodium Phosphate	10% in diet for 24 h to 72 h	Rats	Histological and histochemical changes in the kidneys.[8,99]
Disodium Phosphate	1.8%, 3%, and 5% in modified Sherman diet for 6 months	Young rats (groups of 34 to 36)	Significant decrease in growth and kidney damage (nephrocalcinosis) at dietary concentrations of 3% and 5%. Normal growth and slight increase (statistically significant) in kidney weight at 1.8% in the diet.[8,100]
Disodium Phosphate	0%, 1.1%, 1.8%, 3%, or 5% in diet for 39 weeks	Rats	Slight kidney calcification. LOEL = 495 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][8,47,101]
Disodium Phosphate	1%, 2.5%, and 5% in Sherman diet for 16 weeks	Rats	Severe kidney damage in 5% dietary group (number of animals not stated). Hypertrophy and hemorrhage of the stomach (number of animals not stated).[8,102]
Disodium Phosphate	5% disodium phosphate in the diet for 1 month (2571 mg/kg/day)	Weanling rats	Renal tubular necrosis. LOEL < 2571 mg/kg/day [assuming that 0.35 kg rat consumes18 g food/day][29,87]
Disodium Phosphate	1%, 2.5%, or 5% in diet containing 0.6% calcium and 0.5% phosphorus for 100 days	20 rats per sex	Renal histopathology, decreased renal function, and increased kidney weight in all dietary groups. LOEL for 5% in diet = 2571 mg/kg/day (assuming that 0.35-kg rat consumed 18 g food per day).[29,102]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Disodium Pyrophosphate	1%, 2.5%, or 5% in basal diet (contained 0.6% calcium and 0.5% phosphorus) for 100 days	Groups of 20 rats per sex	Renal histopathology, decreased renal function, and increased kidney weight in all groups except 1% dietary group. LOEL for 1% dietary group = 450 mg/kg/day (assuming that 0.35 kg rat consumes18 g food/day).[29,102]
Pentasodium Triphosphate	0%, 0.2%, 2%, or 10% for 30 days	Rats	NOEL = 103 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Pentasodium Triphosphate	0%, 0.2%, 2%, or 10% for 30 days	Rats	NOEL = 90 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Pentasodium Triphosphate	1% solutions (pH of 5) of 3%, and 5% pentasodium triphosphate (effective concentrations of 0.03% and 0.05%, respectively) in Sherman diet for 24 weeks	Groups of rats (36 males, 36 females/group)	Growth retardation at 0.05% in diet. Temporary growth retardation at 0.03% in diet. Nephrocalcinosis at both concentrations.[8,103,104,100]
Pentasodium Triphosphate	0%, 1.1%, 1.8%, 3%, and 5% for 39 weeks	Rats	LOEL = 495 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][47,101]
Pentasodium Triphosphate	1.8%, 3%, and 5% (pH of 5 for each) in Sherman diet for 24 weeks	Groups of rats (36 males, 36 females/group)	Growth retardation at 5% in diet, temporary growth retardation at 3% in diet, and normal growth at 1.8% in diet. Nephrocalcinosis at 1.8%, 3%, or 5% in diet. Extent of kidney damage less at test substance pH of 5 than at pH 9.5.[8,103,104,100]
Pentasodium Triphosphate	0.05%, 0.5%, or 5% in diet for 2 years	Weanling rats (groups of 50 males and 50 females)	Growth reduction only at 5% in diet (significant in males; slight in females). Smaller number (not stated) of rats fed 5% in diet survived. Low grade of anemia and increased kidney weight only at 5% in diet. NOEL = 225 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][8,87]
Pentasodium Triphosphate	Oral dose rate of 0.1 g/kg/day for 1 month (1 dog). 2 other dogs dosed similarly for 1 month, and dose had increased to 4 g/kg/day by end of 5-month period	3 dogs	Kidney tubule damage in dogs receiving higher doses. No treatment-related changes in dog dosed with 0.1 g/kg/day only.[8]
Pentasodium Triphosphate	0 and 100 mg/kg/day for 30 days	Dogs	NOAEL = 100 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Sodium Hexametaphosphate	0.9% and 35% in diet for up to 150 days. Control group: diet containing 0.4% P and 0.5% Ca	Groups of 12 male rats	Kidney weight significantly heavier in 30% dietary group (possibly due to high salt load on kidneys), when compared to control. No histopathological abnormalities in either group.[8,105]
Sodium Hexametaphosphate	0.2%, 2%, or 10% in diet for 1 month	Groups of 5 weanling male rats	Increased relative kidney weight and renal tubular necrosis at 120% in diet. Dietary no-effect-level of 0.2% in diet (equivalent to 103 mg/kg/day, assuming that 0.35-kg rat consumes 18 g food/day).[29,87]
Sodium Hexametaphosphate	0.05%, 0.5%, or 5% in diet for 2 years	Groups of 50 male and 50 female weanling rats	Calcification and increased kidney weight (not significant changes) in 5% dietary group. High mortality in all groups (unrelated to dietary concentration).[8]
Sodium Hexameatphosphate	1% in diet containing iron (1000 ppm) and iodine (30 ppm) for 9 months. Control group: unfortified salt diet	8 Wistar/NIN rats	No gross bone abnormality. Normal histology of kidneys and parathyroid gland in test and control groups.[106]
Sodium Hexametaphosphate	Oral dose rate of 0.1 g/kg/day for 1 month (1 dog). 2 other dogs dosed similarly for 1 month, and dose had increased to 4 g/kg/day by end of 5-month period	3 dogs	Kidney tubule damage in dogs receiving higher doses. No treatment-related changes in dog dosed with 0.1 g/kg/day only.[8]
Sodium Polyphosphate/Sodium Hexametaphosphate	0%, 0.2%, 2%, or 10% in diet for 30 days	Rats	NOEL = 103 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Sodium Polyphosphate/Sodium Hexametaphosphate	0%, 0.1%, 1%, and 10% in diet for 104 weeks	Rats	NOAEL = 450 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Sodium Polyphosphate/Sodium Hexametaphosphate	0%, 0.05%, 0.5%, or 5% in diet for 104 weeks	Rats	NOAEL = 225 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Sodium Polyphosphate/Sodium Hexametaphosphate	0%, 0.93%, or 3.5% in diet for 21 weeks	Rats	NOAEL = 1575 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][47,105]
Sodium Polyphosphate/Sodium Hexametaphosphate	0 or 100 mg/kg/day for 30 days	Dogs	NOAEL = 100 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87]
Sodium Phosphate	0.4% or 0.6% in diet for 28 days	Juvenile female Wistar rats (RIV:TOX)	At 0.6% in diet, significant increase in kidney weight (25%) and in incidence of nephrocalcinosis.[29,107]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Sodium Phosphate	1%, 2.5%, or 5% in Sherman diet for 16 weeks	Groups of 20 male and female rats	Increased kidney weight (females) and decreased kidney function (males) at ≥ 2.5% in diet. Kidney damage (calcification, degeneration, and necrosis) in greater % of rats in 1% dietary group, when compared to control group.[8]
Sodium Phosphate	1.8%, 3%, or 5% in modified Sherman diet for 6 months	Groups of 34 to 36 young rats	Nephrocalcinosis in 3% and 5% dietary groups. At microscopic examination, kidney calcification in some of the animals (number not stated). Slight increase (statistically significant) in kidney weight in 1.8% dietary group.
Sodium Phosphate	8% in diet for 7 months or until exitus	Weanling rats	Gradual bone decalcification, renal calcium deposition, and significant parathyroid hypertrophy and hyperplasia. Histological evidence of metastatic calcium deposits in renal tubules and long-bone periosteum and endosteum.[62]
Sodium Phosphate	1.1% in diet for 39 weeks	Rats	Slight degree of kidney calcification.[8,101]
Sodium Phosphate	0, 43, 129, or 258 mg/kg/day for 70 days	Sheep	NOEL = 258 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][97]
Sodium Trimetaphosphate	0.2%, 2%, or 10% in diet for 1 month	Weanling male rats (5 per group)	Reduced body weight, increased relative kidney weights, and renal tubular necrosis at 10% in diet. Acute inflammation or pelvic lesions in some of the rats (number not stated) fed 2% in diet. Dietary no-effect-level of 0.2% in diet (equivalent to 103 mg/kg/day, assuming that 0.35-kg rat consumes 18 g of food/day).[29,87]
Sodium Trimetaphosphate	0.1%, 1%, or 10% in diet for 2 years	Rats	At 10% in diet, substantial growth retardation (males and females) and anemia (females).[108]
Sodium Trimetaphosphate	0.05%, 0.5%, or 5% in diet for 2 years	Rats	Substantial growth retardation in males of 5% dietary group, but females slightly affected. 65% of rats examined in 5% dietary group presented with intertubular calcification, as distinguished from the coexistent pyelonephritis present in old rats. NOAEL = 450 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][87,108]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Sodium Trimetaphosphate	0 and 100 mg/kg/day for 30 days	Dogs	NOAEL = 100 mg/kg/day.[87]
Tetrasodium Pyrophosphate	250, 500, or 1000 mg/kg/day by gavage for 90 days (5 days/week) (OECD Guideline 408)	Groups of 20 Sprague-Dawley rats (10 males and 10 females/group)	No treatment-related mortalities. Increased white blood cell count (males and females) and decreased red blood cell count (males) at 1000 mg/kg/day. Significantly increased liver weight in males and females of 500 and 1000 mg/kg/day groups. Kidney lesions in males and females of 1000 mg/kg/day group. NOEL = 250 mg/kg/day; NOAEL = 500 mg/kg/day.[30]
Tetrasodium Pyrophosphate	0%, 1.1%, 1.8%, 3%, or 5% in diet for 39 weeks	Rats	LOEL = 495 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][47,101]
Trisodium Phosphate	8% in diet for 7 months or until animals died	Mature rats	Pathological effects in parathyroids, kidneys, and bones. LOEL < 3600 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.] [8,109,110]
Sodium and Potassium Salts			
Diets high (1.5%) in P (as monophosphate or tripolyphosphate sodium or potassium salts)	Feeding for 13 days	Male rats	Nephrocalcinosis.[29,111]
Tetrasodium Pyrophosphate + Potassium Metaphosphate	0.5% commercial preparation containing 67% tetrasodium pyrophosphate and 33% potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 0.5% x 67% = 0.34%; effective concentration [potassium metaphosphate] = 0.5% x 33% = 0.17%]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth, average lifespan, and kidney weight normal.[8,61]
Tetrasodium Pyrophosphate + Potassium Metaphosphate	1% commercial preparation containing 67% tetrasodium pyrophosphate and 33%potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 1% x 67% = 0.67%; effective concentration [potassium metaphosphate] = 1% x 33% = 0.33 %]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth and average lifespan normal. Nephrocalcinosis and slight increase (significant increase only in males) in kidney weight observed.[8,61]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Tetrasodium Pyrophosphate + Potassium Metaphosphate	2.5% commercial preparation containing 67% tetrasodium pyrophosphate and 33% potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 2.5% x 67% = 1.7%; effective concentration [potassium metaphosphate] =2.5% x 33% = 0.83%]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth and average lifespan normal. Nephrocalcinosis and increased kidney weight observed.[8,61]
Tetrasodium Pyrophosphate + Potassium Metaphosphate	5% commercial preparation containing 67% tetrasodium pyrophosphate and 33% potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 5% x 67% = 3.4%; effective concentration [potassium metaphosphate] = 5% x 33% = 1.7%]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth retardation, increased kidney weight, and nephrocalcinosis observed.[8,61]
		Potassium Salts	
Dipotassium Phosphate	10% in diet for 8 weeks	Male Wistar rats	Nephrotoxicity at 10% in diet.[66]
Dipotassium Phosphate	0.87% and 5.1% in diet for 60 days and 150 days. 5.1% in diet equivalent to 2623 mg/kg/day, assuming that 0.35-kg rat consumes 18 g food/day	Groups of 12 Wistar male rats	Kidney weight significantly increased after 150 days of feeding at 5.1% in diet; no histopathological lesions in kidney. No other treatment-related effects at gross or histopathological examination. NOAEL = 2623 mg/kg/day.[18]
Dipotassium Phosphate	0.87% or 5.1% for 21 weeks	Rats	NOAEL = 2295 mg/kg/day [Extrapolated from level of chemical in diet, assuming 0.35-kg rat eats 18 g food/day.][47,105]
Dipotassium Phosphate	5% in diet in medium-term bioassay	Male Wistar rats	Renal calcification and severe nephropathy.[66]
Dipotassium Phosphate	Oral doses of 1000 mg/kg/day for 42 days (males) and 42 to 54 days (females)	Rats (males and females)	Significant decreases in liver and heart weights-to-body weight ratio. No gross or histopathological alterations. LOEL = 1000 mg/kg/day.[112]
Dipotassium Phosphate	Dose of 1000 mg/kg/day for 42 days (males) and for 42 to 54 days (females)	Sprague-Dawley rats (16 males and 16 females/group)	No deaths or abnormal clinical changes. Statistically significant reductions in red blood cells in females, but not in males. Significantly lower relative liver and heart weights observed not considered toxicological findings, due to absence of histopathological changes. LOEL = 1000 mg/kg/day.[18]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Dipotassium Phosphate	Diet providing 800 mg/kg/day for 14 and 38 weeks	15 Beagle dogs	Renal damage consisted of disseminated tubular atrophy (usually of the proximal tubules), focal scar tissue, and nephrocalcinosis. Renal morphological changes in all dogs after 14 and 38 weeks; renal damage greater after 38 weeks. LOEL < 800 mg/kg/day. [18, 47,113,114]
Tetrapotassium Pyrophosphate	0.6%, 1.25%, 2.5%, 5%, or 10% in diet (to estimate maximum tolerable dose for long-term carcinogenicity study)	Groups of 60 male and female F344 rats	3 rats (from 10% dietary group) died of renal failure. Histopathological exam results for 5% and 10% dietary groups: necrosis and calcification of renal tubules, ulceration and /or granuloma formation in tongue mucosa, and hypertrophy of salivary glands.[115]
		Calcium Salts	
Calcium Phosphate	0.8% calcium and 0.9% phosphorus in diet (duration not stated)	Guinea pigs	Calcium deposits in soft tissues. Reduction in deposits when phosphorus content reduced to 0.5%.[8,116]
Calcium Phosphate	0.56% calcium and 0.42% phosphorus in the diet for up to 150 days	12 rats	No adverse physiological effects at necropsy or microscopic examination.[8,105]
Calcium Phosphate	0.47% calcium and 0.43% phosphorus in the diet for up to 150 days	12 rats	No adverse physiological effects at necropsy or microscopic examination.[8,105]
Calcium Phosphate	0.5% calcium and 1.30% phosphorus in the diet for up to 150 days	12 rats	No adverse physiological effects at necropsy or microscopic examination.[8,105]
Calcium Phosphate	High phosphorus containing diets (Ca:P ratios of up to 1:4) for 88 months	Cinnamon ringtail monkeys (*Cebus albiffrons*)	Minor bone changes observed microscopically.[8,117]
β-Calcium Pyrophosphate (in saline)	Feeding 7 days/week (30 mg/kg/day) for 90 days.	Sprague-Dawley rats (10 males, 10 females)	No deaths or adverse toxic effects.[36]
Dicalcium Phosphate	Doses of 0, 250, 500, or 1000 mg/kg/day by gavage for 28 days	Rats (10 per sex in control and highest dose groups; 5 per sex in other groups)	No treatment-related clinical, hematological, or necropsy findings. Statistically significant increase in relative liver weight in males of the 250 mg/kg group, but no morphological findings in the liver. NOAEL = 1000 mg/kg/day.[81,118]
Dicalcium Phosphate	Doses of 0, 250, 500, or 1000 ml/kg/day for 28 days by gastric intubation	Sprague-Dawley rats (10/sex/dose)	No gross or microscopic effects. NOAEL > 1000 ml/kg/day.[83]

Table 7. Repeated Dose Oral Toxicity Studies

Ingredient	Test Concentration/Dose	Animals (number stated, if available from source)	Results
Tricalcium Phosphate	Doses of 0, 250, 500, or 1000 mg/kg/day by gavage. Males dosed from 2 weeks before mating to end of mating. Females dosed from 2 weeks before mating to day 4 of lactation (including the mating and gestation periods)	Rats (10 per sex in each group)	No deaths or toxicologically significant findings. NOAEL = 1000 mg/kg/day.[54,55]

*NOEL = no-observed-effect level; NOAEL = no-observed-adverse-effect level; LOEL = lowest-observed-effect level

Table 8. Reproductive and Developmental Toxicity Studies

Ingredient	Test Protocol	Animals/Embryos	Results
		Acids	
Phosphoric Acid	0.4% and 0.75% in diet for 90 weeks	Rats from 3 successive generations (number not stated)	No adverse effects on reproduction at either dietary concentration.[8,119]
Phosphoric Acid	Oral doses of 0, 125, 250, or 500 mg/kg/day, to male rats for 42 days (2 weeks prior to mating to 2 weeks after mating); to female rats for 40 to 52 days (2 weeks prior to mating to day 4 post partum)	Rats (13 males 13 females/group)	No reproductive effects or treatment-related changes in neonatal survival or external abnormalities.[79,80]
		Ammonium Salts	
Diammonium Phosphate	Oral doses of 0, 250, 750, or 1500 mg/kg/day (7 days/week) for 35 days	Rats (5 males and 10 females/group)	No reproductive or developmental effects at doses administered. NOAEL = 1500 mg/kg/day.[85,98]
		Sodium Salts	
Disodium Pyrophosphate	Doses (in water) up to 335 mg/kg/day on gestation days 6-15	19 to 22 CD-1 mice	No treatment-related effects (NOEL > 335 mg/kg).[120]
Disodium Pyrophosphate	Doses (in water) up to 169 mg/kg/day on gestation days 6-15	21 to 24 Wistar rats	No treatment-related effects (NOEL > 169 mg/kg).[120]
Disodium Pyrophosphate	Doses (in water) up to 166 mg/kg/day on gestation days 6-10	20 to 22 Golden hamsters	No treatment-related effects (NOEL > 166 mg/kg).[120]
Disodium Pyrophosphate	Doses (in water) up to 128 mg/kg/day on gestation days 6-18	9 to 12 Dutch-belted rabbits	No treatment-related effects (NOEL > 128 mg/kg).[120]
Pentasodium Triphosphate	Oral doses (in water) up to 238 mg/kg/day on gestation days 6-15	Groups of 21 to 24 pregnant albino, CD-1 outbred mice.	No clearly discernible treatment-related effect on nidation or on maternal or fetal survival. Number of abnormalities (in soft or skeletal tissues) in test animals did not differ from number occurring in sham-treated controls. NOEL > 238 mg/kg.[121,122]
Pentasodium Triphosphate	Oral doses (in water) up to 170 mg/kg/day on gestation days 6-15	Groups of 19 to 23 Wistar albino rats	No clearly discernible treatment-related effect on nidation or on maternal or fetal survival. Number of abnormalities (in soft or skeletal tissues) in test animals did not differ from number occurring in sham-treated controls. NOEL > 170 mg/kg.[121,122]
Pentasodium Triphosphate	Oral doses (in water) up to 141 mg/kg/day on gestation days 6-10	Groups of 20 to 21 pregnant female golden hamsters	No clearly discernible treatment-related effect on nidation or on maternal or fetal survival. Number of abnormalities (in soft or skeletal tissues) in test animals did not differ from number occurring in sham-treated controls. NOEL > 141 mg/kg.[121,122]

Table 8. Reproductive and Developmental Toxicity Studies

Ingredient	Test Protocol	Animals/Embryos	Results
Pentasodium Triphosphate	Oral doses (in water) up to 250 mg/kg/day on gestation days 6-18	Groups of 13 to 16 pregnant female Dutch-belted rabbits	No clearly discernible treatment-related effect on nidation or on maternal or fetal survival. Number of abnormalities (in soft or skeletal tissues) in test animals did not differ from number occurring in sham-treated controls. NOEL > 250 mg/kg.[123,124]
Pentasodium Triphosphate	5% in diet for 2 years	Groups of weanling rats (50 males and 50 females/group). Feeding through 3 generations (2 litters produced in each generation)	Normal reproduction and no adverse reproductive effects in offspring.[8]
Pentasodium Triphosphate	Injection (increasing doses of 0.7 to 10 mg, and dose of 30 mg) into air chamber of chick embryo after 24 h and 72 h of incubation	Chick embryos	No effects at any dose after 24 h or 72 h of incubation. [125]
Sodium Hexametaphosphate	5% in diet for 2 years	Groups of weanling rats (50 males and 50 females/group). Feeding through 3 generations (2 litters produced in each generation)	Normal reproduction and no adverse reproductive effects in offspring.[8]
Sodium Hexametaphosphate	Doses (vehicle not stated) up to 370 mg/kg/day on gestation days 6-16	~ 24 albino CD-1 mice	No treatment-related effects (NOEL > 370 mg/kg).[8]
Sodium Hexametaphosphate	Doses (vehicle not stated) up to 138 mg/kg/day on gestation days 6-16	~ 24 Wistar albino rats	No treatment-related effects (NOEL > 138 mg/kg).[8]
Sodium Hexametaphosphate	Injection via the air cell/yolk. Doses up to 10 mg/egg (maximum volume injected = 100 µl). LD_{50} values determined and gross examination for developmental abnormalities performed	100 chick embryos per dose level	LD_{50} = 1.53 mg/egg (air cell injection). Cleft palate and other anomalies at all doses (0.5 to 10 mg/egg). Teratogenic.[126]
Sodium Metaphosphate	Injection (increasing doses of 0.7 to 10 mg, and dose of 30 mg) into air chamber of chick embryo after 24 h and 72 h of incubation	Chick embryos	No effects at any dose after 72 h of incubation. Doses of 10 to 15 mg had lethal effect after 24 h of incubation. Embryos of 2nd and 3rd brooding day had characteristic misshapes of the brain, heart primordium, and somites. Anomalies observed at microscopic examination.[125]
Sodium Phosphate	Injection via the air cell/yolk. Doses up to 10 mg/egg (maximum volume injected = 100 µl). LD_{50} values determined and gross examination for developmental abnormalities performed	100 chick embryos per dose level	LD_{50} = 2 mg/egg (air cell injection); LD_{50} = 0.53 mg/egg (yolk injection). Cleft palate and other anomalies at all doses (0.5 to 10 mg/egg). Teratogenic.[126]

Table 8. Reproductive and Developmental Toxicity Studies

Ingredient	Test Protocol	Animals/Embryos	Results
Sodium Polyphosphate/Sodium Hexametaphosphate	Doses (vehicle not stated) up to 141 mg/kg/day; days of gestation not stated	Rats and mice	No treatment-related effects (NOEL > 141 mg/kg).[110]
Sodium Phosphate	Doses (in water) up to 370 mg/kg/day on gestation days 6-15	19 to 22 CD-1 mice	No treatment-related effects (NOEL > 370 mg/kg).[127]
Sodium Phosphate	Doses (in water) up to 410 mg/kg/day on gestation days 6-15	20 Wistar rats	No treatment-related effects (NOEL > 410 mg/kg).[127]
Sodium Trimetaphosphate	0.1%, 1%, or 10% in diet for 2 years	Weanling rats (number/strain not stated)	At up to 10% in diet, no effect on fertility or litter size through F_2 generation.[62]
Tetrasodium Pyrophosphate	Doses (in corn oil) up to 130 mg/kg/day on gestation days 6-15	18 to 21 CD-1 mice	No treatment-related effects (NOEL > 130 mg/kg).[128]
Tetrasodium Pyrophosphate	Doses (in corn oil) up to 138 mg/kg/day on gestation days 6-15	19 to 21 Wistar rats	No treatment-related effects (NOEL > 138 mg/kg).[128]
Tetrasodium Pyrophosphate	Injection via the air cell/yolk. Doses up to 5 mg/egg (maximum volume injected = 100 µl). LD_{50} values determined and gross examination for developmental abnormalities performed	100 chick embryos per dose level	LD_{50} values: 3.87 mg/egg (air cell injection at 0 h), 0.34 mg/egg (air cell injection at 96 h), and 0.12 mg/egg (yolk sac injection at 0 h). Serious terata reported, including one observation of ectopia cordis. Teratogenic.[126]
Sodium and Potassium Salts			
Tetrasodium Pyrophosphate + Potassium Metaphosphate	0.5% commercial preparation (in Sherman diet) containing 67% tetrasodium pyrophosphate and 33% potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 0.5% x 67% = 0.34%; effective concentration [potassium metaphosphate] = 0.5% x 33% = 0.17%]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth and fertility were normal. No difference in incidence of abnormalities between treated and control animals.[8,61]
Tetrasodium Pyrophosphate + Potassium Metaphosphate	1% commercial preparation (in Sherman diet) containing 67% tetrasodium pyrophosphate and 33% potassium metaphosphate (effective concentration [tetrasodium pyrophosphate = 1% x 67% = 0.67%; effective concentration [potassium metaphosphate] = 1% x 33% = 0.33 %]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth and fertility were normal. No difference in incidence of abnormalities between treated and control animals.[8,61]

Table 8. Reproductive and Developmental Toxicity Studies

Ingredient	Test Protocol	Animals/Embryos	Results
Tetrasodium Pyrophosphate + Potassium Metaphosphate	5% commercial preparation (in Sherman diet) containing 67% tetrasodium pyrophosphate and 33%potassium metaphosphate (effective concentration [tetrasodium pyrophosphate =5% x 67% = 3.4%; effective concentration [potassium metaphosphate] = 5% x 33% = 1.7%]	Rats (10 males, 10 females). Feeding continued through 2nd and 3rd generations	Growth and fertility were normal. No difference in incidence of abnormalities between treated and control animals.[8,61]
		Potassium Salts	
Dipotassium Phosphate	Doses of 1000 mg/kg/day for 42 days (males) and 42 to54 days (females)	Sprague-Dawley rats (males and females)	No reproductive or developmental toxic effects. NOAEL = 1000 mg/kg/day.[18]
Potassium Phosphate	Doses (in water) up to 320 mg/kg/day on gestation days 6-15	20 to 22 CD-1 mice	No treatment-related effects (NOEL > 320 mg/kg).[129]
Potassium Phosphate	Doses (in water) up to 282 mg/kg/day on gestation days 6-15	20 to 25 Wistar rats	No treatment-related effects (NOEL > 282 mg/kg).[129]
Potassium Phosphate	Injection (in water) via the air cell and via the air cell/yolk. Doses up to 10 mg/egg (maximum volume injected = 100 µl). LD_{50} values determined and gross examination for developmental abnormalities performed	100 chicken embryos per dose level	LD_{50} = 1.51 mg/egg. Non-teratogenic.[126]
		Calcium Salts	
Calcium Phosphate	Doses (in water) up to 465 mg/kg/day on gestation days 6-15	19 to 24 CD-1 mice	No treatment-related effects (NOEL > 465 mg/kg).[130]
Calcium Phosphate	Doses (in water) up to 410 mg/kg/day on gestation days 6-15	19 to 22 Wistar rats	No treatment-related effects (NOEL > 410 mg/kg).[130]
Calcium Phosphate	Doses (in water) up to 217 mg/kg/day on gestation days 6-18	9 to 17 Dutch-belted rabbits	No treatment-related effects (NOEL > 217 mg/kg).[130]
Calcium Phosphate	Injection (in 1 N HCl) via the air cell/yolk. Doses up to 2.5 mg/egg (maximum volume injected = 100 µl). LD_{50} values determined and gross examination for developmental abnormalities performed	100 chick embryos per dose level	LD_{50} = 0.37 mg/egg. Non-teratogenic.[126]
Dicalcium Phosphate	Doses of 0, 250, 500, or 1000 mg/kg/day. Males dosed once daily for 2 weeks prior to, during, and post-mating (42 days total). Females dosed once daily for weeks prior to mating, throughout gestation,	Rats (13/sex/dose)	No dose-related effects on mating, gestation, or external malformations. NOAEL of 1,000 mg/kg/day (parents and pups).[81,118]

Table 8. Reproductive and Developmental Toxicity Studies

Ingredient	Test Protocol	Animals/Embryos	Results
	and 4 days after delivery		
Tricalcium Phosphate	Doses of 0, 250, 500, or 1000 mg/kg/day by gavage. Males dosed from 2 weeks before mating to end of mating. Females dosed from 2 weeks before mating to day 4 of lactation (including the mating and gestation periods)	Rats (10/sex/dose)	No treatment-related adverse effects on reproductive parameters and no externally malformed neonates in any dose group. NOAEL for reproductive and developmental toxicity = 1000 mg/kg/day.[54,55]
Tricalcium Phosphate	Injection (in water) via the air cell and via the air cell/yolk. Doses up to 2.5 mg/egg (maximum volume injected = 100 µl)	100 chick embryos per dose level	LD_{50} = 0.85 mg/egg. Non-teratogenic.[126]

Table 9. Genotoxicity Studies

Ingredient/Similar Chemical	Strain/cell type	Assay	Dose/Concentration	Results
		Acids		
Phosphoric Acid	*Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and *E. coli* strain WP2*uvr*A	Ames test	up to 5000 µg/plate	Negative in all strains (with and without metabolic activation).[79,80]
Phosphoric Acid (75%-85% solution)	*Salmonella typhimurium* strains TA97, TA98, TA100, TA102, and TA1535	Ames Test	Concentrations not stated (pHs ranged from 4 to 9)	Negative in all strains (with and without metabolic activation).[80,131]
Phosphoric Acid (75%-85% solution)	*Salmonella typhimurium* strains TA97, TA98, TA100, and TA104	Ames Test	up to 2 µl/plate	Negative in all strains (with and without metabolic activation).[132]
Phosphoric Acid	Chinese hamster lung cells	Chromosome aberrations assay	Up to 450 µg/ml	Negative (with and without metabolic activation).[79,80]
		Ammonium Salts		
Diammonium Phosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537 and *E. coli* strain WP2*uvr*A	Ames Test	up to 5000 µg/plate	Negative (with and without metabolic activation).[95]
Diammonium Phosphate	Chinese hamster ovary cells	Chromosome aberrations assay	Up to 1230 µg/ml	Negative (with and without metabolic activation).[95]
		Sodium Salts		
Disodium Phosphate	*Salmonella typhimurium* strains TA92, TA94, TA98, TA100, TA1535 and TA1537	Ames Test	up to 100 mg/plate	Negative in all strains (with and without metabolic activation).[133]
Disodium Phosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535 and TA1537	Ames Test	up to 10,000 µg/plate	Negative in all strains (with and without metabolic activation).[134]
Disodium Phosphate	Chinese hamster fibroblasts (CHL cell line)	Chromosome aberrations assay	up to 2 mg/ml	Negative.[133]
Disodium Pyrophosphate	*Salmonella typhimurium* strains TA92, TA94, TA98, TA100, TA1535 and TA1537	Ames Test	up to 10 mg/plate	Negative in all strains (with and without metabolic activation).[133]
Disodium Pyrophosphate	*Salmonella typhimurium* strains TA97, TA98, TA100, TA102, and TA1535	Ames Test	5% (w/v)	Negative in all strains (with and without metabolic activation).[110]
Disodium Pyrophosphate	*Saccharomyces cerevisiae*	*S. cerevisiae* mutation assay	Not stated	Negative (with or without metabolic activation not stated).[110]
Disodium Pyrophosphate	*Salmonella typhimurium* strain TA1530 and *S. cerevisiae* strain D3	Host mediated assay	up to 1400 mg/kg	Negative in both strains.[110]
Disodium Pyrophosphate	Rats	Dominant lethal test	up to 720 mg/kg	Negative.[110]

Table 9. Genotoxicity Studies

Ingredient/Similar Chemical	Strain/cell type	Assay	Dose/Concentration	Results
Disodium Pyrophosphate	Male mice	Mouse translocation test	up to 1400 mg/kg	Negative.[110]
Disodium Pyrophosphate	Chinese hamster fibroblasts (CHL cell line)	Chromosome aberrations assay	up to 0.5 mg/ml	Negative.[133]
Pentasodium Triphosphate	WI-38 human lung cells (without metabolic activation)	*In vitro* cytogenetics assay	up to 10 µg/ml.	Negative.[135]
Pentasodium Triphosphate	Rats (bone marrow cells)	*In vivo* cytogenetics assay	up to 2500 mg/kg	Negative.[135]
Pentasodium Triphosphate	*Salmonella typhimurium* strains his G46 and TA1530, and *S. cerevisiae* strain D3	Host mediated assay (cells inoculated into mice)	up to 2500 mg/kg	Negative.[135]
Pentasodium Triphosphate	Rats	Dominant lethal test	up to 2500 mg/kg	Negative.[135]
Sodium Hexametaphosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538	Ames test	Not stated	Negative in all strains (with and without metabolic activation).[8]
Sodium Polyphosphate/Sodium Hexametaphosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538	Ames Test	up to 0.018 µg/plate	Negative in all strains (with and without metabolic activation).[110]
Sodium Polyphosphate/Sodium Hexametaphosphate	*S. cerevisiae* strain D4	*S. cerevisiae* mutation assay	up to 0.018 µg/plate	Negative (with and without metabolic activation).[110]
Sodium Phosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538	Ames Test	up to 1.25%	Negative in all strains (with and without metabolic activation).[136]
Sodium Phosphate	*S. cerevisiae* strain D4	*S. cerevisiae* mutation assay	up to 5%	Negative (with and without metabolic activation).[136]
Sodium Phosphate	*Escherichia coli* strain WP2uvrA	SOS chromotest (without metabolic activation)	10 to 100,000 nM/ml	Negative.[137,138]
Tetrasodium Pyrophosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538	Ames test	up to 0.1% (w/v)	Negative in all strains (with and without metabolic activation).[135]
Tetrasodium Pyrophosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1537, and *Escherichia coli* strain WP2uvrA	Ames test	Up to 4820 µg/plate	Negative in all strains (with and without metabolic activation).[139]
Tetrasodium Pyrophosphate	*S. cerevisiae* strain D4	*S. cerevisiae* mutation assay	up to 2.25% (w/v)	Negative (with and without metabolic activation).[135]
Potassium Salts				
Dipotassium Phosphate (liquid)	*Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and	Ames Test	up to 5 µl/plate	Negative in all strains (with and without metabolic

Table 9. Genotoxicity Studies

Ingredient/Similar Chemical	Strain/cell type	Assay	Dose/Concentration	Results
	TA1538; *S. cerevisiae* strain D4			activation).[47]
Dipotassium Phosphate	*Salmonella typhimurium* strains TA97 and TA102	Ames test	Up to ~ 10 mg/plate	Negative (with and without metabolic activation).[18]
Dipotassium Phosphate	Chinese hamster lung cells	Chromosome aberrations assay	Up to 5000 µg/ml	Negative (with and without metabolic activation).[18]
Potassium Phosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538; *S. cerevisiae* strain D4	Ames Test	up to 5% (w/v)	Negative in all strains (with and without metabolic activation).[140]
Tetrapotassium Pyrophosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535, TA1537, and TA1538; *S. cerevisiae* strain D4	Ames Test	up to 5 µl/plate	Negative in all strains (with and without metabolic activation).[47]
Calcium Salts				
Calcium Phosphate	*Salmonella typhimurium* strains TA1535, TA1537, and TA1538	Ames Test	up to 0.75%	Negative in all strains (with and without metabolic activation).[141]
Calcium Phosphate	*S. cerevisiae* strain D4	*S. cerevisiae* mutation assay	up to 5% (w/v)	Negative.[141]
Dicalcium Phosphate	*Salmonella typhimurium* strains TA97 and TA102	Ames Test	Not stated	Negative (with or without metabolic activation not stated).[47,142]
Dicalcium Phosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1537; *E. coli* strain WP2*uvr*A	Ames test	Up to 2000 µg/plate	Negative (with or without metabolic activation).[81]
Dicalcium Phosphate	Chinese hamster lung fibroblasts (CHL cells)	Chromosome aberrations assay	Up to 500 µg/ml	Not clastogenic (with or without metabolic activation).[81]
Tricalcium Phosphate	*Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1537; *E. coli* strain WP2*uvr*A	Ames test	Up to 1250 µg/plate	Negative (with or without metabolic activation).[13,55]
Tricalcium Phosphate	Chinese hamster lung cells (CHL/IU)	Chromosome aberrations assay	Up to 200 µg/ml	Negative (with or without metabolic activation).[13]

Table 10. Skin Irritation/Sensitization Studies

Ingredient (test concentration, if available)	Test Protocol	Non-humans/Humans (number stated, if available from source)	Results
		Acids	
Non-human Studies			
Phosphoric Acid (5% and 30%)	Intracutaneous application (intact skin). 6-h observation period	Juvenile white mice	5% concentration moderately irritating; 30% concentration severely irritating.[80]
Phosphoric Acid (100%)	4-h application (under occlusion) to abraded and intact skin	Rabbits	Corrosive.[47]
Phosphoric Acid (85% solution)	24-h application (under occlusion) to abraded and intact skin	Rabbits	Moderately to severely irritating.[47]
Phosphoric Acid (85% solution)	24-h application	New Zealand white rabbits	Corrosive.[80]
Phosphoric Acid (75%-85%)	24-h application (0.5 ml under semi-occlusive patch)	New Zealand albino rabbits	Corrosive.[143]
Phosphoric Acid (80%)	24-h application (0.5 ml under 1" x 1"occlusive patch) to abraded and intact skin	Rabbits (at least 6)	Highly irritating.[144]
Phosphoric Acid (75%, 80%, and 85%)	4-h application (0.5 ml under 1" x 1"occlusive patch) to abraded and intact skin	Albino rabbits (at least 6)	Non-corrosive (75% and 80%). Corrosive (85%).[145]
Phosphoric Acid (75%)	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Phosphoric Acid (75%)	4-h application (semiocclusion) to intact skin	1 New Zealand white rabbit	Non-irritating.[80]
Phosphoric Acid (70%)	4-h application (under occlusion) to abraded and intact skin	Rabbits	Corrosive.[47]
Phosphoric Acid (52%)	Applied (under occlusion) to abraded and intact skin	Rabbits	Severely irritating and corrosive.[47]
Phosphoric Acid (30%)	Buchner method.[146]	Not stated	Highly irritating.[147]
Phosphoric Acid (19%)	Not stated	2 Rabbits	Non-irritating.[148]
Phosphoric Acid (≥ 17.5 % [pH 0.6 to 0.2])	Under occlusion for 4 h	Rabbits	Corrosive (formation of scar tissue).[79]
Phosphoric Acid (2.5%, pH 2.1)	Not stated	3 Rabbits	Severe erythema with mild to moderate swelling (1 rabbit) at 42 h to 72 h after exposure.[79]
Human Studies			
Phosphoric Acid (concentration not stated)	Not stated	Human subjects	Non-sensitizer.[47,88]
		Ammonium Salts	
Non-human Studies			
Ammonium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Mildly irritating.[47]
Ammonium Phosphate	24-h application (under	Rabbits	Non-irritating.[47]

Table 10. Skin Irritation/Sensitization Studies

Ingredient (test concentration, if available)	Test Protocol	Non-humans/Humans (number stated, if available from source)	Results
	occlusion) to intact skin		
Diammonium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Mildly irritating.[47]
Diammonium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Diammonium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
	Sodium Salts		
Non-human Studies			
Disodium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Moderately irritating (abraded skin) and mildly irritating (intact skin).[47]
Disodium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Disodium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Mildly irritating.[96]
Disodium Pyrophosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating.[47]
Disodium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Pentasodium Triphosphate	4-h application (no occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Pentasodium Triphosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly to moderately irritating.[47]
Pentasodium Triphosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Moderately irritating.[47]
Pentasodium Triphosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating.[47]
Sodium Polyphosphate/Sodium Hexametaphosphate	4-h application (no occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Sodium Polyphosphate/Sodium Hexametaphosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Sodium Phosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Sodium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Sodium Phosphate	Local lymph node assay. Up to 10% in propylene glycol	Female mice of the CBA/Ca (CBA/CaOlaHsd) strain	Non-sensitizer.[83]
Sodium Trimetaphosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Tetrasodium Pyrophosphate (50% aqueous paste)	24-h application (under occlusion) to intact skin	Rabbits	Irritating.[47]

Table 10. Skin Irritation/Sensitization Studies

Ingredient (test concentration, if available)	Test Protocol	Non-humans/Humans (number stated, if available from source)	Results
Tetrasodium Pyrophosphate (25% aqueous suspension)	24-h application (under occlusion) to abraded and intact skin	Rabbits	Irritating.[47]
Tetrasodium Pyrophosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Tetrasodium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating[96]
Tetrasodium Pyrophosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Trisodium Phosphate (95% purity)	24-h application (under occlusion) to abraded and intact skin	Rabbits	Minimally irritating (abraded skin) and non-irritating (intact skin).[96]
Trisodium Phosphate (95% purity)	4-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[96]
Trisodium Phosphate (19% solution)	4-h or 24-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating at 4 h and non-irritating at 24 h
Trisodium Phosphate (15% solution)	4-h or 24-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating at 4 h and non-irritating at 24 h
Trisodium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Irritating (abraded and intact skin).[47]
Trisodium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Human Studies			
Pentasodium Triphosphate (50% solution)	Not stated	6 subjects	Negligible irritation potential.[29]
Sodium Metaphosphate (1%)	Application to intact skin	20 subjects (with suspected or verified contact allergy to cosmetic products)	Mild skin irritation.[29]
Potassium Salts			
Non-human Studies			
Dipotassium Phosphate	4-h (under occlusion) or 24-h (no occlusion) application to intact skin	Rabbits	Slightly irritating,[47]
Dipotassium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Mildly irritating.[47]
Dipotassium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Minimally irritating.[47]
Dipotassium Phosphate (liquid)	24-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating.[47]
Pentapotassium Triphosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Potassium Phosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]

Table 10. Skin Irritation/Sensitization Studies

Ingredient (test concentration, if available)	Test Protocol	Non-humans/Humans (number stated, if available from source)	Results
Potassium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Potassium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Tetrapotassium Pyrophosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Tetrapotassium Pyrophosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Tetrapotassium Pyrophosphate (aqueous solution)	24-h application (under occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Tetrapotassium Pyrophosphate (aqueous solution)	24-h application (under occlusion) to intact skin	Rabbits	Mildly irritating.[47]
Tetrapotassium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Slightly irritating.[47]
Tetrapotassium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
		Calcium Salts	
Non-human Studies			
Calcium Dihydrogen Phosphate	24 h application of 0.5 g (wrapped in rubber)	Rabbits (3 males and 3 females)	Non-irritating.[81]
Calcium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Mildly irritating.[47]
Calcium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Calcium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[96]
Calcium Pyrophosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating[47]
Dicalcium Phosphate	24-h application (0.5 g, under occlusion) to abraded and intact skin	6 Rabbits	Non-irritating.[83]
Dicalcium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Tricalcium Phosphate	4-h application (no occlusion) to intact skin	Rabbits	Non-irritating.[47]
Tricalcium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Slightly irritating.[47]
Tricalcium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]

Table 10. Skin Irritation/Sensitization Studies

Ingredient (test concentration, if available)	Test Protocol	Non-humans/Humans (number stated, if available from source)	Results
Magnesium Salts			
Non-human Studies			
Magnesium Phosphate	4-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Magnesium Phosphate	4-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]
Magnesium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Trimagnesium Phosphate	24-h application (under occlusion) to abraded and intact skin	Rabbits	Non-irritating.[47]
Trimagnesium Phosphate	24-h application (under occlusion) to intact skin	Rabbits	Non-irritating.[47]

Table 11. Ocular Irritation/Toxicity Studies

Ingredient	Test Protocol	Animals (number stated, if available from source)	Results
		Acids	
Phosphoric Acid (119 mg)	Not stated	Rabbits	Irritating. Risk of serious damage to eyes.[149]
Phosphoric Acid (75%, 80%, and 85% solutions)	Draize Test	3 rabbits	All corrosive.[80,84]
Phosphoric Acid (85%)	Draize Test	Rabbits	Severe irritant.[47]
Phosphoric Acid (70% solution)	Draize Test	Rabbits	Corrosive.[47]
Phosphoric Acid (10% and 17% in water)	OECD Guideline 405. Instilled (100 µl) into lower conjunctival sac	6 New Zealand white albino rabbits	Conjunctivitis observed (both concentrations), but classified as non-irritating.[79,80]
Phosphoric Acid	Irrigation with 0.16 M solution (buffered to pH 3.4)	Rabbits	Slight transient epithelial edema and conjunctival hyperemia.[3]
Metaphosphoric Acid	Injection into corneal stroma or application to cornea after removal of epithelium	Rabbits	Injury detected at < pH 5.5.[3]
		Ammonium Salts	
Ammonium Phosphate	Draize Test	Rabbits	At 24 h, slightly irritating.[47]
Ammonium Phosphate (solution, concentration not stated)	Draize Test	Rabbits	At 24 h, mildly to moderately irritating.[47]
Diammonium Phosphate	Draize Test	Rabbits	At 24 h, slightly irritating to moderately irritating.[95]
		Sodium Salts	
Disodium Phosphate	Draize Test	Rabbits	At 24 h, practically non-irritating (rinsed eyes) and minimally irritating (unrinsed eyes).[47]
Disodium Phosphate (solid)	Instilled into eye	Rabbits	Minimal ocular irritation.[29]
Disodium Pyrophosphate	Draize Test	Rabbits	At 24 h, mildly irritating (rinsed eyes) and extremely irritating (unrinsed eyes).[150]
Disodium Pyrophosphate	Instilled into eye (rinsed or unrinsed)	Rabbits	Marked ocular irritation in unrinsed eyes. Minimal-to-mild irritation after ocular rinsing.[29]
Pentasodium Triphosphate	Draize Test	Rabbits	Non-irritating (rinsed eyes) and mildly irritating (unrinsed eyes).[47]
Pentasodium Triphosphate	Draize Test	Rabbits	At 24, irritating.[47]
Sodium Metaphosphate	Not stated	Rabbits	Non-irritating.[29]
Sodium Polyphosphate/Sodium Hexametaphosphate	Draize Test	Rabbits	Non-irritating (rinsed eyes) and minimally irritating (unrinsed eyes)
Sodium Phosphate	Draize Test	Rabbits	At 24 h, practically non-irritating (rinsed eyes) and minimally irritating (unrinsed eyes).[47]
Sodium Phosphate (solid)	Instilled into eye	Rabbits	Minimal ocular irritation.[29]
Sodium Trimetaphosphate	Draize Test	Rabbits	At 24 h, slightly irritating.[47]

Table 11. Ocular Irritation/Toxicity Studies

Ingredient	Test Protocol	Animals (number stated, if available from source)	Results
Tetrasodium Pyrophosphate	Draize Test	Rabbits	Minimally irritating (rinsed eyes) and extremely irritating (unrinsed eyes).[150]
Tetrasodium Pyrophosphate (10% solution)	Draize Test	Rabbits	At 24 h, irritating.[47]
Trisodium Phosphate	Draize Test	Rabbits	Moderately irritating (rinsed eyes) and extremely irritating (unrinsed eyes).[150]
Trisodium Phosphate	Draize Test	Rabbits	Slightly irritating (rinsed eyes) and corrosive (unrinsed eyes).[47]
Trisodium Phosphate (15% aqueous solution)	Draize Test	Rabbits	Mildly irritating.[29]
Trisodium Phosphate (10% solution)	Draize Test	Rabbits	At 24 h, irritating.[47]
Potassium Salts			
Dipotassium Phosphate	Draize Test	6 rabbits	Dipotassium phosphate (0.1 g solid or 0.1 ml liquid) practically non-irritating (rinsed eyes) and mildly irritating (unrinsed eyes).[47]
Pentapotassium Triphosphate	Draize Test	Rabbits	Non-irritating (rinsed eyes) and mildly irritating (unrinsed eyes).[47]
Potassium Phosphate	Draize Test	Rabbits	Non-irritating (rinsed and unrinsed eyes).[47]
Potassium Phosphate	Draize Test	Rabbits	Slightly irritating.[47]
Tetrapotassium Pyrophosphate	Draize test	Rabbits	Mildly irritating (rinsed eyes) and moderately irritating (unrinsed eyes).[47]
Calcium Salts			
Calcium Dihydrogen Phosphate	0.1 g in eye for 24 h	6 New Zealand albino rabbits	Transient, slight erythema. Non-irritating.[81]
Calcium Dihydrogen Phosphate	SkinEthic reconstituted human corneal model. Tissues treated with 30 mg for 10 minutes		Non-irritant.[81]
Calcium Phosphate	Draize Test	Rabbits	Practically non-irritating (rinsed eyes) and moderately irritating (unrinsed eyes).[150]
Calcium Phosphate	Draize Test	Rabbits	Extremely irritating (rinsed and unrinsed eyes).[47]
Calcium Pyrophosphate	Draize Test	Rabbits	At 24 h, slightly irritating.[47]
Dicalcium Phosphate	Draize Test	6 New Zealand rabbits	Slight erythema, fully reversible within 24 h. Non-irritating.[83]
Dicalcium Phosphate	Draize Test	Rabbits	At 24 h, slightly irritating.[47]
Dicalcium Phosphate	Reconstructed human corneal model (human-derived keratinocytes, triplicate tissues) treated with 30 mg for 10 minutes		Relative mean viability of tissues was 102% after exposure. Test material unable to directly reduce MTT. Non-irritant.[83]

Table 11. Ocular Irritation/Toxicity Studies

Ingredient	Test Protocol	Animals (number stated, if available from source)	Results
Dicalcium Phosphate Dihydrate	0.1 g in eye for 24 h	3 albino rabbits (1 male and 2 females)	Transient, slight erythema. Low potential for ocular irritation.[81]
Tricalcium Phosphate	Draize Test	Rabbits	Non-irritating (rinsed eyes).[47]
Magnesium Salts			
Magnesium Phosphate	Draize Test	Rabbits	Slightly irritating (unrinsed eyes).[47]
Trimagnesium Phosphate	Draize Test	Rabbits	At 24 h, non-irritating.[47]

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