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# Final Report on the Safety Assessment of Potassium Silicate, Sodium Metasilicate, and Sodium Silicate[1]

**Potassium Silicate, Sodium Metasilicate, and Sodium Silicate combine metal cations with silica to form inorganic salts used as corrosion inhibitors in cosmetics. Sodium Metasilicate also functions as a chelating agent and Sodium Silicate as a buffering and pH adjuster. Sodium Metasilicate is currently used in 168 formulations at concentrations ranging from 13% to 18%. Sodium Silicate is currently used in 24 formulations at concentrations ranging from 0.3% to 55%. Potassium Silicate and Sodium Silicate have been reported as being used in industrial cleaners and detergents. Sodium Metasilicate is a GRAS (generally regarded as safe) food ingredient. Aqueous solutions of Sodium Silicate species are a part of a chemical continuum of silicates based on an equilibrium of alkali, water, and silica. pH determines the solubility of silica and, together with concentration, determines the degree of polymerization. Sodium Silicate administered orally is readily absorbed from the alimentary canal and excreted in the urine. The toxicity of these silicates has been related to the molar ratio of $SiO_2/Na_2O$ and the concentration being used. The Sodium Metasilicate acute oral $LD_{50}$ ranged from 847 mg/kg in male rats to 1349.3 mg/kg in female rats and from 770 mg/kg in female mice to 820 mg/kg in male mice. Gross lesions of variable severity were found in the oral cavity, pharynx, esophagus, stomach, larynx, lungs, and kidneys of dogs receiving 0.25 g/kg or more of a commercial detergent containing Sodium Metasilicate; similar lesions were also seen in pigs administered the same detergent and dose. Male rats orally administered 464 mg/kg of a 20% solution containing either 2.0 or 2.4 to 1.0 ratio of sodium oxide showed no signs of toxicity, whereas doses of 1000 and 2150 mg/kg produced gasping, dypsnea, and acute depression. Dogs fed 2.4 g/kg/day of Sodium Silicate for 4 weeks had gross renal lesions but no impairment of renal function. Dermal irritation of Potassium Silicate, Sodium Metasilicate, and Sodium Silicate ranged from negligible to severe, depending on the species tested and the molar ratio and concentration tested. Sodium Metasilicate was negative in the local lymph node assay (LLNA), but a delayed-type hypersensitivity response was observed in mice. Potassium Silicate was nonirritating in two acute eye irritation studies in rabbits. Sodium Metasilicate (42.4% $H_2O$) was corrosive to the rabbit eye. Sodium Silicate was a severe eye irritant in some eye irritation studies, but was irritating or nonirritating in others. A skin freshener containing Sodium Silicate was nonirritating. Sodium Metasilicate was nonmutagenic in bacterial cells. Rats given Sodium Silicate (600 and 1200 ppm of added silica) in the drinking water in reproductive studies produced a reduced number of offspring: to 67% of controls at 600 ppm and to 80% of controls at 1200 ppm. Three adult rats injected intratesticularly and subcutaneously with 0.8 mM/kg of Sodium Silicate showed no morphological changes in the testes and no effect on the residual spermatozoa in the ductus deferens. Sodium Metasilicate (37% in a detergent) mixed with water was a severe skin irritant when tested on intact and abraded human skin, but 6%, 7%, and 13% Sodium Silicate were negligible skin irritants to intact and abraded human skin. Sodium Silicate (10% of a 40% aqueous solution) was negative in a repeat-insult predictive patch test in humans. The same aqueous solution of Sodium Silicate was considered a mild irritant under normal use conditions in a study of cumulative irritant properties. The Cosmetic Ingredient Review (CIR) Expert Panel recognized the irritation potential of these ingredients, especially in leave-on products. However, because these ingredients have limited dermal absorption and Sodium Metasilicate is a GRAS direct food substance, the Panel deemed the ingredients safe for use in cosmetic products in the practices of use and concentration described in this safety assessment, when formulated to avoid irritation.**

## INTRODUCTION

This report reviews the safety of silicate salts as used in cosmetic formulations. Because they are considered to have similar safety profiles, the following silicate salts are reviewed in this assessment: Potassium Silicate (CAS no. 1312-76-1), Sodium Metasilicate (CAS no. 6834-92-0), and Sodium Silicate (CAS no. 1344-09-8).

## CHEMISTRY

These ingredients combine metal cations (potassium or sodium) with silica to form inorganic salts. A tabular presentation of chemical descriptions is provided in Table 1.

### Physical and Chemical Properties

The properties, synonyms, and specifications are listed in tabular form in Table 2.

According to O'Conner (1961), pH determines the solubility of silica and, together with concentration, determines its degree of polymerization. At about pH 7, silica is only slightly soluble in water. At around pH 12, in a Sodium Metasilicate solution (0.1%), silica is very soluble and exists in monomeric form. At an intermediate pH, Sodium Metasilicate is partially neutralized; that is, it changes ratio and becomes a Sodium Silicate of $1Na_2O{:}XSiO_2$, where X is greater than unity. Conversely, a Sodium Silicate of the ratio $1Na_2O{:}XSiO_2$ could be converted to Metasilicate by the addition of alkali.

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**TABLE 1**
Ingredient descriptions

| Ingredient | Description | Reference |
|---|---|---|
| Potassium Silicate | $SiO_2$:$K_2O$ ratio varies | Budavari (1989) |
| | Potassium salt of silicic acid | Gottschalck and McEwen (2004) |
| Sodium Metasilicate | $Na_2SiO_3$ | Gottschalck and McEwen (2004) |
| | Inorganic salt | Gottschalck and McEwen (2004) |
| Sodium Silicate | $Na_2O{\cdot}xSiO_2$ | Lide (1993) |
| | Sodium salt of silicic acid | Gottschalck and McEwen (2004) |

## Method of Manufacture

Soluble silicates (Sodium Silicate and Sodium Metasilicate) are manufactured by the reaction of silica sand and sodium carbonate (soda ash) at ~1400°C. Typically, a no. 1 grade of glass sand containing no more than 300 ppm iron and a medium density soda ash are used. Potassium Silicates are manufactured in a similar manner by the reaction of $K_2CO_3$ and sand (Kirk-Othmer 1982).

Sodium Silicates are either made by the high temperature fusion of silica sand ($SiO_2$) and soda ($Na_2CO_3$) at about 1300°C or by a hydrothermal process using silica sand and sodium hydroxide as starting materials. Solutions, termed "waterglass," are prepared by the solubilization of lumps of silicate salts in water at elevated temperatures and pressure. The water content of "waterglass" is between 45% and 80%. Powders are prepared by spray- or drum-drying of "waterglass" solutions. The residual water content can be between 0% and 25% (EUCLID 2000).

## Impurities

Kirk-Othmer (1982) provided a range of trace elements in a typical Sodium Silicate solution as shown in Table 3. Impurity limits for Arsenic and Lead are shown in Table 2.

**TABLE 2**
Properties, synonyms, and specifications

| | | |
|---|---|---|
| | *Potassium Silicate* | |
| Synonyms | Silicic acid, potassium salt | Gottschalck and McEwen (2004) |
| Form/description | Yellowish to colorless, translucent to transparent, hygroscopic | Budavari (1989) |
| Solubility | Insoluble in alcohol, slightly soluble in water | Budavari (1989) |
| | *Sodium Metasilicate* | |
| Synonyms | Silicic acid, disodium salt | Gottschalck and McEwen (2004) |
| | Crystamet, disodium metasilicate, disodium monosilicate, Metso, water glass, sodium metasilicate anhydrous | RTECS (1999) |
| Form/description | Nonahydrate, efflorescent platelets | Budavari (1989) |
| Molecular weight | 122.08 | Budavari (1989) |
| pH | 12 (0.1% solution) | O'Conner (1961) |
| Density | 2.614 | Budavari (1989) |
| Solubility | Insoluble in alcohol, acids, and salt solns. | Budavari (1989) |
| Melting point | 1089°C | CTFA (2000a) |
| Forms | Anhydrous, pentahydrate, and nonahydrate | 21 CFR 184.1769a |
| Impurity limits | Arsenic (as As) 3 ppm maximum | Nikitakis and McEwen (1990) |
| | Lead (as Pb) 20 ppm maximum | Nikitakis and McEwen (1990) |
| | *Sodium Silicate* | |
| Synonyms | Silicic acid, sodium salt | Gottschalck and McEwen (2004) |
| | Sodium waterglass, waterglass, soluble glass, sodium silicate glass | EUCLID (2000) |
| Form/description | Colorless to white or grayish-white, crystal-like clumps or aqueous solutions | Budavari (1989) |
| pH | Strongly alkaline | Budavari (1989) |
| Impurity limits | Arsenic (as As) 3 ppm maximum | Nikitakis and McEwen (1990) |
| (40% solution) | Lead (as Pb) 20 ppm maximum | Nikitakis and McEwen (1990) |

**TABLE 3**
Trace elements in Sodium Silicate (Kirk-Othmer 1982)

| | Measured Values | | | Measured Values | |
|---|---|---|---|---|---|
| Impurity | Low | High | Impurity | Low | High |
| F | 6.7 ppm | 9.5 ppm | V | Below 0.3 ppm detection limit | 0.8 ppm |
| Cl | 130 ppm | 1900 ppm | Cr | Below 0.3 ppm detection limit | 1.0 ppm |
| $SO_4$ | Below 160 ppm detection limit | 1700 ppm | Ni | Below 0.3 ppm detection limit | 0.3 ppm |
| N | 0.1 ppm | 44 ppm | Co | Below 0.3 ppm detection limit | <0.3 ppm |
| As | Below 1 ppm detection limit | <1 ppm | Zn | Below 0.6 ppm detection limit | 2.8 ppm |
| Hg | Below 0.26 ppb detection limit | 2.5 ppb | Cu | Below 0.6 ppm detection limit | 1.1 ppm |
| Pb | 0.17 ppm | 0.60 ppm | Bi | Below 25 ppm detection limit | <25 ppm |
| Cd | Below 10 ppb detection limit | 21 ppb | Sr | Below 0.2 ppm detection limit | 1.5 ppm |
| Fe | 36 ppm | 120 ppm | Ba | Below 0.2 ppm detection limit | 2.8 ppm |
| Mg | 4 ppm | 26 ppm | Mn | 0.1 ppm | 1.8 ppm |
| Ca | Below 1 ppm detection limit | 76 ppm | Sn | Below 60 ppm detection limit | <60 ppm |
| Al | 50 ppm | 220 ppm | Sb | Below 15 ppm detection limit | < 15 ppm |
| P | Below 18 ppm detection limit | <18 ppm | Se | Below 20 ppm detection limit | <20 ppm |

## USE

### Cosmetic

Potassium Silicate functions as a corrosion inhibitor in cosmetics (Gottschalck and McEwen 2004). Voluntary reports by industry to the Food and Drug Administration (FDA) on product use included use of Potassium Silicate in two formulations as shown in Table 4 (FDA 2001). Industry did not report any concentration of use information for Potassium Silicate.

Sodium Metasilicate functions as a chelating agent and corrosion inhibitor in cosmetic formulations (Gottschalck and McEwen 2004). Of the 191 formulations reported to the FDA, over 80% were used in hair dyes and colors (FDA 2001). Table 4 shows the types of cosmetic formulations in which Sodium Metasilicate is reported to be used and gives current concentrations of use as provided by industry.

In those cases where a current concentration of use is provided, but there are no reports to FDA of use, it should be assumed that the ingredient may be in current use.

Sodium Silicate functions as a buffering agent, corrosion inhibitor, and a pH adjuster (Gottschalck and McEwen 2004). Sodium Silicate was reported to be used in 22 formulations (FDA 2001). Table 4 shows the types of cosmetic formulations in which Sodium Silicate is reported to be used and gives current concentrations of use as provided by industry.

There are no restrictions for the use of these silicate salts in cosmetics in Japan according to the Ministry of Health, Labor, and Welfare (2000) nor in Europe according to the European Economic Community (1999).

### Noncosmetic

The principle uses of soluble silicates are in the manufacturing of soaps and detergents. They provide a constant pH value in the detergent system and aid in the saponification of oils and fats by means of their alkaline nature and buffering ability. Soluble Silicates are also used in water treatment, as an adhesive and fireproof coating additive, as a paper de-inking agent, as an egg preservative, and as a inhibitor of metal corrosion (Kirk-Othmer 1982).

FDA affirmed Sodium Metasilicate as a GRAS (generally regarded as safe) direct food substance (Code of Federal Regulations, 21CFR184.1769a) with no limitation other than current good manufacturing practice. Sodium Metasilicate's uses in foods include processing aid; washing and lye peeling of fruits, vegetables, and nuts; denuding agent in tripe; hog scald agent in removing hair; and a corrosion preventative in canned and bottled water. The Select Committee of the Federation of American Societies for Experimental Biology (FASEB) (1981) concluded: "There is no evidence in the available information on Sodium Metasilicate that demonstrates or suggests reasonable grounds to suspect a hazard to the public when it is used as a food ingredient in a manner now practiced at levels that are now current or might reasonably be expected in the future."

Rhone-Poulenc (1971a) reported Sodium Silicate being used in industrial cleaners and detergents.

Potassium Silicate was reported by Reynolds et al. (1998) as an alternative to sulfur for controlling powdery mildew. Rhone-Poulenc (1971b) reported Potassium Silicate being used in industrial cleaners and detergents.

## GENERAL BIOLOGY

### Absorption, Distribution, Metabolism, and Excretion

Two groups of four male Sprague-Dawley Cox rats were fasted for 17 to 18 h and then administered Sodium Silicate orally in doses of 40 or 1000 mg/kg body weight (bw). Four control

**TABLE 4**
Product formulation data

| Product category (number of formulations in each category) (FDA 2001) | Formulations containing ingredient (FDA 2001) | Reported range of use concentrations (CTFA 1999, 2000b) |
|---|---|---|
| | *Potassium Silicate* | |
| Noncoloring hair preparations | | |
| Other hair preparations (276) | 1 | — |
| Skin care preparations | | |
| Paste masks (mud packs) (269) | 1 | — |
| Totals/ranges for Potassium Silicate | 2 | |
| | *Sodium Metasilicate* | |
| Noncoloring hair preparations | | |
| Hair straighteners (63) | 1 | — |
| Hair coloring preparations | | |
| Hair dyes and colors (1588) | 158 | — |
| Hair lighteners with color (5) | 2 | 14% |
| Hair bleaches (115) | 24 | 13%–18% (diluted to 7%–14% before use) |
| Other hair coloring preparations (59) | 4 | — |
| Shaving preparations | | |
| Shaving cream (133) | 2 | — |
| Totals/ranges for Sodium Metasilicate | 191 | |
| | *Sodium Silicate* | |
| Baby products | | |
| Other baby products (29) | — | 0.6% |
| Eye makeup preparations | | |
| Other eye makeup preparations (151) | 1 | — |
| Hair-coloring preparations | | |
| Hair bleaches (115) | 7 | 16%–55% (diluted to 1%–20% before use) |
| Hair dyes and colors (1572) | — | 1% |
| Other hair coloring preparations (59) | 1 | 35% |
| Bath preparations | | |
| Bath soap and detergents (405) | 2 | 0.06%–7% |
| Oral hygiene products | | |
| Dentrifrices (aerosol, liquid, pastes, and powders) (38) | — | 0.6% |
| Shaving preparations | | |
| Shaving cream (133) | 6 | 0.3%–5% |
| Shaving soap (<4) | — | 0.4% |
| Skin care preparations | | |
| Skin cleansing creams, lotions, liquid, and pads (653) | — | 10% |
| Depilatories (28) | 4 | 2% |
| Face and neck skin care preparations (304) | 1 | — |
| Other skin preparations (692) | — | 1% |
| 2001 Totals/ranges for Sodium Silicate | 22 | 0.06%–35% |

animals received 10 ml of quartz-distilled water. All suspensions contained <0.5 ppm of silicon and aluminum. Urine samples were collected over an 8-h period and afterwards the remaining urine in the bladder was collected. The concentrations of silicon were measured by induction-coupled RF plasma optical emission spectrometry. Silicon excretion was most rapid during the first 24 h after dosing. After subtracting the control values, the urinary silicon excretion at 40 and 1000 mg Sodium Silicate/kg was 18.9% and 2.8%, respectively (Benke and Osborn 1979).

## In Vitro Assays

*Sodium Metasilicate*

Neutralized Sodium Metasilicate, at concentrations of up to 0.025 M, inhibited urease and invertase in vitro, but had

little effect on many other enzymes such as pepsin, trypsin, lipase, catalase, or cholinesterase (Kind et al. 1954; Alexander 1968).

Skin$^2$ ZK 1350 cultures were used to evaluate skin corrosion and develop a classification of 50 chemicals in a study by Liebsch et al. (1995). Skin$^2$ cultures are a three-dimensional human skin model with a stratum corneum grown from neonatal human skin cells. The epidermal side of the cultures was placed onto 15 $\mu$l of Sodium Metasilicate on glass coverslips for 10 s. Phosphate-buffered saline was used to wash the test material residue. Cell viability was assessed using the tetrazolium derivative reduction cytotoxicity assay. The controls were treated with distilled water. In this assay, a corrosive chemical will have a $<80\%$ viability rate. A noncorrosive classification corresponds to a $>80\%$ viability rate. Sodium Metasilicate had a mean viability ($\pm$SD) of 65.8 $\pm$ 10.4. The authors classified Sodium Metasilicate as corrosive.

*Sodium Silicate*

Sodium Silicate was also tested by Liebsch et al. (1995) in the same study as the previous experiment. Two different chemical names were tested, Sodium Silicate A140 and Sodium Silicate H100. Sodium Silicate A140 is classified as group II and Sodium Silicate H100 is classified as non-corrosive according to in vivo UN packing guidelines. The ZK 1350 percent viability mean $\pm$ *SD* for Sodium Silicate A140 and Sodium Silicate H100 were 82.3 $\pm$ 12.0 and 91.5 $\pm$ 10.9, respectively. The corrosivity classification for Sodium Silicate A140 was determined to be non-corrosive, but was noted to be a false negative. Sodium Silicate H100 was classified as non-corrosive. Both chemicals were predicted by the ZK 1350 assay to be non-corrosive according to United Nations (UN) packing guidelines.

## ANIMAL TOXICOLOGY

### Acute Oral

*Sodium Metasilicate*

Rhone-Poulenc (1971b) conducted a study in which male Sprague-Dawley rats were administered a 20% solution of Sodium Metasilicate by gastric intubation. Five animals per dose of 464, 1000, 2150, and 4640 mg/kg were used. The animals were observed for 14 days for mortality and signs of toxicity.

All rats given the largest dose died and necropsy was performed on these animals. No apparent signs of toxicity were produced at 464 mg/kg. Animals treated with either ratio at doses of 1000 and 2150 mg/kg had gasping, dyspnea, and acute depression. Signs in groups given 4640 mg /kg included acute depression, nasal discharge, dyspnea, and gasping. All dead rats had gross gastrointestinal hemorrhages with congestion of the kidneys, adrenal glands, liver, lungs, and heart. The acute oral $LD_{50}$ was 847 mg/kg (Rhone-Poulenc 1971b).

Muggenberg et al. (1974) gave groups of three beagle dogs single doses of 0.1, 0.25, 0.5, 1.0, and 2.5 g/kg of a commercially available detergent containing Sodium Metasilicate. No details about the percentage of Sodium Metasilicate in the detergent were given.

All dogs that received the highest dose died within 54 h. Gross lesions of variable severity were found in the oral cavity, pharynx, esophagus, stomach, larynx, lungs, and kidneys of all dogs receiving 0.25 g/kg or more. No lesions were found in dogs that received 0.1 g/kg. Microscopic lesions included acute necrosis of the epithelial lining of the digestive tract, necrosis, ulceration and edema of the larynx, edematous lungs, and necrosis of the proximal renal tubules.

In a second experiment, three pigs were given a single dose of 0.25 g/kg of the same detergent used in the dog study. One pig died 95 h after ingestion. Lesions in the pigs were similar to those found in the dogs (Muggenberg et al. 1974).

The Federation of American Societies for Experimental Biology (1981) listed the following $LD_{50}$ values for Sodium Metasilicate: rat (oral) 1.28 g/kg; rat (oral) 3 g/kg; and mouse (oral) 3 g/kg, and stated that "accidental exposure to strongly alkaline, concentrated solutions of Sodium Metasilicate such as those used in certain common detergent preparations, can produce caustic, irritating effects on contact with the eye, skin, and mucous membranes of the alimentary tract and respiratory system."

Ito et al. (1986) reported the $LD_{50}$ of Sodium Metasilicate as 1152.8 mg/kg in male rats, 1349.3 mg/kg in female rats, 820 mg/kg in male mice, and 770 mg/kg in female mice. Changes in the animals that survived after peroral administration of large doses in acute studies were mainly bleeding in the stomach and duodenum, and erosion of the small intestine.

*Sodium Silicate*

A summary of information on Sodium Silicate provided by European companies (EUCLID 2000) included acute oral toxicity data shown in Table 5.

In a study by Rhone-Poulenc (1971b), male Sprague Dawley rats were administered a 20% solution of a 2.0 and 2.4 ratio of Sodium Silicate to 1.0 ratio of sodium oxide by gastric intubation. The 2.0 and 2.4 ratios were corrected for moisture content and tested on an equivalent anhydrous basis. Five animals per dose group at 464, 1000, 2150, and 4640 mg/kg were used. The animals were observed for 14 days for mortality and other signs of toxicity. Necropsy was performed on animals of the largest doses.

In the higest dose group, 4/5 rats of the 2.0 ratio material and 5/5 rats of the 2.4 ratio material died. No apparent signs of toxicity were produced at 464 mg/kg. Animals treated with either ratio at doses of 1000 and 2150 mg/kg had gasping, dyspnea, and acute depression. The highest dose group animals had acute depression, nasal discharge, dyspnea, and gasping. Dead animals had gastrointestinal hemorrhages and congestion of the kidneys, adrenal glands, liver, lungs, and heart. The acute oral $LD_{50}$ was reported to be 1960 mg/kg in groups receiving the 2.0 ratio material of Sodium Silicate and 2710 mg/kg

**TABLE 5**
Sodium Silicate oral $LD_{50}$ values in the rat (EUCLID 2000)

| $LD_{50}$ | Molar ratio/concentration | Remarks |
|---|---|---|
| 2000–2500 mg/kg | Molar ratio of 1.6 and a concentration of 51% | The acute oral toxicity of alkaline sodium silicates is dependent on the $SiO_2/Na_2O$ molar ratio, and to a lesser extent on the concentration of dissolved dry matter (due to pH dependence); autopsy results showing acute gastroenteritis, vascular congestion, and mottled livers are consistent with nonspecific causes of death. |
| 1600–8600 mg/kg | Molar ratio of 3.0 and various concentrations | |
| 1500–2200 mg/kg | Molar ratio of 2.0 and concentration of 81% | |
| 1300–2100 mg/kg | Molar ratio of 2.0 and various concentrations | |
| 1600 mg/kg | Molar ratio of 2.0 and concentration of 81% | |
| 7150–10500 mg/kg | Molar ratio of 3.4 | Ten male rats of different species were used and the observed range in $LD_{50}$ values was due to intraspecies susceptibility. |
| >2000 mg/kg | Molar ratio of 3.45 and concentration of 35% | All symptoms of intoxication were reversible and no signs of histopathologic abnormalities were observed 14 days after application of the substance. |

in groups receiving the 2.4 ratio material (Rhone-Poulenc 1971b).

## Short-Term Oral

*Sodium Metasilicate*

Albino mice (210) and rabbits (20) dosed daily with 200 to 300 mg/kg Sodium Metasilicate for 1 month showed "a cellular proliferation in the internal organs." No details of number of animals by dose, sex, age, strain, or mortality were reported (Shakhbazyan and Karapetyan 1963).

Schwarz and Milne (1972) found that Sodium Metasilicate ($Na_2SiO_3 \cdot 9H_2O$) added to silicon-depleted, chemically defined diets of weanling Fisher 344 rats resulted in 25% to 34% increases in growth rates compared with control animals on silicon-depleted diets. The estimated dose of silicon was about 100 mg/kg/day. Growth retardation and a disturbance in bone formation were reported to be signs of silicon deficiency, presumably as a result of faulty bone matrix formation and inadequate cross-linkage of acid mucopolysaccharides and other connective tissue components.

*Sodium Silicate*

In a study by Kayongo-Male and Jia (1999), 36 male Sprague-Dawley albino rats were randomly allotted into a two-dietary-treatment experiment. The dietary treatments included a control basal diet consisting of dextrose–egg album in that contained <5.0 ppm Si and a diet supplemented with 500 ppm Si obtained by the addition of Sodium Silicate.

The addition of dietary Si affected rat body-weight changes. Rats on the supplemented diet had slower growth rates than control rats. At the end of 8 weeks, rats on the treated diet weighed 257 g on average compared to 273 g for control rats. Hemoglobin levels were lower ($p < .05$) in treated rats. Plasma Ca content was also lower in treated rats ($p < .05$). Plasma Mg levels were higher ($p < .05$) in control rats. Plasma Cu and P were not affected. The source of Si did not affect ($p < .05$) organ weights or their mineral concentrations except liver Zn concentrations, which were higher in the control group (Kayongo-Male and Jia 1999).

## Subchronic Oral

*Sodium Metasilicate*

In a subchronic study with Sodium Metasilicate in the drinking water of Wistar rats, no specific changes in the high-dose animals were observed. Slight degenerative changes in the epithelium of renal tubules were observed in higher doses. Maximum safety concentrations were 1500 ppm/L/day (792 mg/kg/day) (Ito et al. 1986).

*Sodium Silicate*

Newberne and Wilson (1970) fed eight female and eight male beagle dog 2.4 g/kg/day of Sodium Silicate in their diets for 4 weeks to study renal damage. Six animals of each sex were used as controls, receiving the same diet without Sodium Silicate. In addition, 15 rats (Charles River CD strain) of each sex were fed the same diet with Sodium Silicate and 15 rats of each sex received the control diet. Animals were killed at the end of 4 weeks and necropsied. Tissues were preserved in formaldehyde for histopathologic examination.

Body weight, feed intake, and urinary specific gravity and blood (protein and glucose) measurements were the same for both test and control dogs and rats. Polydipsia and polyuria were

observed in both the dogs and rats. Gross renal cortical lesions were seen in 8/8 male and 7/8 female dogs. The authors stated that the appearance of the cut surface suggested cortical infarcts. Despite extensive renal damage, impairment of renal function was not detected. No treatment-related lesions were found in the rats (Newberne and Wilson 1970).

Smith et al. (1973) added a Sodium Silicate solution to the drinking water containing 600 and 1200 ppm of added silica and given to groups of six weanling male and six female Sprague-Dawley rats. Growth, nitrogen and phosphorous retention, and reproductive effects were investigated (discussed later in this report). Control groups received no Sodium Silicate in their drinking water. At 4 months of age, the rats of treatment groups were mated. The treated water, 600 ppm, combined with a normal, commercial diet for rats increased body weight gains of the male rats by ~6% over controls but decreased gains of the female rats by ~5% compared to controls. Retention of nitrogen and phosphorous were significantly affected. No apparent effect of the treatment in the drinking water was found on the longevity in rats having started treatment after weaning.

## Acute Parenteral

Intraperitoneal injections of a neutralized 2% solution of Sodium Metasilicate (~1200 mg/kg on day 1 and 800 mg/kg on days 2 and 3) into white rats resulted in a 60% decrease in spleen weight and relative enlargement of the kidneys when the animals were examined on the third day. There were microscopic lesions of the lymphatic tissues and cellular damage in parts of the intestinal mucosa (Nanetti 1973).

## Dermal Irritation

*Potassium Silicate*

Potassium Silicate was tested for primary skin irritation according to the Draize Dermal procedure after a 24-h exposure in six rabbits (three male and three female). No dose was indicated. The primary irritation index was 1.83 and the compound was classified as a mild irritant (Rhone-Poulenc 1971a).

A summary of information on Potassium Silicate put together by European companies (EUCLID 2000) included the skin irritation data shown in Table 6.

*Sodium Metasilicate*

Sodium Metasilicate (42.4% $H_2O$) was tested for skin irritation according to the Draize Dermal procedure in six rabbits (three male and three female). The results were scored at 8.0 and was classified as a corrosive. The authors stated that the result was expected because the pH of the solution was 12.4 (Rhone-Poulenc 1971b).

A commercial product containing 5% Sodium Metasilicate was tested in acute dermal toxicity studies using male and female white New Zealand rabbits. The dermal $LD_{50}$ was >200 mg/kg. Necrosis and edema were observed at the treatment site (Rhone-Poulenc 1976).

A Sodium Metasilicate/carbonate granular detergent was applied to intact and abraded skin of rabbits and guinea pigs for 4 h. Skin responses were graded at 4, 24, and 48 h after the patch applications. The detergent contained 37% Sodium Metasilicate. Rabbit skin and guinea pig skin reacted differently as shown in Table 7 (Nixon, Tyson, and Wertz 1975).

*Sodium Silicate*

Sodium Silicate was tested for primary skin irritation according to the Draize Dermal procedure after 4 and 24 h exposures in rabbits. Both primary irritation indexes for 4 and 24 h were 8.0 and the compound was classified as corrosive (Rhone-Poulenc 1971a).

A 2.0 ratio and 2.4 ratio of Sodium Silicate to 1.0 sodium oxide with 19.5% water was tested for skin irritation according to the Draize Dermal procedure in rabbits. The 2.0 ratio material was scored a 5.9 and was classified as a severe irritant; the 2.4 ratio material was scored a 4.12 and was classified as a moderate irritant. An acute dermal toxicity study utilizing New Zealand white rabbits was also conducted. Both ratio materials of Sodium Silicate were applied to the closely clipped intact abdominal skin and the skin was exposed for 24 h. After the 24 h, the binders were removed and any residual chemical was removed by washing. The animals were observed for 14 days for toxicity. No signs of toxicity were apparent in any of the animals. The 2.0 ratio material produced severe, irreversible erythema and edema at the test site; while the 2.4 ratio material caused more moderate, reversible irritation at the test site. The acute rabbit dermal $LD_{50}$ was >4640 mg/kg (Rhone-Poulenc 1971b).

**TABLE 6**
Potassium Silicate: acute dermal irritation in rabbits (EUCLID 2000)

| Method | Result | Remarks |
|---|---|---|
| OECD Guideline 404 "Acute Dermal Irritation/Corrosion" | Nonirritating | Diluted Potassium Silicate solution<br>Molar ratio = 3.4<br>Concentration = 8.5–9% |
| OECD Guideline 404 "Acute Dermal Irritation/Corrosion" | Nonirritating | Diluted Potassium Silicate solution<br>Molar ratio = 3.9<br>Concentration = 7–7.5% |

**TABLE 7**
Sodium Metasilicate: dermal irritancy (Nixon, Tyson, and Wertz 1975)

| Concentration of detergent (*w/v* aqueous) | Animal species | Mean scores | | PII | Tissue destruction | | Irritancy judgement |
|---|---|---|---|---|---|---|---|
| | | Intact | Abraded | | Intact | Abraded | |
| 50% | Rabbit | >6.8 | >8.0 | >7.4 | 5/5 | 5/5 | Corrosive |
| 50% | Guinea pig | 0.0 | 0.6 | 0.3 | 0/6 | 0/6 | Negligible |

Three detergents containing Sodium Silicate (7% in a high-carbonate detergent, 13% in a low-12 carbonate detergent, and 6% in a phosphate detergent) were applied to intact and abraded skin of rabbits and guinea pigs for four hours. Skin responses were graded at 4, 24, and 48 h after the patch applications. The results from this study are presented in Table 8 (Nixon, Tyson, and Wertz 1975).

In a single insult occlusive patch test, nine rabbits were treated with a skin freshener that contained 10% of a 40% aqueous solution of Sodium Silicate. The compound had a typical weight ratio of $SiO_2/Na_2O$ of 3.25. The skin irritation potential of the test material was nonirritating (Cosmetic, Toiletry, and Fragrance Association [CTFA] 1979a).

Patch tests were performed using three female Hartley guinea pigs. Occlusive patches containing 20% Sodium Silicate were applied to the shaved backs of the three animals. Erythema was detected 48 h later but did not progress to ulceration. Pathological findings at the occlusive patch test site included dyskeratotic cells in the epidermis and polymorphonuclear leukocytic infiltration around the blood vessels (Tanka, Miyachi, and Horio 1982).

A summary of information on Sodium Silicate put together by European companies (EUCLID 2000) included the skin irritation data shown in Table 9.

## Immunomodulation

The National Toxicology Program (NTP) (2001) evaluated Sodium Metasilicate as an immunomodulatory agent when applied to female BALB/c mice in a mouse ear swelling test and local lymph node assay (LLNA) to measure contact hypersensitivity. Concentrations used in the contact hypersensitivity assays were determined by irritancy testing. The minimal irritating concentration was found to be 6% and the maximal nonirritating concentration was 4%. The. Sodium Metasilicate concentrations were 0.4%, 2%, and 4% for the sensitization phase, and 6% for the challenge phase. In the LLNA, mice were sensitized to 2%, 4%, and 6% Sodium Metasilicate. 1-Fluoro-2,4-dinitrobenzene (DNFB) was used as a positive control at a concentration of 0.15% for the irritancy test and LLNA, and 0.20% for the swelling test. An evaluation of lymph node subpopulations, cytokine mRNA, and serum immunoglobulin E (IgE) levels was also conducted.

Dermal exposure to (2% to 6%) Sodium Metasilicate did not produce cell proliferation in the draining lymph nodes as measured by the LLNA. However, a delayed-type hypersensitivity (DTH) response was observed when mice were sensitized on the back with 4% Sodium Metasilicate, then challenged on the ear with 6% Sodium Metasilicate. The positive control, DNFB, induced cell proliferation in the draining lymph nodes, and elicited a DTH response. Lymph node subpopulations were also altered by treatment with Sodium Metasilicate. Only B220+lg+ lymph nodes were shown to increase when the data were presented as a percentage of the total lymph node count. The response was observed at concentrations as low as 4%. An evaluation of the cytokine mRNA revealed an increase in the expression of interferon (IFN)-$\gamma$, tumor necrosis factor (TNF)-$\beta$, and migration inhibitory factor (MIF) mRNAs. No change in total serum IgE levels was detected (NTP 2001).

**TABLE 8**
Sodium Silicate: dermal irritancy (Nixon, Tyson, and Wertz 1975)

| Detergent type (Sodium Silicate concentration) | Concentration of detergent (*w/v* aqueous) | Animal species | Mean scores | | PII | Tissue destruction | | Irritancy judgement |
|---|---|---|---|---|---|---|---|---|
| | | | Intact | Abraded | | Intact | Abraded | |
| High carbonate (7%) | 50% | Rabbit | 0.9 | 2.6 | 1.7 | 0/6 | 0/6 | Negligible |
| | 50% | Guinea pig | 0.0 | 0.4 | 0.2 | 0/6 | 0/6 | Slight |
| Low carbonate (13%) | 50% | Rabbit | 0.7 | 0.8 | 0.8 | 0/6 | 0/6 | Slight |
| | 50% | Guinea pig | 0.1 | 1.0 | 0.5 | 0/6 | 0/6 | Slight |
| Phosphate (6%) | 50% | Rabbit | 1.2 | >5.6 | >3.4 | 0/5 | 2/5 | Moderate |
| | 50% | Guinea pig | 0.2 | 1.0 | 0.6 | 0/6 | 0/6 | Slight |

**TABLE 9**
Sodium Silicate acute dermal results in rabbits (EUCLID 2000)

| Method | Result |
|---|---|
| Undiluted substance (0.5 ml) applied for 4 h; molar ratio of 3.45; concentration of 35% | Nonirritating |
| 0.5 g substance moistened with physiological saline applied to intact abraded skin for 24 h; molar ratios of 2.9 and 3.2; concentrations of 43%, 36%, and 80% | Irritating; the PII was 3, 3, 0 respectively for 43%, 36%, and 80% |
| Same application, but molar ratios of 2.4 and 3.2, and concentrations of 44% and 38% | Irritating |
| Same application, but pH 13.6 material; molar ratio of 1.6; concentration of 52% | Corrosive |
| 0.5 ml solution of pH 12 with a molar ratio of <2 | Corrosive |
| A powder product—2:1 dilution with water; molar ratio was 2; concentration was 66.6% | Nonirritating |
| Undiluted substance (0.5 ml) applied for 4 h; molar ratio was 3.91; concentration was 28% | Nonirritating |
| Same application, but molar ratio was 2.83 and concentration was 45% | Slightly irritating |
| Same application, but molar ratio was 2.09 and concentration was 55% | Moderately irritating |
| Same application, but molar ratio was 3.3 and concentration was 38% | Slightly irritating |
| Same application, but molar ratio was 2.09 and concentration was 55% | Slightly Irritating |
| Same application, but molar ratio was 2.4 and concentration was 40% | Irritating |
| Same application, but molar ratio was 2 and concentration was 41% | Irritating |
| The powder was applied dry. The molar ratio was 2 | Nonirritating |
| Molar ratio of 1.6 and concentration of 53.5% | Corrosive |
| Molar ratio of 3.4 and concentration of 34.5% | Slightly irritating |

## Ocular Irritation

*Potassium Silicate*

A summary of information on Potassium Silicate put together by European companies (EUCLID 2000) included the ocular irritation data shown in Table 10.

*Sodium Metasilicate*

Sodium Metasilicate (42.4% $H_2O$) was tested in acute ocular irritation studies that were in accordance with the procedure outlined in the Code of Federal Regulations (21CFR191.12.1). Six New Zealand rabbits were exposed to 0.1 ml in one eye; the other eye served as a control. The sample was corrosive to the eye; total destruction of the eye of all the test animals was observed (Rhone-Poulenc, 1971b).

*Sodium Silicate*

Sodium Silicate ratios (2.0: 1.0 and 2.4:1.0 $Na_2O$ with 19.5% $H_2O$) were tested in acute ocular irritation studies that were in accordance with the procedure outlined in the Code of Federal Regulations (21CFR191.12.1). Six New Zealand rabbits were exposed to 0.1 ml in the conjunctival sac of one eye; the other eye served as a control. The 2.0 ratio material produced corneal opacity with scar tissue formation in four of the six rabbits. The remaining two had severe iritis and conjunctivitis. The 2.0 ratio material was classified as corrosive. The 2.4 ratio material produced conjunctivitis, moderate iritis, and two of six test rabbits had slight corneal opacity. Sodium Silicate was classified as a severe occular irritant (Rhone-Poulenc 1971b).

**TABLE 10**
Potassium Silicate: ocular irritation in rabbits (EUCLID 2000)

| Method | Result |
|---|---|
| Diluted solution; molar ratio = 3.9; concentration = 7%–7.5% | Nonirritating |
| Diluted solution; molar ratio = 3.4; concentration = 8.5%–9% | Nonirritating |

A skin freshener (10% of a 40% aqueous solution of Sodium Silicate) was tested in a Draize eye irritation study in six rabbits. The compound had a typical weight ratio of $SiO_2/Na_2O$ of 3.25. No eye irritation potential as judged by the Draize classification of eye irritation was demonstrated in this study (CTFA 1979b).

A summary of information on Sodium Silicate put together by European companies (EUCLID 2000) included the ocular irritation data shown in Table 11.

## GENOTOXICITY

*Sodium Metasilicate*

DNA damage and repair assays without metabolic activation were conducted on *Bacillus subtilis* recombination-repair-deficient and wild-type strains. Sodium Metasilicate at concentrations of 0.005–0.5 M was not genotoxic (Kada, Brun, and Marcovich 1960).

*Sodium Silicate*

Strains B/Sd-4/1,3,4,5 and B/Sd-4/3,4 of *Escheria coli* were used to study the mutagenic action of Sodium Silicate (Demerec, Bertani, and Flint 1951). The streptomycin-dependent bacteria

**TABLE 11**
Sodium Silicate: Draize ocular irritation in rabbits (EUCLID 2000)

| Method | Result | Remark |
|---|---|---|
| Molar ratios of 1 and 2; concentrations of 10% and 8% | Irritating | Sodium Silicate solutions of less than 10% are irritating but not highly irritating. |
| Molar ratios of 2 and 2.9; concentrations of 44% and 43% | Highly irritating | Concentrated solutions of molar ratios >2.9 are severely irritating. |
| Molar ratio of 3.2; concentration of 36% | Nonirritating | |

(Sd-4) were treated with 0.025%, 0.01%, 0.05%, 0.1%, 0.15%, or 0.3% Sodium Silicate for three hours at 37°C. The control suspension was distilled water instead of streptomycin. At the end of treatment, both treated and control suspensions were assayed on streptomycin-agar plates. Samples from the suspensions (0.1 ml) were also plated on streptomycin-free plates, incubated for 6 days, and the frequency of mutants was calculated. Sodium Silicate was nonmutagenic.

## REPRODUCTIVE AND DEVELOPMENTAL TOXICITY

Groups of three adult albino rats were injected intratesticularly and subcutaneously with doses of 0.08 mM/kg Sodium Silicate. By the testicular route, the left testis was treated and the right testis served as the control. The rats were killed 2, 7, and 30 days after injection. The testis and the spermatozoa were prepared for microscopic examination. No morphological changes were seen in the testis at anytime after either of the Sodium Silicate injections. No effect on the residual spermatozoa in the ductus deferens was apparent either (Kamboj and Amiya 1964).

As described earlier, Smith et al. (1973) added a Sodium Silicate solution to the drinking water containing 600 and 1200 ppm of added silica and given to groups of six weanling male and six female Sprague-Dawley rats. Control groups received no Sodium Silicate in their drinking water. At 4 months of age, the rats of treatment groups were mated. At 600 ppm and 1200 ppm, the treated water decreased the numbers of offspring born to 67% and 80% of controls, respectively. Also these treatments decreased the numbers of surviving offspring until weaning (3 weeks) to 46% and 24% of the control values.

## CLINICAL ASSESSMENT OF SAFETY

### Dermal Irritation

*Sodium Metasilicate*

A Sodium Metasilicate/carbonate granular detergent was applied to intact and abraded skin of humans for four hours. Each subject afforded eight test sites aligned four on each side of the back about 5 cm from the midline. Sites were vertically spaced 3 cm apart in the area between the scapula and the waist. Erythema and edema were graded 4, 24, and 48 h after the patch applications. Primary irritation indices (PIIs) were calculated by averaging the scores for all test sites. The detergent contained 37% Sodium Metasilicate and was applied at a concentration of 50% (w/v aqueous). The results from this study are presented in Table 12. The PII was >3.6 and the material was judged to be a severe irritant (Nixon, Tyson, and Wertz 1975).

Clairol (2000a) studied the irritancy of Sodium Metasilicate in a modified soap chamber test. Two hair color kits including a developer, activator, and lightener were tested. Sodium Metasilicate was a component of the activator at a concentration (*w/w*) of 13.5% in both kits; on-head concentrations were 1.34% (kit 1) and 1.43% (kit 2). The two test patches, a positive-control patch dosed with 2% sodium lauryl sulfate (SLS), and a negative-control patch dosed with deionized water were applied to the lower back of nineteen subjects for approximately 4 h. The test sites were graded for erythema, edema, burning, stinging, and itching approximately 4 h after application (20 min after removal) and approximately 28 h after application (24 h after removal). A separate 24-h 0.75% SLS reactivity patch was applied to the upper back and graded at the 28-h time point only.

No fissuring or scaling was observed over the course of the study. The kit 1 mean erythema + edema grade at 4 h was 1.00 and for 28 h was 0.50. For kit 2, the mean erythema + edema scores at 4 h was 0.95 and for 28 h was 0.53. The positive control had a 28-h erythema + edema grade of 2.92. No adverse events occurred during the course of the study (Clairol 2000a).

In a second modified soap chamber test, Clairol (2000b) tested Sodium Metasilicate to determine the incidence and severity of irritation. Procedures stated in the above study were followed. Twenty-one subjects completed this study. Sodium Metasilicate was a part of the activator in the hair coloring system and concentrations (*w/w*) were 13.5% in the activator and 2.58% on the head.

No burning or itching was recorded. The mean 6-h and 24-h erythema + edema scores were 1.36 and 0.56, respectively.

**TABLE 12**
Sodium Metasilicate: human dermal irritancy (Nixon, Tyson, and Wertz 1975)

| End point | Intact | Abraded |
|---|---|---|
| Mean irritation scores | >3.0 | >4.2 |
| Tissue destruction | 0/8 | 1/8 |

The reactivity control containing 0.75% SLS had a 28-h mean erythema + edema score of 0.89 (Clairol 2000b).

L'Oreal (2000a) assessed 15 bleach formulations in the elbow crease test. Experimental groups comprised 20 to 40 healthy adults. Approximately 0.7 ml of mixed product (developer + activator or developer + base + activator) was applied in the elbow creases on 40 $cm^2$ for 50 min without occlusion. The test sites were evaluated for erythema, edema, and vesicles by a trained grader using a 4-point visual scoring system for each parameter. Time points for evaluation were 5 min, 4 h, and 24 h following the removal of the products by rinsing. The Sodium Metasilicate concentrations in the activators and in the product mixtures ranged from 3.4% to 14% and 1% to 7%, respectively.

Under the study conditions, all products induced low grade irritation: almost exclusively mild erythema and only occasionally moderate erythema at 5 min. Observable changes subsided quickly after product removal, leaving slight erythema at 1 h in only a few volunteers. No correlation could be observed between Sodium Metasilicate concentrations and the irritation potential of the product (L'Oreal, 2000a).

L'Oreal (2000b) tested 32 hair bleaches in semioccluded patch tests. Sodium Metasilicate concentrations ranged from 3.4% to 14% in the activators and from 0.75% to 6.8% in mixed products; 0.2 ml of the mixed product were applied under patch tests for 1 h and 15 min on the back. Experimental groups were comprised of 25 healthy adults. Test sites were evaluated for erythema, edema, and vesicles using a 7-point visual scoring system encompassing all the parameters at 30 min and 24 h following the removal of the products by rinsing. Mean irritation scores were calculated for each time point.

Under the study conditions, Sodium Metasilicate produced only mild and transient irritation under exaggerated conditions of application. Irritation scores appeared to be independent of silicate concentration (L'Oreal 2000b).

*Sodium Silicate*

Nixon, Tyson, and Wertz (1975) applied three detergents containing Sodium Silicate to intact and abraded skin of humans for four hours. One sample contained 7% Sodium Silicate in a high-carbonate detergent, the second contained 13% in a low-carbonate detergent, and the third contained 6% in a phosphate detergent. Eight subjects were tested for each detergent. Each subject afforded eight test sites aligned four on each side of the back about 5 cm from the midline. Sites were vertically spaced 3 cm apart in the area between the scapula and the waist. Erythema and edema were graded 4, 24, and 48 h after the patch applications. PIIs were calculated by averaging the scores for all test sites.

The authors concluded that each sample had negligible irritancy. The results from this study are presented in Table 13 (Nixon, Tyson, and Wertz 1975).

Hill Top Research, Inc. (1979) conducted a study of cumulative irritant properties of a series of test materials with 10% of a 40% aqueous solution of Sodium Silicate on 12 male and female panelists. The test material was applied to the backs of the panelists in randomized manner. Each sample was reapplied to the same test site on each panelist for the remainder of the study (21 consecutive days) or until the max irritation score was reached. If the max score was reached, the patch was omitted and the patch area was scored for residual irritation for the next three scoring dates.

The test patches were removed by the panelists 23 h after application. The panelists were instructed to take a bath or shower immediately following removal of the patches and to keep the patch areas dry at other times. Approximately 0.3 ml of each sample was applied to each patch. Reactions to the test samples were scored 24 h after application (1 h after patch removal). Scores were classified as following: 0–49 (mild material, no irritation); 50–199 (probably mild in normal use); 200–449 (possibly mild in normal use); 450–580 (experimental cumulative irritant); 581–630 (experimental primary irritant).

The total score calculated for the panelists was 155, classifying the test compound as probably a mild irritant in normal use (Hill Top Research, Inc. 1979).

A skin freshener (10% of a 40% aqueous solution of Sodium Silicate) was evaluated via a 4-day minicumulative irritancy assay. A currently marketed product was used as a mildness frame of reference. Both materials were tested full strength under occlusive patch conditions in 20 humans. The PII for the test product was 0.5 and was 0.88 for the currently marketed product. The test product exhibited acceptable irritancy results and was significantly milder than the reference control (CTFA 1989).

Clairol (2000c) studied the irritancy of Sodium Silicate in a modified soap chamber test. Two hair color kits including a developer, activator, and lightener were tested. Sodium Silicate

**TABLE 13**
Sodium Silicate: human dermal irritancy (Nixon, Tyson, and Wertz 1975)

| Detergent type (Sodium Silicate concentration) | Concentration of detergent (*w/v* aqueous) | Mean scores | | PII | Tissue destruction | | Irritancy judgement |
|---|---|---|---|---|---|---|---|
| | | Intact | Abraded | | Intact | Abraded | |
| High carbonate (7%) | 50% | 0.0 | 0.0 | 0.0 | 0/8 | 0/8 | Negligible |
| Low carbonate (13%) | 50% | 0.0 | 0.2 | 0.1 | 0/8 | 0/8 | Negligible |
| Phosphate (6%) | 50% | 0.0 | 0.4 | 0.3 | 0/8 | 0/8 | Negligible |

was a component of the activator at 35.75% (*w/w*) with on the head concentrations of 4.26% (kit 1) and 7.61% (kit 2). The two patches listed before, along with a positive-control patch dosed with 2% SLS and a negative-control patch dosed with deionized water, were applied to the lower back of 19 subjects for approximately 4 h. The test sites were graded for erythema, edema, burning, stinging, and itching approximately 4 h after application (20 min after removal) and approximately 28 h after application (24 h after removal). A separate 24-h 0.75% SLS reactivity patch was applied to the upper back and graded at the 28-h time point only.

No fissuring or scaling was observed over the course of the study. The mean erythema + edema scores at 4 and 28 h were 1.24 and 0.45, respectively, for kit 1; the mean erythema + edema scores at 4 and 28 h were 1.26 and 0.53, respectively, for kit 2. The positive control containing 0.75% SLS had a mean 28-h erythema + edema score of 2.92. No adverse events occurred during the course of the study (Clairol 2000c).

In a second modified soap chamber test, Sodium Silicate was tested to determine the incidence and severity of irritation. Procedures stated in the Clairol 2000 study were followed. Twenty-one subjects completed this study. Sodium Silicate was a part of the activator in the hair coloring system and concentrations (%, *w/w*) in the activator and on the head were 35.75 and 2.13, respectively. No burning or itching was recorded. The mean 6-h and 24-h erythema + edema scores were 0.58 and 0.19, respectively. The reactivity control containing 0.75% SLS had a 28-h mean erythema + edema score of 0.89 (Clairol 2000d).

Sodium Silicate was evaluated in an elbow crease test previously described in the clinical dermal irritation section under Sodium Metasilicate (L'Oreal 2000). Sodium Silicate was present in only two activators at concentrations of 10.6% and 29.6% (2.1% and 8.5% respectively, in the product mixture). Under the study conditions, all products induced low-grade irritation: almost exclusively mild erythema and only occasionally moderate erythema at 5 min. Observable changes subsided quickly after product removal, leaving slight erythema at 1 h in only a few volunteers (L'Oreal, 2000c).

Sodium Silicate was evaluated in semiocclusive patch tests previously described in the clinical dermal irritation section under Sodium Metasilicate (L'Oreal 2000b). Sodium Silicate concentrations ranged form 10.6% to 29.6% in the activators and 1.2% to 6.5% in the mixed products. Under the conditions of this study, all products induce only mild and transient irritation under exaggerated conditions of application. Irritation scores appeared to be independent of silicate concentration (L'Oreal 2000d).

## Skin Sensitization

To determine its capacity to induce skin irritation and allergic sensitization, 10% of a 40% aqueous solution of Sodium Silicate was used in a repeat-insult predictive patch test. Ten patches were applied to the upper backs of 94 panelists. Five were placed on the right side and five were placed on the left side. The sample was applied to all panelists for 24 h every Monday, Wednesday, and Friday for 3 consecutive weeks. The samples were applied to the same site each time. The challenge was conducted in week 6 of the study. A single patch was applied to a previously unpatched site. These patches were removed 24 h following application. Reactions were scored 24 and 48 h after removal. Subjects exhibiting challenge patch reactions indicative of possible induced sensitization participated in follow-up testing after 1 week. Within the limits imposed by the sample size and the test procedure itself, the test material did not exhibit any potential for inducing allergic sensitization (CTFA 1979c).

## Case Reports

*Sodium Metasilicate*

Colloidal Sodium Metasilicate, 0.5 L, was orally ingested and led to the patient's death within 1 to 1.5 h. At autopsy, alkali burns were present in the gastric mucosa; and the stomach contained a small amount of liquid with a pH of 11.5. The liquid was chemically analyzed and was found to be condensed "waterglass." At microscopic examination of the lungs, numerous bronchioles and alveoli were filled with amorphous Sodium Metasilicate. Due to the obstruction of the airways, inhibition of alveolar gas diffusion could have been the cause of death. Liquid Sodium Metasilicate solidification occurred in the lungs by means of carbonic acid of expired air. This occurred due to the fact that Sodium Metasilicate starts to solidify at pH 11.3. Gas tric secretions had lowered the pH of the Sodium Metasilicate from 12.5 to 11.5 (Sigrist and Flury 1985).

*Sodium Silicate*

A man who drank 200 ml of a neutralized Sodium Silicate solution (estimated to contain about 100 g of solid Sodium Silicate or more than 1 g/kg) demonstrated prompt vomiting, diarrhea, and gastrointestinal bleeding, and later had albumin, acetone, "sugar," and blood in the urine. The patient recovered even at this dose. The authors noted that such a neutral silicate would be expected to be less corrosive than unneutralized, strongly alkaline Sodium Metasilicate (Eichhorst 1921).

Tanka, Miyachi, and Horio (1982) reported a case involving a 57-year-old man exposed to Sodium Silicate. At first examination, the eruption consisted of lichenified lesions with hyperpigmentation and four ulcers on the dorsum of the left hand. The lesions appeared oval to round and punched out with irregular and elevated margins. Urticarial wheals were not present and axillary lymph nodes were not palpable. A patch test was performed on the flexor surface of the skin using 20% aqueous solution of Sodium Silicate. Within 24 h, macular erythema and papules with itching were noted. A wheal appeared at the application site immediately after the patch was removed at 24 h. The wheal was not seen after a 15-min patch test. Itchy erythema progressed into ulcer formation after 1 week. A scratch test was also performed and resulted in wheal formation after

15 min. A skin biopsy of a lichenified site near an ulcer revealed spongiosis and exocytosis with individual cell keratinization in the upper epidermis. Patchy perivascular cell infiltration of polymorphonuclear leukocytes also was noted. The patch test biopsy specimen had similar lesions.

To further investigate these findings, these authors performed patch tests with 20% Sodium Silicate on the flexor surface of 30 people. After 48 h, positive reactions were noted in 22 of the volunteers. Erythema similar to that of the case study was seen. No ulcers formed. Scratch tests were also performed on the same volunteers with 20% Sodium Silicate. No wheal formation was observed (Tanka, Miyachi, and Horio, 1982).

## SUMMARY

This report provides a review of the safety of Potassium Silicate, Sodium Metasilicate, and Sodium Silicate. These ingredients combine metal cations (potassium or sodium) with silica to form inorganic salts.

Aqueous solutions of Sodium Silicate species are a part of a chemical continuum of silicates based on an equilibrium of alkali, water, and silica. pH determines the solubility of silica and, together with concentration, the degree of polymerization.

These ingredients function as corrosion inhibitors in cosmetics; Sodium Metasilicate also functions as a chelating agent and Sodium Silicate as a buffering and pH adjuster. Sodium Metasilicate is currently used in 168 formulations at concentrations ranging from 13% to 18%. Sodium Silicate is currently used in 24 formulations at concentrations ranging from 0.3% to 55%.

Potassium Silicate and Sodium Silicate were reported as being used in industrial cleaners and detergents. Sodium Metasilicate is a GRAS food ingredient.

Sodium Silicate administered orally acts as a mild alkali and was readily absorbed from the alimentary canal and excreted in the urine. Urinary excretion of Sodium Silicate given orally to rats at 40 and 1000 mg/kg was 18.9% and 2.8%, respectively.

The toxicity of these silicates has been related to the molar ratio of $SiO_2/Na_2O$ and the concentration. The acute oral $LD_{50}$ of Sodium Metasilicate ranged from 847 mg/kg in male rats to 1349.3 mg/kg in female rats, and from 770 mg/kg in female mice to 820 mg/kg in male mice. Gross lesions of variable severity were found in the oral cavity, pharynx, esophagus, stomach, larynx, lungs, and kidneys of dogs receiving 0.25 g/kg or more of a commercial detergent containing Sodium Metasilicate. Similar lesions were seen in pigs given the same detergent and dose as in the previous study. Male Sprague-Dawley rats orally administered 464 mg/kg of a 20% solution containing either 2.0 or 2.4 ratio to 1.0 ratio of sodium oxide showed no signs of toxicity, whereas doses of 1000 and 2150 mg/kg produced gasping, dypsnea, and acute depression.

Beagle dogs fed 2.4 g/kg/day of Sodium Silicate for 4 weeks had gross renal lesions but no impairment of renal function. In a oral subchronic study (drinking water containing 600 and 1200 ppm of added silica), there were body weight gains in male rats, but decreases in female rats. No apparent effect of the treatment in the drinking water was found on the longevity in rats having started treatment after weaning.

Intraperitoneal injections of a neutralized 2% solution of Sodium Metasilicate in white rats resulted in a decrease in spleen weight and relative enlargement of the kidneys.

Dermal irritation of Potassium Silicate, Sodium Metasilicate, and Sodium Silicate ranged from negligible to severe, depending on the species tested and the molar ratio and concentration tested.

Sodium Metasilicate was negative in the local lymph node assay, but a delayed-type hypersensitivity response was observed in mice.

Potassium Silicate was nonirritating in two acute eye irritation studies in rabbits. Sodium Metasilicate (42.4% $H_2O$) was corrosive to the rabbit eye. Sodium Silicate was a severe eye irritant in acute eye irritation studies. A skin freshener (10% of a 40% aqueous solution) containing Sodium Silicate was nonirritating. Sodium Silicate in another three Draize eye irritation studies was highly irritating, irritating, and nonirritating, respectively.

Sodium Metasilicate was nonmutagenic in a DNA damage and repair assay without metabolic activation using *B. subtilis*. Sodium Silicate was nonmutagenic in studies using *E. coli* stains B/Sd-4/1,3,4,5 and B/Sd-4/3,4.

Rats given Sodium Silicate (600 and 1200 ppm of added silica) in the drinking water in reproductive studies produced a reduced number of offspring; to 67% of controls at 600 ppm and to 80% of controls at 1200 ppm. Three adult rats injected intratesticularly and subcutaneously with 0.8 mM/kg of Sodium Silicate showed no morphological changes in the testes and no effect on the residual spermatozoa in the ductus deferens.

Sodium Metasilicate/carbonate detergent (37% Sodium Metasilicate) mixed 50/50 with water was considered a severe skin irritant when tested on the intact and abraded human skin. Detergents containing 7%, 13%, and 6% Sodium Silicate mixed 50/50 with water, however, were negligible skin irritants to intact and abraded human skin. A 10% of a 40% aqueous solution of Sodium Silicate was negative in a repeat-insult predictive patch test in humans. The same aqueous solution of Sodium Silicate was considered mild under normal use conditions in a study of cumulative irritant properties. Sodium Metasilicate and Sodium Silicate were studied in modified soap chamber tests. No burning or itching was observed and low erythema + edema scores were noted. Sodium Metasilicate and Sodium Silicate, tested in elbow crease studies and semioccluded patch tests, produced low grade and transient irritation.

Colloidal Sodium Metasilicate was fatal to one man and neutralized Sodium Silicate produced vomiting, diarrhea, and gastrointestinal bleeding in another man in separate case reports.

## DISCUSSION

The Cosmetic Ingredient Review (CIR) Expert Panel determined that the data provided in this report are sufficient to

address the safety of the tested ingredient Potassium Silicate, Sodium Metasilicate, and Sodium Silicate. The Panel recognized the irritation potential of these ingredients, especially in leave-on products. However, because these ingredients have limited dermal absorption and Sodium Metasilicate is a GRAS direct food substance, the Panel deemed the ingredients safe as currently used, when formulated to avoid irritation.

## CONCLUSION

Based on the available data contained within this report, the CIR Expert Panel concluded that Potassium Silicate, Sodium Metasilicate, and Sodium Silicate are safe for use in cosmetic products in the practices of use and concentration described in this safety assessment, when formulated to avoid irritation.

## REFERENCES


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