SODIUM AND POTASSIUM HYDROXIDES #103

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SUMMARY

Description Sodium and potassium hydroxides are white, deliquescent, corrosive, solids marketed in the form of pellets, flakes, sticks, lumps, and powder in varying degrees of purity. Both are very soluble in water, ethanol, and glycerol forming highly alkaline solutions. Although stable when dry, they rapidly absorb moisture and carbon dioxide from the air forming carbonates.

Occurrence Sodium and potassium hydroxides are manufactured chemicals and do not occur naturally in plants or animals. Both, however, are used in many commercial products. Sodium hydroxide is used as an alkalinizer or processing aid in many areas of the food industry, and in certain formulated drinking waters. Large quantities are employed in the manufacture and bleaching of paper pulp; in mercerizing cotton; in making cellophane, rayon, and casein plastics; and in reclaiming rubber. Both alkalies are used in soap making and in the formulation of certain pharmaceuticals and cosmetics. Sodium hydroxide is also a component of a number of water softeners, boiler cleaning compounds, household cleansers, and regenerators for water treatment outfits (110,116,228,262)

Acute Toxicity The oral LD_{50} of potassium hydroxide for rats is 1230 mg/kg body weight (224). Sodium hydroxide has an oral LD_{50} of 500 mg/kg BW for the rabbit (228). Both alkalies kill fish at levels of 25-100 ppm (020,254). The minimum fatal dose for man by mouth is not known with certainty. Fatalities have been recorded with potassium hydroxide following ingestion of as little as 2.6 grams (239). Quantities smaller than the adult fatal dose may be lethal for children (058).

Short-term Studies Sodium hydroxide at a level of 1% in the drinking water caused growth retardation and nervous symptoms in rats. At a level of 0.5%, growth was unaffected but none of the females conceived and bore litters (111).

Sodium hydroxide poisoning in the rabbit is characterized by an alteration of the sugar metabolism and of the blood ionic equilibrium accompanied by a marked acidosis. Hyperglycemia, definite increase in blood inorganic phosphorus, decreased serum calcium and chloride, slight increase in serum sodium and a decrease in the alkali reserve are the main features (071).

Fat emboli, resulting from lipemia, were found in 94% of rabbits poisoned with NaOH. The emboli occurred as early as 7 hours after administration of the alkali and were most prevalent in the lungs. Also affected were the choroid plexus, kidney, and to a lesser extent, the liver, spleen, and heart (073).

Calves were not adversely affected on a ration of wheat straw sprayed with 3.3% NaOH at a level of 1000 liters per ton. Over a 12-week period, the animals ruminated normally, gained weight, and remained in good health. Results at higher levels (6.7 and 10%) were not as good as with the control diet (221).

Small portions of maize cobs (1 gram) moistened with 10% NaOH (final conctn.) in nylon bags and introduced into the fistulated rumen of steers were digested much better than the untreated control material. Residual alkali (unneutralized) in the meal was 24% of the amount added (042).

Sodium hydroxide (0.1 N) administered to human subjects by stomach tube, at a rate of 6 to 10 ml per minute for 20 to 30 minutes, increased lower esophageal sphincter pressure without producing any harmful effects (041).

Long-term Studies

No long-term studies other than those reported as Special Studies were found in the literature.

Special Studies

Results of carcinogenicity studies with sodium and potassium hydroxides were negative for the most part (061,105,216). In one study, malignant tumors developed in approximately 1/7 of a large number of mice skin-painted with acqueous potassium hydroxide over a period of 25-46 weeks. Unfortunately, however, data on untreated and pH controls were not given (181).

Slight chromosome abnormalities were detected in ascites tumor cells in rats given an injection (1800 mg/kg BW) of potassium hydroxide, although results with control animals indicated that one type of aberration might have been due to a pH-induced effect (135).

Chromosome abnormalities were detected also in grasshoppers injected with sodium hydroxide; the authors tentatively concluded, however, that the aberrations observed were due to "pH shocks" (160).

Reports that the sex ratio of swine could be modified by alkali treatment of semen for artificial insemination were not confirmed in studies by USDA scientists (169).

Etiologic relationships in carcinoma of the esophagus at the site of lye strictures in man are uncertain (011,017).

Biochemistry

Sodium and potassium hydroxides are strongly corrosive chemicals and concentrated solutions cause severe tissue damage. Both react with tissue proteins to form proteinates and with fats to form soaps thus producing deep, penetrating burns; levels such as these, however, are found only in accidents or suicide attempts. Trace amounts that might be encountered in foods would be neutralized quickly and completely by the hydrochloric acid of the stomach. Since the resultant sodium, potassium, and chloride ions are normal body electrolytes, they would follow the same absorption, metabolic, and excretory pathways of their dietary counterparts. In view of the fact that these alkalies are sanctioned in

food processing only in accordance with good manufacturing practice and permitted in foods in amounts that will not significantly increase the dietary load of Na or K ions (126), quantities ordinarily ingested with foods would present no metabolic or excretory problems to the organism normally. Acid-neutralized, lye-peeled tomatoes, however, have been found to contain concentrations of NaCl that are too high for persons on a low sodium diet (163).

Consumer Exposure

Sodium and potassium hydroxides are direct food additives widely used in many areas of the industry as alkalinizer or processing aids (078,082,086). Food starch, smoked meats, potatoes, caramel, frozen dairy products, instant tea and coffee, baked goods, confections, and infant formulas represent some of the foods in which these alkalies are used as neutralizers or processing aids (007,078,100). Sodium hydroxide may enter foods also from paper and paperboard food containers, and from certain textile packaging materials. Large quantities of this compound are used in the manufacture and bleaching of paper pulp and in mercerizing cotton (110). Cellophane, rayon, casein plastics and reclaimed rubber also may contain traces used in manufacturing processes (228). Both alkalies are employed in the preparation of soaps and in the formulation of certain pharmaceuticals and cosmetics. Sodium hydroxide is used in certain formulated drinking waters, in regenerators for water treatment outfits and as a component of a number of water softeners, boiler cleaning compounds and cleansers (116).

Safe Levels

Sodium and potassium hydroxides are permitted as direct food additives or in food processing "in accordance with good manufacturing practice provided the increased dietary load of sodium or potassium ions is assessed and considered acceptable" (126).

The Threshold Limit Value (TLV) for sodium hydroxide is 2 mg per cubic meter of air (004,227) and is estimated to be the same for potassium hydroxide (188).

CHEMICAL INFORMATION

I. Nomenclature

A. Common names:

Sodium Hydroxide (Sodium hydrate; soda lye; caustic soda; white caustic; lye)

Potassium Hydroxide (Potassium hydrate; potassa; caustic potash; potash lye)

B. Chemical names:

Sodium Hydroxide

Potassium Hydroxide

C. Trade names:

Buckeye, Columbia, IRS, Gold Bond, Lewis, Lewis Eagle, Lewis' Indian Head, Lewis' Dixie.

D. Chemical Abstracts Services Unique Registry Numbers:

Sodium Hydroxide: 1310732

Potassium Hydroxide: 1310583

II. Empirical formulae

Sodium Hydroxide: HNaO

Potassium Hydroxide: HKO

III. Structural formulae

Sodium Hydroxide: Na-O-H

Potassium Hydroxide: K-O-H

IV. Molecular Weights

Sodium Hydroxide: 40.01

Potassium Hydroxide: 56.11

V. Specifications

Sodium hydroxide is produced in the following grades: Reagent; C.P.; Highest purity; U.S.P.; F.C.C.; Rayon; Commercial (015).

Reagent grade

Assay (NaOH)	98.000%
Sodium carbonate (Na_2CO_3)	0.500%
Chloride (Cl)	0.005%
Nitrogen compounds (as N)	0.001%
Phosphate (PO_4)	0.001%
Sulfate (SO_4)	0.003%
Ammonium hydroxide precipitate	0.020%
Heavy metals (as Ag)	0.002%
Iron (Fe)	0.001%
Nickel (Ni)	0.001%
Potassium (K)	0.020%

Food Chemicals Codex (047)

Solid sodium hydroxide must assay not less than 95% of total alkali, calculated as NaOH.

Solutions of sodium hydroxide must assay not less then 97% and not more than 103% by weight, of the labeled amount of NaOH calculated as total alkalinity.

The limits of impurities are:

Arsenic (as As)	not more than 3 ppm	(0.0003%)
Mercury	not more than 1 ppm	(0.0001%)
Lead	not more than 10 ppm	(0.001%)
Heavy metals (as Pb)	not more than 30 ppm	(0.003%)
Carbonate as Na_2CO_3	not more than 3%	
Insoluble & organic matter	Passes test	

Potassium hydroxide is manufactured in Reagent, Mercury Cell, Highest purity, C.P., U.S.P., F.C.C, and commercial grades (117).

Mercury Cell Grade

KOH	90.00%	min.
NaOH	0.45%	max.
K_2CO_3	0.80%	max.
KCL	100.00	ppm max.
$KClO_3$	1.00	ppm max.
K_2SO_4	20.00	ppm max.
Fe	10.00	ppm max.
SiO_2	40.00	ppm max.
Ca	5.00	ppm max.
Mg	5.00	ppm max.
Hg	0.02	ppm max.

Food Chemicals Codex (047)

Solid potassium hydroxide must be not less than 85% of total alkali, calculated as KOH.

Solutions of potassium hydroxide must be not less than 97% and not more than 103% by weight, of the labeled amount of KOH calculated as total alkali.

The limits of impurities are:

Arsenic (as As)	3 ppm (0.0003%)
Mercury	1 ppm (0.0001%)
Lead	10 ppm (0.001%)
Heavy metals (as Pb)	30 ppm (0.003%)
Carbonates (as K_2CO_3)	3.5%
Insoluble & organic matter	Passes test

VI. Description

Sodium and potassium hydroxides are white, highly deliquescent, caustic solids which are marketed in several forms - pellets, flakes, sticks, lumps, powder - and in varying degrees of purity.

Both compounds are very soluble in water (1g/ml), ethanol, and glycerol forming highly alkaline solutions (pH 13.5 - 14.0).

Sodium hydroxide melts at 318°C. and boils at 1390°C. The refractive index is 1.36 and specific gravity 2.13.

Potassium hydroxide melts at 360°C. and boils at 1320-1324°C. The specific gravity is 2.044.

Both alkalies rapidly absorb moisture and carbon dioxide when exposed to the air and containers must be kept tightly closed. Sodium and potassium hydroxides are strongly caustic to all tissues and care must be exercised in handling. Dust and fumes cause severe damage to the respiratory tract. Both are very corrosive to certain metals and cannot be stored in containers lined with aluminum, magnesium, zinc (galvanized), tin, chromium, brass, or bronze. Both may react violently or explosively with a number of chemicals. They are non-combustible and stable when dry.

VII. Analytical Methods

1. Socium and potassium hydroxides are strong bases and completely dissociate in aqueous solutions to Na^+, K^+ and OH^- ions. Measurement of the alkalinity (OH^- concentration) of the solution is a measurement of added sodium and/or potassium hydroxide. Alkalinity is measured as the pOH, where pOH = 14 = pH (pH is usually the quantity which is measured).

The pOH is related to the OH^- concentration as $pOH = -\log_{10} OH^-$, where OH^- is the hydroxyl ion concentration. The concentration of base is determined by the equation:

$$C_B = OH^- - (10^{-14}/OH^-)$$

where C_B is the analytical concentration of the base and 10^{-14} is the ion product constant of water. (013).

2. Where sodium and/or potassium hydroxide are the sole source of alkalinity in an aqueous solution, the amount present can be determined by titration with standard acid in the presence of a suitable indicator. The usual laboratory method is titration with standard hydrochloric acid to a bromthymol blue endpoint.

Because both of the above methods measure only the alkalinity of a solution, they are not qualitative for sodium or potassium hydroxide. Quantitative determination of these compounds by pH measurement or by neutralization is limited by the presence of other acids and bases.

3. Several spot tests have been presented which are qualitative and semi-quantitative for Na^+, K^+, and OH^- ions (075):

a. Hydroxyl ions, OH^-

In a neutral solution, an equilibrium between dimethylglyoxime and nickel dimethylglyoximate has been established:

$$Ni^{+2} + 2\ DH_2 \rightleftharpoons Ni(DH)_2 + 2\ H^+$$

where DH_2 represents dimethylglyoxime and DH the radical. The nickel dimethylglyoximate is an insoluble red compound. In the presence of OH^- ions, the equilibrium is shifted to the left because H^+ ions are removed. Under these conditions, the red nickel dimethylglyoximate will precipitate.

In the presence of silver ions, manganese ions (Mn^{+2}) will be oxidized to MnO_2 according to the equation:

$$2\ Ag^+ + Mn^{+2} + OH^- \longrightarrow 2\ Ag^o + MnO_2 + 2\ H_2O.$$

A positive test for hydroxyl ions results in the formation of a black precipitate.

b. Sodium ions, Na^+

There are two methods for sodium ion detection which involve precipitation of zinc uranyl acetate from a neutral or acetic acid solution.

The first method is useful for measuring 12.5 μg of sodium, which is detected by formation of a yellow crystalline precipitate having the formula $NaZn(UO_2)_3(CH_3COO)_9 \cdot 9\ H_2O$. Lithium salts precipitate when present in amounts greater than 1 g/liter, potassium salts when in excess of 5 g/liter. The following salts affect the sensitivity when in concentrations greater than 5 g/liter: Cu, Hg, Cd, Ni, Al, Mn, Zn, Ca, Sr, Ba, Mg, and NH_4.

The second method, involving the formation of zinc uranyl acetate, detects smaller quantities of sodium ions by utilizing the fact that the solid compound gives a bright greenish-yellow fluoresence in ultraviolet light. The limit of identification is 2.5 μg of sodium.

Sodium ions may be detected in the presence of chlorides, nitrates, phosphates, and sulfates as well as in high concentrations of lithium, potassium and magnesium salts by reaction in an aqueous ethanolic solution with alpha-methoxyphenylacetic acid. A white precipitate indicates the presence of sodium ions, and the test is good for 30 μg of sodium. Barium, strontium, calcium and cesium interfere in the determination.

Sodium ions react with the magnesium salt of 8-amino-1-naphthalene sulfonic acid to form a grey precipitate. The limit of identification is 30 μg. No interference is observed by the ions of potassium, lead, magnesium, ammonium, and lithium when present in amounts not exceeding the concentration of Na^+ by 4, 7, 15, 3, and 4 times respectively.

As little as 0.5 μg of sodium ion can be detected by the formation of an orange-yellow crystalline precipitate when the sodium is reacted with 5-benzamidoanthraquinone-2-sulfonic acid. The ions of other alkali metals and ammonium must not be present.

A red precipitate is formed when sodium ions react with the dipotassium salt of 4,5-dihydroxycyclopent-4-ene-1,2,3-trione. No interference is observed from other alkali metals, ammonium and magnesium in 10 to 100 fold amounts. The test is good for 1.7 μg of sodium.

c. Potassium ions, K^+

Sodium cobaltinitrite, $Na_3(Co(NO_2)_6)$ reacts with potassium salts in neutral or slightly acid solutions, yielding a yellow crystalline precipitate. The chief product is the dipotassium salt, though varying amounts of the mono- and tripotassium salts are formed. The test is good for 4 μg of potassium.

The sensitivity of the above test may be increased by the presence of silver ions, in which case the compound formed has the formula $K_2Ag(Co(NO_2)_6)$. The limit of identification when silver is used is 1 μg of potassium. When using the silver ion method, no halides may be present. In addition, lithium, thallium, and ammonium salt must not be present.

Potassium can be detected in the presence of sodium, when the sodium concentration is less than 10 times that of potassium, by reacting it with dipicrylamine in an alkaline medium. The limit of identification is 3 μg. It is advisable to heat the mixture first with mercuric oxide to precipitate excess metal ions, which interfere by lowering the active form of dipicrylamine.

Potassium is also detectable in the presence of much sodium by reaction with water-soluble sodium tetraphenylborate. Cesium, rubidium, and ammonium ions react with the reagent, as do the heavy metal ions. The limit of identification is 1 μg though it may be used to detect as little as 0.09 μg of potassium by carrying out the reaction at pH 5.4 using acetate buffer.

This method may also be used as a quantitative gravimetric method for potassium (031).

4. There are two methods of quantitative determination of sodium and potassium which initially involve conversion to the chlorides, NaCl and KCl (031).

a. Chloroplatinate Method.

The mixed chlorides, NaCl + KCl are dissolved in water containing excess chloroplatinic acid (H_2PtCl_6) which converts them to K_2PtCl_6 and Na_2PtCl_6. The mixture is evaporated and the remaining solid is treated with 80% ethanol which dissolves only the sodium chloroplatinate. The residual solid is dried at 100-130° and weighed as K_2PtCl_6, for potassium determination.

The alcohol solution from the above is placed under hydrogen gas after most of the solution has been evaporated. The chloroplatinate is reduced to metallic platinum, which is filtered off. The filtrate is dried, ignited to 800°C. and weighed as NaCl for sodium determination.

b. Perchlorate Method

The mixed chlorides are dissolved in a small volume of water, 70-72% perchloric acid is added, and the solution evaporated to dryness. The solid perchlorates are extracted with n-butanol:ethyl acetate, 1:1. The

sodium perchlorate dissolves leaving the potassium perchlorate which is separated on a filtering crucible, washed with the butanol:ethyl acetate solvent, dried and heated in an oven. The residual solid is weighed as $KClO_4$ for potassium determination.

After the potassium perchlorate is separated from the butanol:ethyl acetate solution, the solution is evaporated to less than 40% of its original volume. A 20% excess of HCl gas in n-butanol is added. This will precipitate NaCl which is collected, washed, dried and heated to 600°C. The residue is weighed as NaCl for sodium determination.

VIII. Occurrence and Levels (086,110,116,228,262)

Sodium and potassium hydroxides do not occur naturally in plants or animals but both are widely used in industry.

Sodium hydroxide is used as an alkalinizer or processing aid in many areas of the food industry. It is used also in certain formulated drinking waters and in regenerating water treatment outfits. It is a component of a number of water softeners and boiler cleaning compounds.

Both alkalies are used in the formulation of certain pharmaceuticals and cosmetics and in the manufacture of hard and soft soaps. Sodium hydroxide is widely used also in the manufacture of other household cleansers. Many paint and varnish removers contain sodium hydroxide.

Large quantities of sodium hydroxide are used in the manufacture and bleaching of paper pulp, in mercerizing cotton, in the manufacture of cellophane and rayon, in the preparation of casein plastics, in reclaiming rubber, and in the manufacture of glass and ceramics.

Sodium hydroxide is used also in petroleum refining and in the manufacture of dyestuffs and printing inks.

There are no natural inorganic sources of sodium and potassium hydroxides.

BIOLOGICAL DATA

I. Acute Toxicity

A. Fish

1. Van Horn (254) immersed minnows, one to five per group, in varying concentrations of sodium hydroxide in two-liter amounts at 18°C. in open battery jars in a study of kraft pulp mill wastes on aquatic organisms. After immersion, the fish were observed hourly for signs of toxicity over a period of five days. Survival times were recorded for all fatalities. In addition, determination of pH, total alkalinity, and oxygen content were made at the conclusion of each test. If the oxygen level fell below 4 ppm, or if either of the other factors was unfavorable for fish life, the data were discarded. Moreover, 100 percent survival of the untreated controls was required in each experiment. The minimum lethal concentration calculated from the mortality data is given in Acute Toxicity Table 1.

2. Belding (020) determined the MLD (by immersion) values for brook trout of sodium and potassium hydroxides using fish two to three years old (about 26 cm. long and 215 grams BW) exposed to varying dilutions of the alkalies in water at 56°F. held in large wooden tanks. Preliminary control tests indicated that these conditions were satisfactory. Pre-lethal toxic effects were noted in addition to the mortality data given in Table 1.

With minimum lethal concentrations of sodium hydroxide, the onset was slow with the fish resting quietly at the bottom of the tank for some time. Gradually they became restless and covered with a grayish mucus (probably a protective mechanism, according to the author) and began to rise rapidly to the surface grasping. Periods of rapid dashing and leaping followed. Finally, there was a loss of equilibrium, respiratory distress, marked evidence of oxygen hunger, and death. Potassium hydroxide caused the same syndrome but appeared to be somewhat less toxic.

B. Rats

Symth et al (223,224) determined the oral (by gastric intubation) LD_{50} values for potassium hydroxide with Carworth-Wistar male rats, four to five weeks of age, 90-120 g. BW, using five animals per group. The observation period was 14 days (See Acute Toxicity Table 1).

Table 1. Acute Toxicity of Sodium and Potassium Hydroxides

Substance	Animal	Sex & No.	Route	Dosage	Measurement	Reference Bibliography No.
Sodium Hydroxide	Minnows	-	Immersion	100[a]	MLC[b]	Van Horn (254)
Sodium Hydroxide	Brook trout	-	Immersion	25[a]	MLD[c]	Belding (020)
Sodium Hydroxide	Rabbits	46	p.o.	237[d]	MLD	Fazekas (071)
Sodium Hydroxide	Rabbits	-	p.o.	400[d]	MLD	Steyn (231)
Sodium Hydroxide	Rabbits	-	p.o.	500[d]	LD_{50}	Merck Index (228)
Potassium Hydroxide	Brook trout	-	Immersion	50[a]	MLD[c]	Belding (020)
Potassium Hydroxide	Rats	-	p.o.	1230[d]	LD_{50}	Smyth (224)

[a] Parts per million
[b] Lowest concentration which killed any of the fish within five days
[c] Minimum concentration capable of causing death within 24 hours
[d] mg/kg BW

C. Rabbits

1. Fazekas (071) determined the oral (by stomach probe) MLD value for sodium hydroxide for rabbits using 46 animals, 2500-3500 grams BW (strain, sex, age not given), during a study on blood chemistry in experimental sodium hydroxide poisoning. Single doses ranging from 500 to 2850 mg in the form of a 1, 2, 3, 5, or 10% solution were given, one day after fasting. The animals were closely observed for several weeks and toxic symptoms noted. The time of death was recorded for all fatalities. The results are given in Tables 1 and 2.

The animals became restless 1-2 minutes after administration of the alkali. At first, they stretched out, pressing the stomach against the floor, then suddenly jumped up, or rolled from one side to the other. Five to ten minutes later, breathing was greatly accelerated and incontinence was observed. This condition gradually ceased after one to two hours, the feet were drawn under the body and the animals remained almost motionless in the cage and moved very reluctantly when exposed to external stimuli. Breathing gradually became slow and artificial. In the animals that died after 1-2 days, a general weakness and steadily increasing loss of strength was observed as early as 2-3 hours after receiving the poison; the eyes were half closed and the gait became unsteady. This condition deteriorated visibly, breathing and heart beat became weaker, until the animal died with (or without) convulsions. In the animals that died after more than three days, initial symptoms were milder. Survivors gave a healthy impression as early as a few hours after the early light symptoms ceased.

2. Steyn (231) gave rabbits (strain, age, sex and weight not specified), two to four per group, by stomach tube, sodium hydroxide in graded doses ranging from 200 to 2000 mg/kg BW. The animals were observed for signs of toxicity and the time of death recorded for all fatalities. Each animal that succumbed was autopsied to ascertain pathologic effects. The results are presented in Tables 1 and 3.

At autopsy, the gastric mucosa and stomach wall of all animals that were given 400 mg/kg BW showed pronounced dissolution (corrosion). In one of the cases, the stomach wall was almost perforated in two places. The remainder of the internal surface of the wall was very slimy and dark red-brown in color (alkali hematin). In animals that received 800-2000 mg/kg BW, the lesions were much more severe.

Table 2. Oral Toxicity of Sodium Hydroxide for the Rabbit (071)

Animal number	Dosage (mg/kg BW)	Time of death (hrs)	Animal number	Dosage (mg/kg BW)	Time of death (hrs)
			GROUP I		
1	827	7	9	350	40
2	943	10.25	10	530	3.5 days
3	621	12	11	237	5 days
4	600	22.5	12	487	9 days
5	570	26	13	490	14.5 days
6	908	28	14	429	survived
7	460	28	15	211	survived
8	568	37	16	161	survived
			GROUP II		
1	785	2.5	9	748	24.5
2	750	7.5	10	751	27.5
3	750	12	11	509	28
4	750	15	12	556	35
5	750	15	13	502	3 days
6	750	16	14	470	12 days
7	750	18	15	517	survived
8	740	23	16	407	survived
			GROUP III		
1	748	7	8	748	29
2	747	7	9	750	29
3	745	12	10	750	30
4	748	15	11	746	35
5	748	16.5	12	748	2.5 days
6	747	22	13	500	survived
7	747	22.5	14	500	survived

3. The Merck Index (228) reports the oral LD_{50} of sodium hydroxide for rabbits (strain, sex, etc. not given) as 500 mg/kg.

Table 3. Acute Toxicity of Sodium Hydroxide for Rabbits (231)

Number of animals	Route	Dosage (mg/kg BW)	Mortality[a]
2	p.o.	200	0/2
4	p.o.	400	4/4[b]
2	p.o.	800	2/2[c]
2	p.o.	1000	2/2[d]
2	p.o.	2000	2/2[e]

[a] Numerator - number of fatalities; Denominator - Total number used

[b] Death occurred within 40 hours

[c] Death occurred between 20 and 30 hours

[d] Deaths occurred at 1-1/2; 30 hours

[e] Death occurred within 3 hours

D. Human Toxicity

Sodium and potassium hydroxides are dangerous caustic substances and many cases of poisoning occur each year in spite of legislation (Federal Caustic Poison Act, 1927) requiring that they be plainly labeled POISON! (033). The fatal dose for man by mouth is not known with certainty but fatalities have been recorded for potassium hydroxide following ingestion of quantities as low as 2.6 grams (265,239).

Most cases are accidental poisonings of children of the one-to-five age group resulting from ingestion of powdered lye thought to be sugar or salt, or from drinking lye solutions mistaken for milk or sugar water (033). Ignorance and/or negligence on the part of parents in the use and storage of caustic cleansers are responsible for most such fatalities (131). Quantities smaller than the estimated adult fatal dose may be lethal for children (058).

Sodium and potassium hydroxides combine with tissue proteins to form proteinates, and with fats to form soap, thus producing deep corrosive and penetrating burns involving the mouth, esophagus, and sometimes the stomach.

Typical symptoms of alkali ingestion are described as ". . . burning pain from mouth to stomach. Swallowing is difficult at first, and then becomes impossible. Mucous membranes are soapy and white, but become brown, edematous, and ulcerated. Vomitus is bloody and may contain shreds of mucous membrane. The pulse is feeble but rapid; respiration is increased and collapse may ensue. Death due to shock, asphyxia from glottic edema, or intercurrent infection and pneumonia may occur within 48-72 hours" (009).

II. Short-term Studies

A. Rats

Heller (111) gave rats, males and females, six to seven per group, (strain, age, and weight not given), drinking water containing sodium hydroxide at levels of 0.5% and 1.0%. The animals were fed a balanced diet consisting of yellow corn, whole wheat, milk powder, alfalfa (dry), cottonseed meal, tankage, 1% sodium chloride, and 1% calcium chloride. The sodium hydroxide-treated drinking water was the sole source of fluid. Effects on growth, reproduction, litters, lactation, and general health were noted (see Table 4). At the 1% level, growth was stunted and the animals became nervous and highly irritable. The eyes became sore and diarrhea was a characteristic symptom. At the 0.5% level, growth was normal but none of the females conceived and bore litters. There were no untreated controls in this study.

B. Rabbits

1. Fazekas (071) studied the blood chemistry of rabbits during experimental sodium hydroxide poisoning via the oral route. Rabbits weighing between 2500 and 3500 grams, (strain, sex, and age not given), in groups of 14 to 16, were given, by stomach probe, single doses of sodium hydroxide ranging from 500 to 2850 mg, in the form of a 1, 2, 3, 5, or 10% solution, one day after fasting.

Sodium hydroxide poisoning in the rabbit was found to be characterized by a hyperglycemia, marked increase in inorganic phosphorus in whole blood, decreased serum calcium and chloride, and a slight increase in serum sodium. Also, there was a marked acidosis in the form of decreased serum alkali reserve (CO_2-capacity). The pathology of sodium hydroxide poisoning in the rabbit, therefore, was indicative of a disruption of sugar metabolism and of the blood ionic equilibrium, and of a marked acidosis. The results obtained were in agreement with the findings in humans suffering from caustic alkali poisoning, and with the results of similar animal experiments.

Table 4. Effect of Sodium Hydroxide and Some Other Alkalies on the Growth of Rats and Their Offspring (111)

Compound	Conctn.[a] (%)	Males	Females	Litters	Offspring Lived	Offspring Died	Remarks
NaOH	0.5	2	4	0	-	-	Growth normal
	1.0	3	4	0	-	-	Little growth. Nervous, sore eyes diarrhea.
Na_2CO_3	1.0	3	7	7	31	24	Growth of offspring unsatisfactory.
	1.5	1	7	2	0	19	Adults-Rough Coat, red eyes, diarrhea.
$NaHCO_3$	1.5	2	4	7	48	7	Growth of adults & offspring retarded
	2.0	1	2	2	7	7	Growth & appearance unsatisfactory.
$Ca(OH)_2$	Satd.	4	4	4	19	11	Some growth retardation during lactation.

[a] In drinking water, the sole source of fluid.

2. Discovery of severe fat emboli in the brain and other organs of human lye poisoning victims at autopsy prompted a detailed study by Fazekas (073) of this pathologic phenomenon during experimental sodium hydroxide poisoning in the rabbit.

Thirty-four rabbits, weighing between 2000 and 3800 grams, (strain, age, sex, not specified), were given by stomach probe, single doses of sodium hydroxide ranging from 0.75 to 2.5 grams, in the form of a 1, 2, 3, 5 or 10% solution, after one day of fasting (See Table 5). A parallel group of 32 animals received varying doses of ammonium hydroxide by the same route. Brain, lungs, kidneys, heart, liver, spleen, and other organs were fixed in 4% formalin immediately after death. Frozen sections stained with Sudan III-Hematoxylin were then examined for the prevalence and severity of fat emboli. These results also are presented in Table 5.

Table 5. Fat Embolism in Various Organs of the Rabbit During Experimental Sodium Hydroxide Poisoning (073)

Nr.	Körpergewicht in g [a]	Dosis der NaOH [b] ccm	%	g	Fettembolie [c] der Lungen [d]	des Plexus chorioideus [e]	der Nieren [f]	der Leber [g]	der Milz [h]	Lebensdauer nach der Vergiftung [i]
1	2680	67	3	2,01	+	+	—	—	+	7 (hours)
2	2700	75	3	2,25	++	+	—	—	—	7 „
3	2650	25	10	2,50	++++	++	—	—	—	10¼ „
4	2400	75	2	1,50	+	+	—	—	—	12 „
5	2600	65	3	1,95	++++	—	+	—	—	12 „
6	2900	73	3	2,12	+++	++	+	—	—	15 „
7	3100	78	3	2,34	+++	+	—	—	—	16 „
8	2800	72	3	2,26	+	—	—	—	—	17 „
9	2500	43	3	1,29	++	++	—	—	—	17 „
10	3200	80	3	2,40	++++	—	+	—	—	18 „
11	2100	25	5	1,25	+	+	—	—	—	22½ „
12	3000	45	5	2,25	+	++	—	—	—	23 „
13	2700	45	3	1,35	+	+	—	—	—	24 „
14	2980	74	3	2,23	+	—	—	—	—	24½ „
15	2600	75	2	1,50	++	+	+	—	+	26 „
16	2835	71	3	2,13	++	+	+	+	—	27½ „
17	3200	75	2	1,50	—	+	+	—	—	28 „
18	2470	75	3	2,25	++	++	+	—	—	28 „
19	2650	45	3	1,35	+	++	+	—	—	28 „
20	2700	46	3	1,38	+++	+	—	—	—	32 „
21	3170	79	3	2,37	+++	++	+	+	—	33 „
22	3600	100	2	2,00	+++	+	—	—	—	35 „
23	4000	75	3	2,25	+++	++	—	—	—	37 „
24	2200	25	5	1,25	—	+	—	—	—	37 „
25	3200	75	2	1,50	+	+++	—	+	—	40 „
26	4200	75	2	1,50	—	+++	—	—	—	40 „
27	3800	75	3	2,25	++	—	+	—	—	2½ (days)
28	3570	60	3	1,79	+	—	—	—	—	3½ „
29	2800	75	2	1,50	—	+	—	—	—	3½ „
30	2660	44	3	1,32	+	+	—	—	—	5 „
31	3160	75	1	0,75	—	—	—	—	—	5 „
32	2560	12,5	10	1,25	+++	—	—	—	—	9 „
33	3200	75	2	1,50	—	—	+	—	—	12 „
34	2550	12,5	10	1,25	—	—	—	—	—	14 „

[a] Body weight
[b] Dose of NaOH
[c] Fat embolism
[d] in lungs
[e] in plexus choroideus
[f] Kidneys
[g] in liver
[h] in spleen
[i] Duration of life after poisoning

Table 6. Food Intake and Nutrient Digestibility Coefficients of Sodium-hydroxide Treated Wheat Straw Fed to Calves (221).

Exp.	Level of NaOH treatment (%)	Dry-matter* intake, g/kg body weight$^{0.75}$	Nutrient digestibility coefficients (%)		Calculated digested organic matter, %, of dry-matter	Calculated digestible organic matter intake, g/kg body weight$^{0.75}$
			Organic matter	Crude protein		
1	0	86	53	48	46	40
	3·3	95	63	55	53	50
	6·7	78	63	53	52	41
	10.0	66	62	56	51	34
	S.E. of mean	6·2	1·9	2·8	—	1·6
	Error D.F.	15	15	15	—	15
2	0	95	55	62	48	46
	3·3	121	70	63	61	75
	6·7	105	71	61	61	64
	10·0	89	71	51	60	53
	S.E. of mean	1·3	1·3	0·8	-	0·6
	Error D.F.	7	7	7	-	7

* The mean green forage dry-matter intake for all rations in both experiments was 9 g/kg body weight$^{0.75}$.

Fat emboli were found in 94% of the rabbits poisoned with NaOH in this study. The emboli occurred as early as seven hours after poisoning and were most prevalent (91%) and most severe in the lungs. Seventy percent of the animals had emboli also in the choroid plexus of the brain; 32% in the kidneys. Emboli were less prevalent in the liver, spleen, heart (5-10%), and were absent in other organs. Pulmonary emboli severe enough to cause sudden death were found. The author believes that many deaths attributed to shock in human lye poisoning victims actually may have been due to fat emboli. The mechanism involved in emboli development appears to be a lipemia which develops in response to the poisoning. Similar results were obtained in experimental ammonia poisoning.

C. Cattle

1. Singh and Jackson (221) fed 20 male calves (Sahiwal and Saliwal-Jersey), 9-18 months old, two to three per group, wheat straw sprayed with sodium hydroxide (3.3, 6.7, and 10% solutions), at the rate of 1000 liters per ton, for a period of 12 weeks. Excess alkali was not neutralized nor removed by washing, but the treated straw was fortified with groundnut cake, molasses, and minerals. In addition to the experimental diet, the animals were given 1 kg of green forage daily. Water was offered ad libitum. Food intake and organic matter digestibility coefficients were determined for the three NaOH-treated diets in comparison with an untreated basal control ration. The animals were observed for toxic effects throughout. Results are presented in Table 6.

The calves ruminated normally, gained weight, and remained in good health throughout in both experiments[a]. Food intake and digestibility values with the 3.3% NaOH-treated straw were considerably higher than those with the basal control ration. Results with the higher levels of NaOH (6.7 and 10%), however, were not as good as those with the control diet. Nitrogen and phosphorus retention were not adversely affected up to the 3.3% treatment level. Calcium retention actually increased with NaOH treatment up to 6.7%.

The amount of unneutralized NaOH in the rations may possibly be estimated from results obtained in another study (042) with the same type of forage (See Tables 7, 8, and 9).

2. Chandra and Jackson (042) investigated the effect of sodium hydroxide and a number of other chemical substances on lignin removal and digestibility of wheat straw and some other roughages (maize cobs, paddy straw, sorghum straw, and sugar cane tops) in cattle by the nylon-bag, rumen-digestion technique.

Sahiwal steers, 250-300 kg. BW, two per group, were given, via the fistulated rumen, 1 gram portions of roughage, moistened with NaOH at levels of 1, 2, 3, 4, 6, 8, 10, 12, and 15% (final concentration), in a nylon bag. Control groups of the same number were included for each substance. During the experimental period the animals were fed a low-bulk diet (5 kg. fresh lucerne herbage and 3 kg. concentrated salt mixture) in the regular manner and watered twice daily. After a period of 72 hours, the percentage of test material digested was determined. The results are given in Figure 1 and Tables 7, 8, and 9.

Digestibility of ground maize cobs was increased more than 100% and the lignin reduced by 26% in meal moistened with NaOH at a final concentration of 10%. Higher concentrations of alkali were no more effective in either respect; lower concentrations were proportionally less effective (Fig. 1 and Table 7).

At the 10% level, residual (unneutralized) sodium hydroxide was 24% of that added to maize cobs and 34% of that added to wheat straw. The highest level treatment in which there was no residual alkali was 1% (See Table 8).

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[a] Duplicate experiments were conducted

Table 7. Comparative Rumen Dry-Matter Digestibility (%) of Several Roughages Treated with Different Levels of Sodium Hydroxide (042)

Roughages	Grams NaOH/100 grams roughage			
	0	3.3	6.7	10
Maize cobs	46	66	78	93
Wheat straw	51	67	80	89
Paddy straw	57	69	82	89
Sorghum stover	58	68	83	87
Sugar cane tops	56	65	78	86

Table 8. Residual Sodium Hydroxide in Maize Cobs and Wheat Straw Treated with Varying Concentrations of NaOH (042)

Gms NaOH per 100 g roughage	% NaOH of total NaOH added	
	Maize cobs	Wheat straw
0	0	0
1	0	0
2	2	2
3	3	8
4	4	12
6	12	24
8	21	36
10	24	34
12	32	40
15	32	40

Table 9. Residual Sodium Hydroxide in 6% NaOH-Treated Maize Cobs and Wheat Straw after Varying Periods of Time (042)

Time	Maize cobs	Wheat straw
5 min	23	32
30 min	22	30
1 hr	20	29
4 hrs	19	29
18 hrs	19	27

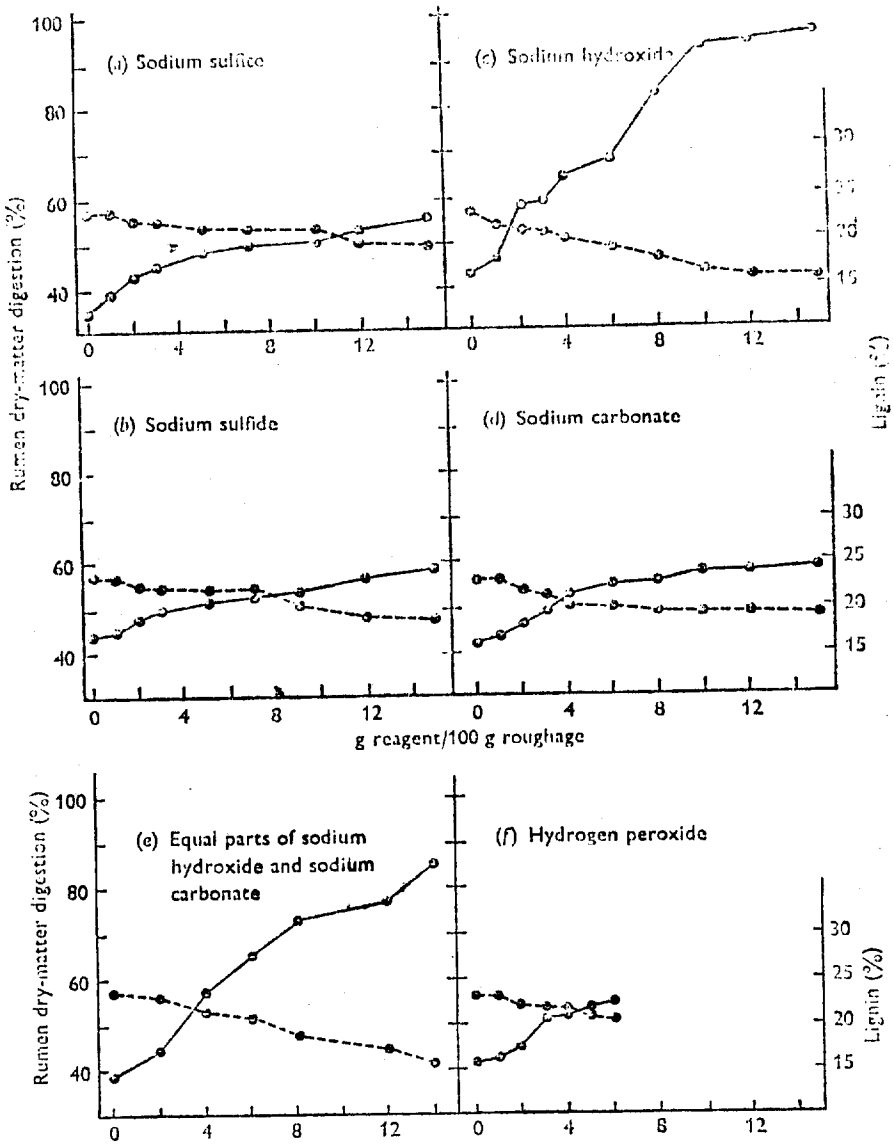

Figure 1. Effect of Treatment with Sodium Hydroxide and Some Other Compounds on the Lignin Content o- - - o and Digestibility o———o of Ground Maize Cobs (042)

D. Human toxicity

1. Trussell (247) reported a series of chemical food poisoning epidemics in a New York state prison in which sodium hydroxide was strongly indicated by circumstantial evidence to have been the cause.

Three epidemics of acute gastroenteritis, each involving 400 to 600 inmates, occurred over a period of several months. The etiologic agent of the first two episodes was not determined although the evidence pointed strongly to food as the source. Gravy left over from a meal, and held

overnight in a kitchen steam kettle, along with soup in which the beef stock also had been used previously, were suspected as the sources of the third epidemic. Six mice, fed portions of the gravy, died; four of seven animals given samples of the soup also succumbed. Bacteriologic findings were entirely negative. Moreover, the pH of the soup and gravy was greater than 13.0. Samples of both were negative for fluorides, silicates and phosphates. No detergents were used in the prison which could have caused such a high pH value. However, lye was available to some of the inmates through the prison plumbing supplies shop and the authorities believed that this was added to the food as a malicious act. The clinical features of the malady, as well as those of the first two epidemics, were strongly suggestive of sodium hydroxide poisoning; the main symptoms were cramps, diarrhea, mucous and pus in the stools over a few hours, with malaise lasting as long as one to two days in many of the victims.

2. Castel and Levine (041) studied the effect of sodium hydroxide, sodium bicarbonate, and a commercial antacid ($Mg(OH)_2$-$Al(OH)_3$ type) on the lower esophageal sphincter pressure in patients.

Twenty-eight, fasted (overnight) human subjects with normal pressure, and six with abnormally low pressure (incompetent sphincter) were given, via stomach tube, 0.1 N HCl solution at a rate of 6 to 10 ml per minute for 20 minutes. This treatment decreased the intragastric pH to less than 1.5. The stomach was then emptied and 0.1 N NaOH solution administered at the same rate for 20 to 30 minutes. The results are presented in Fig. 2.

Sodium hydroxide, at the dosage indicated, resulted in a marked increase in lower esophageal sphincter pressure with values much greater than the basal levels. No harmful effects of the treatment were detected. The probable mechanism is discussed.

3. Sodium and potassium hydroxides are very corrosive to all tissues and severe esophageal strictures oftimes develop in non-fatal cases of their ingestion (009). Sixteen of 102 patients with strictures died during the course of therapy, according to one survey (131).

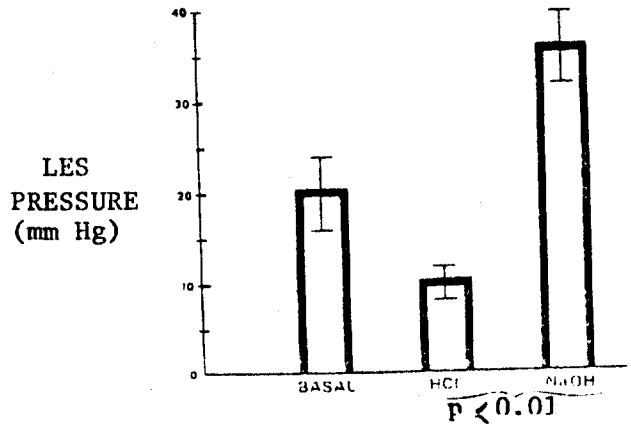

Figure 2. Mean Pressure in the Lower Esophageal Sphincter (LES)=1 SE in Five Subjects During the Basal State and with Subsequent Gastric Acidification (hydrochloric acid) and Alkalinization (sodium hydroxide) (041)

4. Inhalation of dust or mist may cause varying degrees of damage to the respiratory system (228). The Threshold Limit Value (TLV) is 2 mg per cubic meter of air of sodium hydroxide (004,227) and is estimated as the same for potassium hydroxide (188).

5. Sunshine (234) gives the following toxicity ratings for these alkalies:

Substance	Ingestion	Skin penetration	Skin irritation	Eye contact
Sodium hydroxide	3X[a]	1X	5	5
Potassium hydroxide	2	1X	5	5

6. Dermatitis may result from repeated or prolonged contact with even very dilute solutions or mists of these substances (188).

III. Long-term Studies

No information was found excepting the carcinogenicity studies of Dyer (061), Gross (105), Narat (181), and Seilern-Aspang (216) which are reported in the following section - IV. Special Studies.

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[a] 1 is low; 5 is high; x indicates judgement based on analogy with a material of similar structure.

IV. Special Studies

A. Bacteria

Demerec (057) investigated the mutagenic potentialities of sodium and potassium hydroxides by ascertaining their ability to induce back-mutation from streptomycin-dependence to non-dependence with *Escherichia coli* (strain Sd-4).

Varying concentrations of the compounds in distilled water were inoculated with streptomycin-dependent *E. coli* (Sd-4) and incubated at 37°C for six hours. Untreated control cultures were prepared in an analogous manner by inoculating an equal volume of distilled water with the test organism. At the end of the exposure period, both treated and control cultures were plated on streptomycin agar to calculate the percentage of survivors, and on streptomycin-free agar to determine the number of mutants. The results are given in Table 10.

Unfortunately, the results obtained were not conclusive.

Table 10. Results of Experiments Testing Induction of Back-mutations in Sd-4 (streptomycin-dependent) *E. coli* Treated with Certain Chemicals (057)

Chemical	Concentration %	Treatment (hours)	Survival %	Treated			Control		
				No. of plates	Total no. of bacteria	Mutants per 10^8 bacteria	No. of plates	Total no. of bacteria	Mutants per 10^8 bacteria
Sodium hydroxide	0.013	3	86.	10	2.6×10^8	11.7	5	3.0×10^8	18.9
	0.015	3	37.	10	3.0×10^8	32.4	4	6.4×10^7	35.9
	0.02	3	27.	7	5.4×10^8	13.8	5	1.4×10^8	16.8
	0.011	3	24.	10	3.4×10^8	3.3	6	1.9×10^8	3.6
	0.0145	3	20.	10	1.9×10^8	20.2	4	8.5×10^7	8.3
	0.015	3	16.	10	1.2×10^8	16.3	4	7.3×10^7	12.3
	0.0125	3	12.	8	1.2×10^8	28.2	4	1.0×10^8	38.0
	0.0125	3	11.	8	1.0×10^8	130.7	4	9.2×10^7	98.1
	0.014	3	5.7	8	5.3×10^7	43.0	4	6.8×10^7	43.8
	0.022	3	1.3	8	2.3×10^7	21.6	5	1.1×10^8	12.1
Potassium hydroxide	0.00945	3	44.	10	2.8×10^8	10.3	6	9.0×10^7	6.7
	0.015	3	42.	8	3.8×10^8	55.5	4	9.2×10^7	98.1
	0.016	3	32.	8	3.0×10^8	43.0	4	6.8×10^7	43.8
	0.015	3	29.	8	2.0×10^8	79.2	4	7.0×10^7	147.
	0.019	3	20.	10	3.6×10^8	12.5	6	1.8×10^8	5.5
	0.018	3	18.	10	1.4×10^8	9.9	6	1.1×10^8	9.7
	0.018	3	19.	10	3.4×10^8	20.1			5.5
	0.0185	3	13.	10	1.9×10^8	6.4	6	1.9×10^8	3.6
	0.0165	3	13.	10	1.8×10^8	4.4			3.6
	0.017	3	10.	10	7.9×10^7	12.7			9.7
	0.019	24	8.5	10	1.5×10^8	17.8			5.5
	0.018	24	8.3	10	1.5×10^8	9.4			5.5
	0.0175	3	2.9	8	2.9×10^7	37.6	4	1.0×10^8	38.0

B. Grasshoppers (Spathosternum prasiniferum)

Manna et al. (160) injected two groups of male grasshoppers intra-abdominally with 0.02 ml of sodium hydroxide solution of pH 9.0. Thirty insects were used in the first group and 27 in the second set. Control groups of 15 and 25 specimens were injected in like manner with 0.67% saline. Insects were sacrificed at four and 24 hours and the tests removed, fixed, stained, and examined for spermatocyte chromosome aberrations.

The mortality rate varied from 0% (Group I) to 19% (Group II). No deaths occurred in either control group. Chromosome abnormalities similar to those produced by ionizing radiations or radiomimetric chemicals were observed. Chromatid and chromosome type breaks, fragments, constrictions, chromosome bridges at anaphase, interbivalent connections, multipolar spindle, and polyploid cells were detected. However, acetic and hydrochloric acid solutions of pH 3-4, caused the same type of effects. The authors tentatively concluded that the aberrations observed were due to "pH shocks".

C. Newts (Triturus cristatus)

Seilern-Aspang (216) injected 20 newts (sex, age, and weight not given) subcutaneously with 0.01-0.02 ml of a 0.4% acqueous solution of sodium hydroxide and observed the animals for the appearance of epithelial tumors over a period of one year. All survivors as well as fatalities were studied in detail histologically for evidence of neoplastic changes.

Two of the 20 animals died. Eight others showed inflammatory reactions which declined and disappeared after 5 to 10 days. There were no gross or microscopic manifestations of malignancy in any of the experimental animals.

D. Mice

1. Narat (181) painted the skin of white and gray mice, 29 males and 52 females, one to six months of age, (strain and weight not specified), with a 3-6% aqueous solution of potassium hydroxide (no epilation) at intervals of 1-2 days until the first appearance of lesions. The applications were then repeated twice weekly for four to six weeks after development of papillary growths when the treatment was discounted. The total period ranged from 25 to 46 weeks. Crude coal tar was used as a positive carcinogen control. The mice were caged separately throughout and observed for the time of appearance, nature, and progression of lesions. All neoplasms were studied microscopically as well as macroscopically.

Malignant tumors developed in four males and eight females of two strains painted with KOH. Microscopically the tumors were the same in character as those resulting from coal tar applications. Two strains of the mice were refractory to all chemicals studied, including coal tar.

With respect to the positive findings, it should be noted that control chemicals of the same pH and degree of penetrability were not included to rule out the possibility that the malignancy might have resulted from some mechanism triggered by a pH influence rather than from the KOH per se. Furthermore, 3-5% HCl was also used in this study and tumors developed that were similar in all respects to those in both the NaOH- and coal tar-treated mice. The inclusion of untreated control animals was not mentioned.

2. Bogen et al. (030) painted seven white mice, three to six months of age, (strain, sex, weight not specified), with a 10% solution of sodium hydroxide twice weekly (duration not given), and observed the animals six months or more for the appearance of epithelial neoplasms. 1,2,5,6-dibenzanthracene as a positive carcinogen and a number of other irritant substances were included in the study.

In one of the seven mice painted with 10% NaOH a tumor developed within four months. Although its exact nature was not fully determined, the authors finally concluded that the growth was benign rather than malignant. 1,2,5,6-dibenzanthracene produced typical malignant tumors in 16 of 33 mice painted. Untreated controls animals were not included but the authors stated that the mice employed were from a homogenous stock with a very low incidence of spontaneous tumors.

3. Dyer et al. (061) investigated sodium hydroxide and a number of other tissue irritants for carcinogenic potential, alone and in combination with 1,2,5,6-dibenzanthracene, in mice via the oral route.

Inbred A, C3H, I, and Hybrid LA mice of the F_1, F_2, F_3 generations, males and females, averaging two to six months of age, were employed[a]. Sodium hydroxide was administered by stomach tube at a level of 0.01 ml of a 0.1-0.5H solution per gram of bodyweight (40-200 mg/kg BW), five times weekly during the first few months, and three times each week thereafter. Control groups received diluent alone.

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[a] With the C3H mice, males only were used because of the high incidence of spontaneous mammary tumors in the females.

The only abnormalities noted were petechial hemorrhages over a very small portion of the glandular portion of the gastric mucosa. These occurred in 9% of the treated mice, in a small area of the intestinal tract. No evidence of stomach cancer or precancerous lesions was detected in any of the mice used in this study.

E. Rats

1. Russell et al. (202) fed (by stomach tube) a group of five female Wistar rats (average body weight - 187 grams) sodium hydroxide (1/200 N) at a rate of 1.07 mg/kg BW three times weekly over a period of 93 days. The animals served as the sodium hydroxide controls in an investigation of the chronic toxicity of diethylstilbestrol. Ten untreated control animals were also included in the study. Vaginal smears were examined and recorded daily and body weights every five days. At the conclusion of the experiment, all survivors were sacrificed and autopsied. A detailed histologic study was performed on the vital organs of one NaOH- treated animal.

None of the rats showed any toxic effects attributable to the sodium hydroxide administered throughout the study. All organ weights were within normal limits and no microscopic abnormalities were detected in the detailed histologic study.

2. Gross et al. (105) gave 81 anesthesized male white rats (strain, age, weight not specified), intratracheal applications of 0.05 ml of a 5% aqueous solution of sodium hydroxide (pH approx. 14) by means of a microliter syringe and a long, special type 18-gauge needle which permitted distribution of the chemical over a wide area of the tracheal wall. Fifteen animals that survived the treatment served as the sodium hydroxide control in an experimental asbestosis study where the alkali was used to impair clearance of inhaled dust from the lungs. All animals employed in the study were observed throughout their life span for evidence of carcinogenic changes. Histologic studies were made at death.

Eleven of the 81 animals initially employed succumbed to the preliminary intratracheal sodium hydroxide treatment. One of the 15 survivors that comprised the sodium hydroxide group died during the subsequent 16-month period. None of the animals subjected to sodium hydroxide alone, including the animal that died, showed any evidence of malignancy.

3. Kimura et al (135) injected a group of five rats, both sexes, weighing 95-130 grams, (strain and age not given), intraperitoneally with potassium hydroxide solution at a level of 1800 mg/kg BW, three to four days after cells of the MTK-Sarcoma III ascites rat tumor had been transferred intra-abdominally. Prior to the main experiment, physiological saline adjusted to pH 4.2, 5.2, 6.2, 7.2, and 8.2, with normal HCl or NaOH, was injected intraperitoneally into tumor-bearing rats to determine if there was a pH effect on the tumor cells. Cytological preparations were made at intervals of 1, 3, 6, 12, 18, 24, 48 and 72 hours after treatment and examined for evidence of damage to the tumor cells. The results are shown in Figure 3 and Table 11.

As indicated in Table 11, potassium hydroxide at a level of 1800 mg/kg intraperitoneally caused only slight changes in chromosomes (stickiness, contraction, karyorrhexis) and in the resting nucleus of tumor cells. No detrimental effects were produced in the cytoplasm. In the pH controls, the authors report that "cytoplasmic blebbing or karyorrhexis was observed rather infrequently in some tumor cells at the two extremes of pH values used". The test compound (KOH) was used also as the alkaline control chemical. Almost all of the cells were viable for at least 72 hours after injection of the solution.

F. Swine

McPhee and Eaton (169) reinvestigated claims that the sex ratio of offspring could be modified by acid or alkali vaginal douches or by changing the pH of semen used for artificial insemination.

Twenty sows, (strain, age, weight not given), were artificially inseminated with semen treated with N/10 NaOH varying in amount from 0.5 to 2.1 ml per 10 ml of specimen. Untreated semen from the individual boars ranged in pH from 6.90 to 7.48 with an average of 7.25. Alkali treatment raised the pH to 8.65; after return from the vagina, the pH was 8.59. A second group of females received semen with pH lowered to 5.79 by treatment with lactic acid. Data were obtained on a total of 121 offspring from 13 litters (seven sows did not conceive even after two or three trials).

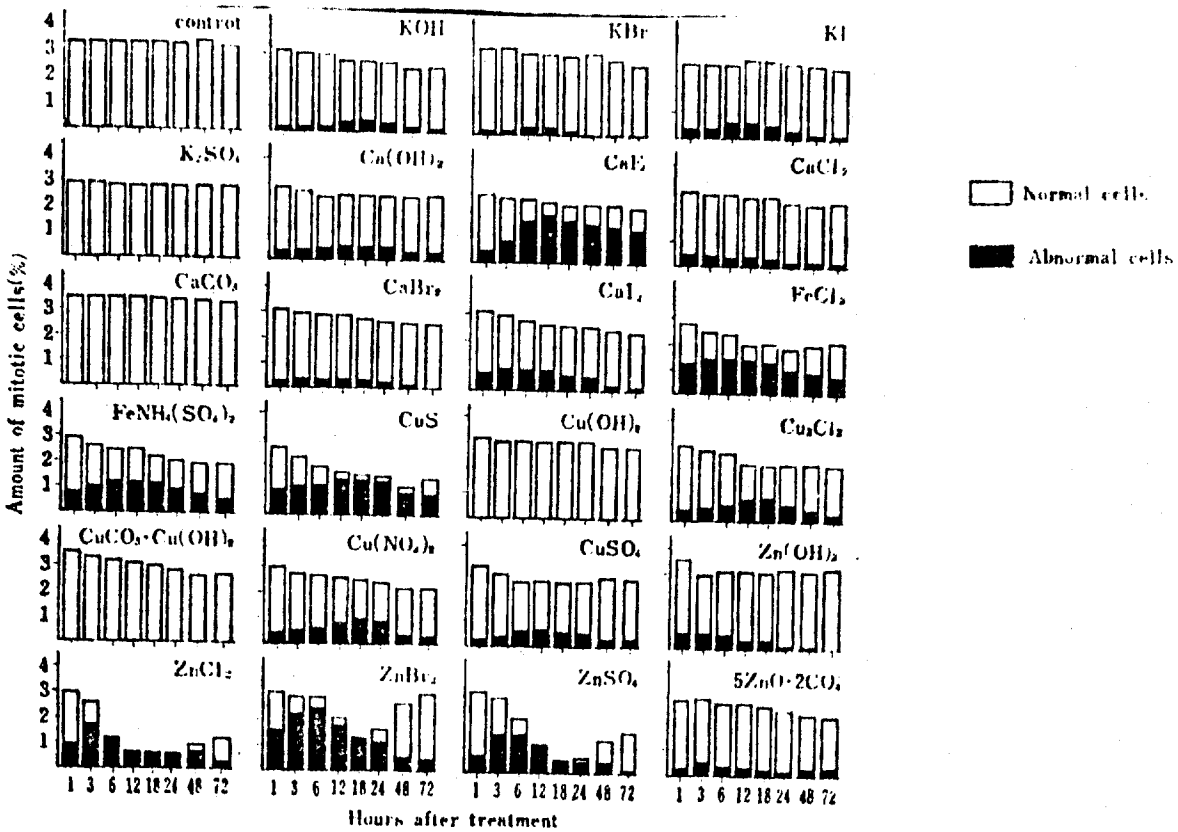

Figure 3. Effect of Potassium Hydroxide and Some Other Compounds on MTK-Sarcome III Cells in Vivo (135)

Table 11. Reaction of MTK-Sarcoma III Tumor Cells to Potassium Hydroxide and Other Inorganic Compounds in Vivo (135)

Chemical	Dose (g/100 g)	Effect of chemicals*	Recovery of cells (hrs. after inj.)	No. of animals	Life span		Evaluation of chemicals		
					single inj.	repeated inj.	resting nucleus	chromosome	cytoplasm
KOH	0.18	4, 5, 6	18-24	5	8.8	-	±	+	−
KBr	0.02	4, 5, 6, 10	18-24	5	8.1	—	±	+	±
KI	0.05	2, 5, 6	18-24	5	8.4	—	+	+	−
K_2SO_4	0.18	2	9-12	6	8	—	±	±	±
$Ca(OH)_2$	0.12	4, 5	18-24	16	8	8.3	+	+	±
CaF	0.1	3, 4, 5, 6, 12, 13	24-48	15	8.4	9.1	+	+++	+
CaCl	0.35	2, 5, 6, 13	18-24	13	8.7	9.8	+	+	++
$CaCO_3 \cdot 3H_2O$	0.1	3, 5, 9	6-12	17	8.7	9.2	±	±	±
$CaBr_2$	0.23	3, 5	18-24	13	8.7	9.8	+	+	±
$CaI_2 \cdot 6H_2O$	0.11	4, 5	24-48	15	9.3	9.8	+	++	±
$FeCl_3 \cdot 6H_2O$	0.05	2, 4, 5, 6, 12, 13	24-48	9	7.9	—	++	++	++
$FeNH_4(SO_4)_2 \cdot 12H_2O$	0.06	2, 5, 6, 10, 12, 13	24-44	10	8.1	—	+	+++	++
CuS	0.015	2, 5, 6, 7, 8, 9	24-48	13	9.6	—	++	+++	±
$Cu(OH)_2$	0.02	2, 5	6-12	5	8.8	—	±	±	±
Cu_2Cl_2	0.012	4, 5	18-24	5	8	—	±	++	±
$CuCO_3 \cdot Cu(OH)_2 \cdot xH_2O$	0.013	2, 5	6-12	5	10.5	—	±	±	±
$Cu(NO_3)_2 \cdot 3H_2O$	0.06	2, 4, 5	18-24	5	8.2	—	++	++	±
$CuSO_4 \cdot 5H_2O$	0.03	1, 4, 11	24-48	5	8.2	—	+	+	+
$Zn(OH)_2$	0.011	2, 5, 9, 10, 13	12-24	9	7.9	8.6	±	+	±
$ZnCl_2$	0.07	2, 4, 5, 9, 10, 12, 13	48-72	12	9.5	10.5	++	+++	++
$ZnBr_2$	0.08	2, 4, 5, 6, 9, 12, 13	24-48	11	8.9	10.7	++	++	++
$ZnSO_4$	0.1	2, 5, 6, 9, 10, 12, 13	24-48	13	9.3	10.1	+	+++	++
$5ZnO \cdot 2CO_2 \cdot 4H_2O$	0.015	2, 5, 13	12-18	9	9.0	9.3	±	±	±

* Cellular events corresponding to numerals given in this column are as follows:

1. lobated nuclei
2. chromatic aggregation
3. pycnosis
4. karyorrhexis
5. stickiness of chromosomes
6. contraction of chromosomes
7. scattering of chromosomes
8. lagging of chromosomes
9. clumping of chromosomes
10. chromosome bridges at anaphase
11. multipolar spindle formation
12. blebbing of cytoplasm
13. disintegration of cytoplasm

The authors concluded that sodium hydroxide or lactic acid treatment of semen did not modify significantly the normal sex ratio for the species tested.

G. Humans

Carcinoma of the esophagus may develop at the site of chronic lye stricture many years after the accident or suicide attempt (011,017). In one survey, the interval varied between 22 and 54 years, with an average age of 46 (011). Histologically, the cancers are usually, if not exclusively, epidermoid although adjacent structures may be invaded (011). There appears to be considerable difference of opinion concerning the incidence of tumors of this type (011,017).

BIOCHEMICAL ASPECTS

I. Breakdown

Sodium and potassium hydroxides are stable when dry but containers must be kept tightly closed. Both compounds strongly absorb moisture and carbon dioxide when exposed to the air to form, in the case of sodium hydroxides, hydrated sodium carbonate and eventually sodium sesquicarbonate - $Na_2CO_3 . NaHCO_3 . 2H_2O$ (228). They are non-flammable and non-combustible. However, both may react violently or explosively with many organic chemicals. They cannot be stored in containers of aluminum, magnesium, zinc (galvanized), tin, chromium, brass, or bronze. KOH reacts with zinc and some other metals to produce hydrogen which constitutes an explosion hazard. The hazard designation is:

In foods, or in living food plants or animals, both alkalies would tend to react with acidic components to form the corresponding salts.

II. Absorption-Distribution

No information was found in the literature survey concerning absorption and distribution of sodium and potassium hydroxides in the animal body. Both compounds in amounts likely to be encountered in foods would be quickly and completely neutralized by the hydrochloric acid of the stomach. Resultant sodium and potassium ions would then follow the absorption and distribution patterns of their dietary counterparts.

Concentrated solutions of either compound, such as those responsible for chemical poisonings or suicide attempts, are highly corrosive and cause severe tissue damage. These alkalies combine with tissue proteins to form proteinates and, with fats, to form soaps thus producing deep penetrating burns (009).

III. Metabolism and Excretion

Sodium and potassium hydroxides are permitted as food additives or in food processing "in accordance with good manufacturing practice provided the increased dietary load of sodium or potassium ions is assessed and considered acceptable" (126). Since both ions are normal body electrolytes,

amounts ordinarily ingested with foods would present no metabolic or excretory problems to the organism normally. The average daily intake of sodium is 10-12 grams and that of potassium about 4 grams on a normal diet (022).

The normal and pathophysiology of sodium and potassium is a vast subject, of course, and will not be dealt with at length in this monograph. Sodium is the main extracellular ion in the body and potassium the main intracellular ion (Table 12). Both ions in proper concentration and balance are indispensable for osmotic functions, nerve conductivity, and muscle contraction. Heart action, in particular, is vitally affected by the sodium-potassium balance. Excess potassium causes a decrease in muscle excitability and the heart beat slows and may stop (cardiac arrest); with insufficient potassium, excitability of the heart muscle becomes exaggerated. Excess sodium increases excitability of muscle tissue; a very low level of sodium brings about a marked suppression of the pacemaker. The "sodium pump", apparently under the influence of adrenical cortical hormones, maintains the proper sodium-potassium balance in the cell. Insulin also apparently is involved under certain circumstances with respect to potassium levels and a decrease of blood sugar is accompanied by a decrease in blood potassium. The sodium-potassium balance or antagonism also affects certain enzyme systems. Sodium tends to inhibit glycolysis whereas potassium has a stimulating effect. Excretion-retention relationships of sodium and potassium appear to be regulated in the main by the adrenal cortical hormones, although the pituitary also influences electrolyte balance in the body (022,102,180).

Table 12. Normal Values for Sodium and Potassium in Blood and Muscle (022)

	Concentration in mg/100 ml		
	Plasma	Muscle Tissue	Muscle water
Sodium	320	80	46
Potassium	20	320	108

The literature survey revealed only one food in which a physiologically-hazardous excess of sodium or potassium ions was pointed out, i.e., acid-neutralized, lye-peeled tomatoes, where the sodium chloride content is too high for persons on a reduced sodium diet (163). No information was found on the sodium content of lye-peeled potatoes where much stronger concentrations of alkali, up to 53% NaOH, are used (040). Data in this respect appear to be lacking also for corn and other cereal grains dehulled with lye (025).

IV. Effects on Enzymes and Other Biochemical Parameters

Goatcher and Church (092) studied the response of sheep to sodium hydroxide and several other chemicals that evoke certain definite taste sensations in man.

Three groups of ten animals each (strain, sex, age and weight not given) were tested to assess taste responses using a two-choice preference procedure where two containers were presented to each animal — one containing tap water and the other the chemical solution (taste stimulant) being tested. The data obtained indicated that sodium hydroxide at the levels used was less distasteful to the sheep than most of the acids tested.

V. Drug Interaction

The only drug interaction study found in the literature survey was that of Wagman (258) who reported that gentamicin sulfate toxicity was unaffected by sodium or potassium hydroxide at the levels employed.

VI. Consumer Exposure Information

Sodium hydroxide is widely used as a direct food additive for a variety of purposes (See Table 13). As a neutralizer or alkalinizer, concentrations ranging from 0.02 to 1.0 percent are used in sour-cream butter, food starch, fats and oils, in pasteurization of egg whites, and in the manufacture of corn syrup, caramel, cereals, table salt, invert syrup, rennet, and pretzels (007,082,138). In canned peas, it may be used in a quantity up to the point where the alkalinity does not exceed pH 8.0 (082).

In the production of instant tea, sodium hydroxide is used in concentrations up to 0.01 percent as a solubilizing agent; it appears in the finished product as a salt of phosphoric acid (078). Another application in the beverage industry is its use in barley steeping water to improve

Table 13. Some Applications of Sodium Hydroxide in the Food Industry

	Purpose of additive	Conctn. used, % ave.	max.	Reference
Food Starch	Alkali modifier	-	1.0	(007)
Potatoes, Tomatoes, etc.	Peeling agent	3.0[a]	53.0	(163)
Corn & other grains	Dehulling agent	15.0	20.0	(025,082)
Tomato juice	Processing aid	0.17	--	(172)
Reconstituted & processed vegetables	Processing aid	0.4	0.5	(078)
Gelatin products	Neutralizer or processing aid	0.4	0.4	(078)
Corn syrup & invert syrup	Process neutralizer	-	0.5	(077)
Fats	Rendering agent	Sufficient for the purpose[b]		(006)
Frozen dairy products	Processing aid	0.15	0.15	(078)
Imitation dairy products	Neutralizer	0.02	0.10	(078)
Canned milk	Processing aid	0.035	--	(029)
Other milk products	Processing aid	0.002	0.002	(073)
Infant formulas	Neut. or proc. aid	0.04	--	(078)
Cheese	Neut. or proc. aid	0.002	0.002	(078)
Beer	Barley steep agent	0.1	--	(134)
Instant tea & coffee	Solubilizing agent	--	0.01	(078)
Spanish peanuts	Color extractant	0.5	--	(193)
Baked goods	Processing aid	0.003	0.05	(078)
Peanut meal	Detoxifying agent	--	3.0	(159)
Sour-cream butter, etc.	Neutralizer	--	--	(062)
Confectionary frostings	Processing aid	0.03	0.05	(078)
Soft candy	Processing aid	0.008	0.009	(078)
Sweet sauce	Processing aid	0.02	0.02	(078)
Egg white prepns.	Processing additive	2.0 [c]	--	(026)
Meat products & gravies	Processing aid	0.001	0.001	(078)
Tripe	Denuding agent to remove mucous membrane	Sufficient for the purpose[d]		(006)
Cured hams, bacon, etc.	To decrease amount of cooked out juices	See original article		(006)

[a]Minimum concentration reported

[b]The rendering agent must be removed during the manufacturing process

[c]Partially neutralized during the manufacturing process

[d]Must be removed from the meat by washing with potable water

taste, tannin content, and color of the beer. In the modern triple steeping process, an initial concentration of 0.1% NaOH has been used without affecting the quality of the product adversely (134). In the canning of 3-fold concentrated whole milk, sodium hydroxide at a level of 8.8 ml N-NaOH/kg raw milk (4 ml/lb) has been recommended (027).

Sodium hydroxide is used also as a glazing agent for pretzels and in other baked goods in concentrations averaging 0.003% with a reported maximum of 0.05%. The alkali is applied as a solution to the outside of the dough; during baking and subsequent storage it combines with CO_2 forming a mixture of NA_2CO_3 and $NaHCO_3$ (078,082).

In rendering fats, sodium hydroxide may be used as a refining agent in amounts sufficient for the purpose, provided it is eliminated during the manufacturing process (006).

The strongest solutions of sodium hydroxide employed in direct contact with food are used in the lye or caustic peeling of potatoes, tomatoes, beets, carrots, apples, pears, papayas, etc., where concentrations ranging from 3.0 to 53% have been used (031,040,082,155,164,192). Recently, a "dry" caustic peeling process for potatoes (WURPEEL) has been developed which greatly reduces B.O.D. of plant effluents and consequently potato peel pollution in streams. The potatoes are first soaked in hot lye solution for 3 minutes, then held at room temperature for 5 minutes to permit lye penetration. A drying period (2-3 minutes) under a gas-fired infra-red surface heater follows and then the skin is removed by means of a soft rubber mechanical peeler. Finally, the tubers are cooled and rinsed in cold water (100).

Commercial lye peeling of tomatoes is used also in many parts of the country to reduce labor costs, increase yield, and produce a cleaner product (163). Concentrations of sodium hydroxide as high as 21% at temperatures up to 210°F, for 20 seconds or more are used. After draining, excess alkali is removed by rinsing in water followed by an acid dip or by addition of acid to the packed fruit in the can. Sterilization problems at 212°F have been encountered if the lye-peeled fruit is not reacidified. One unfortunate feature of the process is the increased sodium content of the pack as compared with conventional steam-peeled tomatoes. In one study,

two lots of lye-peeled, acid-added, fruit contained 107 to 123 ppm of sodium as compared with 38 and 60 ppm for steam-peeled control batches. The author concluded that the increased sodium due to lye peeling would restrict the use of lye-peeled tomatoes in low sodium diets (163).

Papayas (1 lb/gal) also have been successfully lye-peeled in boiling solutions of 10, 15, and 20% sodium hydroxide for periods of 6, 4 and 3 minutes, respectively. Immediately after lye treatment, the fruit is placed in cold water and subjected to water sprays until all peel and softened tissue is removed and the surface is no longer alkaline to phenolphthalein. Lye-peeled papayas are said to compare favorably with hand-peeled fruit (040).

Sodium hydroxide is used also as a dehulling agent for corn and other cereal grains (025). Concentrations as high as 20% have been used but, in general, treating the grain with 15% NaOH at 160°F for three to four minutes with agitation is adequate. Residual alkali is then neutralized with acetic acid. Yields of dehulled corn as high as 93% have been obtained. The treatment has little adverse effect on the ash, ether extract, or protein contents, but the level of niacin is reduced about 50%.

Morgan et al (178) describe a lye-peeling process for wheat which involves treating the pre-heated grain (180°F) with sodium hydroxide solution at a final concentration of 20% for three minutes at 180°F. The loosened bran is then removed in turbulent water at 70°F and the kernels rinsed in 1% acetic acid for five minutes. The grain is next washed in water at room temperature for five minutes and finally air dried at a temperature of 160°F for 150 minutes. Nutrient losses are 1% protein, 0.1% fat, 16 mg/100g. of thiamine, and 0.06 mg/100g of riboflavin. The resultant product is a white, full-shaped kernel.

Another application of sodium hydroxide in food treatment is its use with ripe olives to develop the desirable color (050). The fruit is subjected to repeated 1-1/2 hour exposures in 0.05% lye solution at room temperature until the alkali penetrates to the pits. The olives are then soaked in water, changed three times daily until the lye is thoroughly removed; about six to seven days. They are then stored in 12 salometer brine and canned in the usual manner.

Removal of the red color from peanut skins prior to preparation of refined peanut products can be accomplished by treatment with sodium hydroxide. Alkali concentrations up to 0.5% for periods of five minutes have been used without damaging the kernels and the color of the final product is comparable to that prepared from white-skin peanuts. Lipid and protein losses are low at room temperature, but increase with the processing temperature up to 125°F. The cost is 0.5¢ to 0.75¢ per pound ([193]).

Toxins in certain foods can be inactivated or removed by treatment with sodium hydroxide. USDA scientists have developed procedures for the chemical inactivation of aflatoxins (resulting from contaminating mold action) in peanut and cottonseed meals. Alkali concentrations of 2.0-3.0% at a temperature of 100°C for a period of 120 minutes have proved very effective for removal of the toxins without adversely affecting the food products (159). Castor beans also can be detoxified by treatment with sodium hydroxide. Treating the flaked meat with a 2% solution at 100°C detoxifies the ricin and removes or inactivates the CB-1A allergen (087).

Sodium hydroxide may be used alone or in combination with other chemicals as a denuding agent to remove the mucous membranes in the processing of tripe. Concentrations sufficient for the purpose are permitted but excess alkali must be removed subsequently by rinsing with potable water (006). Many meat curing preparations also contain sodium hydroxide, in concentrations as high as 40% (205,206).

Patents have been granted for the use of sodium and potassium hydroxides as egg white processing aids. Whipping time can be shortened and foam volume and stability increased by addition of the alkalies at a level of 2% (026). Vitamin destruction and rancidity in calcium carbonate-treated foods can be reduced by the use of sodium hydroxide at a final concentration of 0.1% to 0.5% (167). Sodium and potassium hydroxides are used also in conjunction with polyphosphates and sodium oxide for pasteurization of eggs. Amounts sufficient to raise the pH to 8.0-10.0 suffice. Pathogenic microorganisms, such as salmonellae, can then be destroyed at temperatures as low as 51.5-57°C without denaturation of the egg proteins. The pH is subsequently lowered (138).

Sodium hydroxide is an excellent cleansing agent, especially for oily and greasy surfaces, and is strongly bactericidal also. This combination of properties has led to recommendations for its use in the food and pharmaceutical industries for cleansing and disinfecting processing equipment. Charriera et al. (043) demonstrated that a 5% solution of caustic soda was very satisfactory for cleansing and sterilizing the rubber parts of milking machines. Hobbs et al. (114) found that 5% caustic soda destroyed the spores of Bacillus subtilis nearly three times as fast as 5% phenol killed anthrax spores, even in the presence of 1/1000 concentration of milk. Yegian et al. (270) noted that approximately 50% of tubercle bacilli in sputum were killed within the first five minutes of exposure to 20% sodium hydroxide.

Potassium hydroxide is employed also in the food industry but to a more limited extent than sodium hydroxide due to its higher cost. The main uses of potassium hydroxide are in the production of caramel, instant tea and coffee, cheese, baked goods, breakfast cereals, cocoa products, and in removing the color from annato seeds. The concentrations employed are comparable to those of sodium hydroxide (078,082).

Sodium and potassium hydroxides are used also in the manufacture of paper, paperboard, and cotton food packaging materials and consequently are in the group of substances possibly migrating to foods from food containers and dry packaging materials (005).

Comprehensive GRAS Survey, NAS/NRC Questionnaire data on possible daily intakes, average and maximum, of sodium and potassium hydroxides, from NAS Appendix A Substances (Groups I and II), at various age levels, are given in Tables 14, 15 and 16. Usage levels of these alkalies in the various food categories are given in tables 17 and 18. Annual poundage data for NAS Appendix A Substances (Groups I and II) are given in table 19.

The amounts of sodium and potassium hydroxides imported during recent years are given in Table 20.

Table 14. Daily Intake Data for Sodium and Potassium Hydroxides (079)

Age	Possible Daily Intake (mg)[a] NaOH			KOH		
	Average	High A	High B	Average	High A	High B
0-5 months	139	260	21	182	335	182
6-11 months	181	528	197	45	199	46
12-23 months	232	436	281	28	49	30
2-65+ years	439	844	568	87	185	91

[a] Twenty three firms reported for NaOH and nine for KOH

Table 15. Possible Daily Intakes of Sodium Hydroxide (079)

FOOD CATEGORY NO.	NAME	# OF FIRM.	********** POSSIBLE DAILY INTAKE, PC. ********** (AGE)	AVERAGE	HIGH A	HIGH B
01	BAKED GOODS(R)	4	0-5 MO.	.111520	.147600	1.825460
			6-11 MO.	.833120	1.699040	13.637260
			12-23 MO.	1.787600	2.945440	29.261050
			2-65+ YR.	4.500160	6.684640	73.662680
03	OTHER GRAIN(R)	*	0-5 MO.	**********	**********	**********
			6-11 MO.	**********	**********	**********
			12-23 MO.	**********	**********	**********
			2-65+ YR.	**********	**********	**********
04	FATS OILS(R)	*	0-5 MO.	.100000	.100000	**********
			6-11 MO.	.560000	1.500000	**********
			12-23 MO.	1.260000	2.400000	**********
			2-65+ YR.	3.500000	6.320000	**********
05	MILK PRODS(R)	*	0-5 MO.	.082620	.061200	.082620
			6-11 MO.	.954720	4.591550	.954720
			12-23 MO.	.833950	2.668320	.833950
			2-65+ YR.	.604350	1.845180	.604350
06	CHEESE(R)	*	0-5 MO.	**********	.002000	**********
			6-11 MO.	.054000	.194000	.054000
			12-23 MO.	.156000	.444000	.156000
			2-65+ YR.	.188000	.472000	.188000
07	FROZN DAIRY(R)	*	0-5 MO.	1.524000	6.248400	1.524000
			6-11 MO.	14.478000	40.233600	14.478000
			12-23 MO.	21.945600	51.511200	21.945600
			2-65+ YR.	39.014400	94.030800	39.014400
10	MEAT PRODS(R)	*	0-5 MO.	.011000	.029000	.011000
			6-11 MO.	.207000	.558000	.207000
			12-23 MO.	.302000	.519000	.302000
			2-65+ YR.	.784000	1.301000	.784000
14	PROCSD VEGS(R)	*	0-5 MO.	5.051480	15.154440	5.125120
			6-11 MO.	86.596000	202.059200	87.859200
			12-23 MO.	140.719800	235.615460	142.771200
			2-65+ YR.	306.697000	516.694240	311.168000
16	SOFT CANDY(R)	*	0-5 MO.	.015900	.159000	.017880
			6-11 MO.	.174900	.546600	.196680
			12-23 MO.	.278250	.739350	.312900
			2-65+ YR.	.461100	1.399200	.518520
17	CONF FROST(R)	*	0-5 MO.	**********	.034000	**********
			6-11 MO.	.034000	.068000	.050000
			12-23 MO.	.068000	.233000	.100000
			2-65+ YR.	.102000	.272000	.100000
19	SWEET SAUCE(R)	*	0-5 MO.	.060000	.080000	.060000
			6-11 MO.	.180000	.620000	.180000
			12-23 MO.	.520000	1.520000	.520000
			2-65+ YR.	1.360000	3.580000	1.360000
20	GELATIN PUD(R)	*	0-5 MO.	8.000000	10.800000	12.000000
			6-11 MO.	51.200000	155.200000	76.200000
			12-23 MO.	55.200000	134.400000	82.800000
			2-65+ YR.	81.600000	210.000000	122.400000
23	BFV TYPE I(R)	*	0-5 MO.	.005280	.007920	.005280
			6-11 MO.	.049940	.170940	.049940
			12-23 MO.	.119240	[illegible]	.119240
			2-65+ YR.	.228800	.610940	.228800
24	BFV TYPE II(R)	*	0-5 MO.	.000000	.000000	.000000
			6-11 MO.	**********	[illegible]	**********
			12-23 MO.	**********	.000000	**********
			2-65+ YR.	.000000	.000000	.047000

Table 15 (Continued)

FOOD CATEGORY NO.	NAME	# OF FIRMS	(AGE)	POSSIBLE DAILY INTAKE, MG. AVERAGE	HIGH A	HIGH B
26	RECONST VEG(R)	4	0-5 MO.	.000000	.000000	.000000
			6-11 MO.	.000000	.000000	[illegible]
			12-23 MO.	.000000	[illegible]	[illegible]
			2-65+ YR.	.000000	[illegible]	[illegible]
27	GRAVIES(R)	*	0-5 MO.	.001000	.000000	.001040
			6-11 MO.	.014000	.039000	.014560
			12-23 MO.	.036000	.102000	.037440
			2-65+ YR.	.083000	.213000	.086320
28	IMIT DAIRY(R)	*	0-5 MO.	.000000	.000000	[illegible]
			6-11 MO.	.241640	.396980	1.34[illegible]
			12-23 MO.	.138080	.586940	.768000
			2-65+ YR.	.155340	.258900	.864000
34	INS COF TEA(R)	*	0-5 MO.	**********	**********	.024000
			6-11 MO.	**********	**********	.688000
			12-23 MO.	**********	**********	.800000
			2-65+ YR.	**********	**********	15.743000
83	FORMULAS(B)	*	0-5 MO.	124.209000	227.550000	**********
			6-11 MO.	25.308000	126.583000	**********
			12-23 MO.	8.140000	2.294000	**********
ALL CATEGORIES		23	0-5 MO.	13[illegible].171[illegible]	[illegible]	[illegible]
**********			6-11 MO.	1[illegible].[illegible]120	528.45[illegible]	1[illegible]
**********			12-23 MO.	231.504420	436.341110	280.733[illegible]
**********			2-65+ YR.	439.278150	843.681900	567.869410

Table 16. Possible Daily Intakes of Potassium Hydroxide (079)

FOOD CATEGORY NO.	NAME	NO OF FIRMS	(AGE)	POSSIBLE DAILY INTAKE, MG. AVERAGE	HIGH A	HIGH B
01	BAKED GOODS(R)	*	0-5 MO.	.197200	.261000	.282200
			6-11 MO.	1.473200	3.004400	2.108200
			12-23 MO.	3.161000	5.208400	4.523500
			2-65+ YR.	7.957600	11.820400	11.387600
02	BREAK CERLS(R)	*	0-5 MO.	**********	**********	**********
			6-11 MO.	**********	**********	**********
			12-23 MO.	**********	**********	**********
			2-65+ YR.	**********	**********	**********
06	CHEESE(R)	*	0-5 MO.	**********	.118970	**********
			6-11 MO.	3.212190	11.540090	3.392010
			12-23 MO.	9.279660	26.411340	9.799140
			2-65+ YR.	11.183180	28.076920	11.809220
23	BEV TYPE I(R)	*	0-5 MO.	.021600	.032400	.021600
			6-11 MO.	.204300	.699300	.204300
			12-23 MO.	.487800	1.462500	.487800
			2-65+ YR.	.936000	2.499300	.936000
34	INS CCF TEA(R)	*	0-5 MO.	.110000	1.815000	.110000
			6-11 MO.	2.915000	7.205000	2.915000
			12-23 MO.	3.410000	12.320000	3.410000
			2-65+ YR.	66.605000	142.670000	66.605000
83	FORMULAS(B)	*	0-5 MO.	181.747980	332.961000	181.747980
			6-11 MO.	37.031760	176.442260	37.031760
			12-23 MO.	11.910800	3.356680	11.910800
99	ALL CATEGORIES	9	0-5 MO.	182.076780	335.188370	182.161780
			6-11 MO.	44.836450	198.891050	45.651270
			12-23 MO.	28.249260	48.758920	30.131240
			2-65+ YR.	86.681780	185.066620	90.737820

Table 17. Usage Levels Reported for Sodium and Potassium Hydroxides (078)

SUBSTANCE NAME (SURVEY NO.)	FOOD CATEGORY NO.	NAME	# FIRMS REPORTING	*** USUAL USE *** WTD MEAN, %	*** MAXIMUM USE *** WTD MEAN, %
SODIUM HYDROXIDE NAS 0192	01	BAKED GOODS(R)	4	.00328	.05369
	03	OTHER GRAIN(R)	*	********	********
	04	FATS OILS(R)	*	.02000	********
	05	MILK PRODS(R)	*	.00153	.00153
	06	CHEESE(R)	*	.00200	.00200
	07	FROZ DAIRY(R)	*	.15240	.15240
	10	MEAT PRODS(R)	*	.00100	.00100
	14	PROCSD VEGS(R)	*	.36082	.36608
	16	SOFT CANDY(R)	*	.00795	.00894
	17	CONF FROST(R)	*	.03400	.05000
	19	SWEET SAUCE(R)	*	.02000	.02000
	20	GELATIN PUD(R)	*	.40000	.60000
	23	BEV TYPE I(R)	*	.00022	.00022
	24	BEV TYPE II(R)	*	.00000	.00030
	26	RECONST VEG(R)	4	.00000	.49992
	27	GRAVIES(R)	*	.00100	.00104
	28	IMIT DAIRY(R)	*	.01726	.09600
	34	INS COF TEA(R)	*	********	.01300
POTASSIUM HYDROXIDE NAS 0154	01	BAKED GOODS(R)	*	.00580	[illegible]
	02	BREAK CEREALS(R)	*	********	********
	06	CHEESE(R)	*	.11897	.12[illegible]
	23	BEV TYPE I(R)	*	.00090	.00090
	34	INS COF TEA(R)	*	.05500	.05500

Table 18. Usage Levels Reported for NAS Appendix A Substances (Group II) Used in Infant Formula Products and Baby Foods (R) (080)

Compound	Product	Usual Use WTD Mean, %	Max. Use WTD Mean, %
KOH	Formulas B	0.05414	0.05414
NaOH	Formulas B	0.03700	. . . .

Table 19. Annual Poundage Data for NAS Appendix A Substances (Groups I & II) (081)

Compound	Reports to NAS 1960/1970		Poundage Repts to NAS 1960	1970	Total 1970 Poundage Reported to NAS	Total 1970 Poundage NAS + FEMA
KOH	9	9	521,716	1,144,727	1,144,727	1,144,727
NaOH	23	27	7,788,150	12,449,401	15,759,381	15,759,381

Table 20. U.S. Imports of Sodium and Potassium Hydroxides (248)

Year	NaOH Amount (lb)	NaOH Value (dollars)	KOH Amount (lb)	KOH Value (dollars)
1965	6,323,651	336,101	1,943,280	193,585
1966	18,750,437	610,894	4,356,195	402,233
1968	77,271,112	1,285,733	2,537,288	271,920
1969	80,014,352	1,750,715	3,647,707	407,921
1970	125,838,239	2,736,537	5,623,520	509,379
1971	151,451,859	3,754,165	6,839,134	554,922
1972	209,678,074	5,517,969	3,123,791	359,620

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