

Effects of the Ingestion of Various Commercial Detergent Products by Beagle Dogs and Pigs¹

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Effects of the Ingestion of Various Commercial Detergent Products by Beagle Dogs and Pigs. MUGGENBURG, B. A., MAUDERLY, J. L., HAHN, F. F., SILBAUGH, S. A., AND FELICETTI, S. A. (1974). *Toxicol. Appl. Pharmacol.* 30, 134-148. Dose-response relationships resulting from the ingestion of four commercial detergent products—(1) Tide, (2) Sears Heavy Duty Laundry Detergent, (3) Electrosol Dishwashing Detergent, and (4) Tide with nitrilotriacetate (Canadian)—were evaluated in 51 Beagle dogs. Single oral doses of 2.5, 1.0, 0.5, and 0.1 g/kg were used for all the detergents plus an additional dose of 0.25 g/kg Electrosol. Three dogs received 2.5 g/kg of wheat flour and served as controls. There were no deaths among dogs ingesting Tide, and only a slight gastric irritation was observed at the higher doses. One dog died after ingesting Sears detergent and severe damage of the upper alimentary tract was found at the higher doses. All dogs (9) given the three higher doses of Electrosol died within 54 hr. Only mild gastric irritation resulted from the ingestion of Tide with nitrilotriacetate. The control dogs exhibited no signs of illness. Four groups of three pigs were each given a single dose level of each detergent based on the highest dose of the dog study that did not cause 100% mortality. One additional group of three pigs received wheat flour. Two pigs died—one after the ingestion of Sears detergent and the other after the Electrosol detergent. No significant differences were noted in the effects of the detergents between pigs and dogs except for the absence of changes in hematological and clinical chemistry values in pigs.

The controversy regarding the role of phosphates released from commercial laundry detergents in the eutrophication of inland waters has resulted in the introduction of detergent products with low phosphate content or no phosphates. Sodium tripolyphosphate, a major builder in detergents for many years, has been replaced by a number of substances in the United States and Canada, principally sodium nitrilotriacetate (NTA), a sodium carbonate, and sodium metasilicate. According to Hammond (1971), typical household laundry detergents are made up of a builder, a surfactant, and other

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materials which usually include brighteners, perfumes, and antiredeposition agents. The builders act as sequestering agents that tie up calcium and magnesium ions in hard water, which would otherwise interfere with the detergent surfactant. Little information is available concerning the toxicity of detergents that contain little or no phosphate following ingestion. Lee *et al.* (1972) reported that carbonate- and metasilicate-containing detergents resulted in corrosive injury to the stomach and esophagus in cats. Williams and Taber (1972) and MacDonald *et al.* (1972) reported upper alimentary tract lesions in dogs and rabbits from a variety of products after oral administration.

There were 3446 reported cases of ingestion of soaps, detergents, and cleaners by children under 5 yr of age in 1970 (USDHEW, 1971). These products rank third in the number of reported cases of accidental ingestion per year. Because of the possibility of a continued large number of accidental ingestions of detergent products, the potentially toxic effects of the ingestion of nonphosphate detergents should be critically evaluated. The following study was undertaken to evaluate a range of dose levels of several commercial detergent products in dogs and to compare these results with those from pigs at a selected dose level.

METHODS

Fifty-four 8- to 12-mo-old purebred Beagle dogs² were placed into 18 groups of three dogs each (Table 1).

The four commercially available detergent products evaluated were purchased "off the shelf" in retail stores in the United States and Canada. Phosphate-based detergents were represented by Tide.³ The other products containing different builders as partial or complete substitutes for phosphates were Sears Heavy Duty Laundry Detergent⁴ (sodium carbonate), Electrosol Dishwashing Detergent⁵ (sodium metasilicate), and Tide⁶ (Canadian; sodium nitrilotriacetate (NTA)). A partial chemical analysis for each product is listed in Table 2. The detergents were used "as is" for both chemical analyses and administration to the dogs.

The detergents were administered in single doses, with three dogs at each dose level for each product. The dose levels were 2.5, 1.0, 0.5, and 0.1 g/kg with an additional dose level of 0.25 g/kg for Electrosol. An additional group of three dogs received 2.5 g/kg of wheat flour and served as controls. These 54 dogs formed an initial dose-response study and were scheduled for sacrifice at 144 hr after ingestion (Table 1). Later, four groups of three pigs (crossbreds, 12-14 wk old) each were given the highest dose level of each product that did not cause 100% early death in the first study; doses were Tide, 2.5 g/kg; Sears, 2.5 g/kg; Electrosol, 0.25 g/kg; and Tide NTA, 2.5 g/kg. A group of three control pigs was given 2.5 g/kg commercial wheat flour and treated in the same manner as the pigs which ingested detergents. These 15 pigs were also scheduled for serial sacrifice at 144 hr after ingestion (Table 1).

² Purchased from Ridgland Farms, Mt. Hoerb, WI.

³ Tide, Lot No. 162F, purchased April 26, 1972, Albuquerque, NM, Proctor and Gamble, Cincinnati, OH.

⁴ Sears Heavy Duty Laundry Detergent, Albuquerque, NM, Lot No. CO22J0925, purchased April 26, 1972, Sears Roebuck and Co.

⁵ Electrosol Dishwashing Detergent, Lot No. D0402, purchased May 3, 1972, Albuquerque, NM, Economics Laboratory, St. Paul, MN.

⁶ Tide, Lot No. 2126, purchased June 22, 1972, Ottawa, Ontario, Canada.

TABLE 1
DEATHS IN BEAGLE DOGS AND PIGS TO SCHEDULED SACRIFICE
TIMES AFTER THE INGESTION OF VARIOUS COMMERCIAL
DETERGENT PRODUCTS

Dose administered (g/kg)	144 hr postadministration ^a	
	Dogs	Pigs
Tide Laundry Detergent		
2.5	0/3	0/3
1.0	0/3	—
0.5	0/3	—
0.1	0/3	—
Sears Heavy Duty Laundry Detergent		
2.5	1/3	1/3
1.0	0/3	—
0.5	0/3	—
0.1	0/3	—
Tide (NTA) Laundry Detergent		
2.5	0/3	0/3
1.0	0/3	—
0.5	0/3	—
0.1	0/3	—
Electrosol Dishwashing Detergent		
2.5	3/3	—
1.0	3/3	—
0.5	3/3	—
0.25	0/3	1/3
0.1	0/3	—
Controls (flour)		
2.5	0/3	0/3

^a First figure indicates the number of animals in each group that died prior to sacrifice. The second figure gives the number of animals in each group scheduled to be sacrificed at the time indicated.

Food was withheld for 18 hr before administration of the detergent. Each dog and pig was weighed and the appropriate dose calculated and measured. The dog was restrained in a sitting position and the mouth held open. Pigs were restrained in a standing position. A syringe with the tip removed was used to deposit the detergent in the back of the mouth, after which the mouth was held closed for 2 min to ensure that most of the material was swallowed. The dogs were placed in holding cages, observed continuously for 3 hr, and then transferred to a metabolism cage where they remained until death or sacrifice. Pigs were placed in pens with concrete floors. Water was available at all times after transfer to the metabolism cage, and food was offered at 24 hr after ingestion.

Two base-line blood samples were obtained by jugular venipuncture before detergent ingestion and single samples were drawn at 3, 24, 72, and 144 hr after ingestion. Complete hemograms and serum chemistry determinations were performed on each

sample. Total cholesterol, calcium, inorganic phosphorus, total bilirubin, albumin, total protein, uric acid, blood urea nitrogen (BUN), glucose, lactic dehydrogenase (LDH), alkaline phosphatase, and serum glutamic oxaloacetic transaminase (SGOT) values were determined by a sequential multiple analyzer.⁷ Serum sodium and potassium (K) concentrations were determined by a flame photometer, and chloride was measured by an autoanalyzer.⁷

TABLE 2
CHEMICAL ANALYSIS OF DETERGENT PRODUCTS GIVEN AS PERCENT^a

	Tide ^b	Electrosol ^c	Tide NTA ^d	Sears ^e
Orthophosphate	0.006	0.009	0.008	0.042
Total phosphorus	9.54	5.66	5.92	0.03
Bicarbonate	<1.0	<1.0	<1.0	<1.0
Total carbonate (CO ₃)	0.41	19.36	2.45	39.05
Total silicate (SO ₂)	4.32	5.00 ^f	3.88	5.61
Total boron	<0.01	<0.01	<0.01	<0.01
Total sulfate	13.83	0.16	12.61	0.24
Total chloride	0.25	0.25	0.01	0.001
Total sodium	14.8	26.7	14.5	21.5
Total potassium	0.014	0.017	0.0067	0.0037
Total nitrogen	<0.3	2.3	10.4	<0.3
Base mequiv.	0.188	0.894	0.199	0.862
Base as g NaOH/g detergent	0.15	0.79	0.18	0.75

^a Performed by Controls for Environmental Pollution, Inc., Santa Fe, NM, 87501.

^b Lot No. 162F, Proctor and Gamble, Cincinnati, OH.

^c Lot No. D0402, Economics Laboratory, St. Paul, MN.

^d Lot No. 2126, Proctor and Gamble, Ottawa, Ontario, Canada.

^e Lot No. C022J0925, Sears Roebuck and Co.

^f Some silicate as sodium metasilicate.

Necropsies were performed as soon as possible on all dogs and pigs that died before scheduled sacrifice. Scheduled sacrifices were accomplished by iv injections of sodium pentobarbital. The esophagus, stomach, duodenum, jejunum, ileum, colon, liver, gall-bladder, pancreas, kidneys, bladder, ovaries, testes, spleen, midshaft femur, rib, adrenals, thyroids, lung, heart, cerebellum, cerebrum, and eyes were examined grossly and selected specimens were prepared for histopathology.

RESULTS

Dose-Response Study

Results of the base-line serum chemistry measurements are shown in Table 3. Parameters that had values that were outside of the base-line range postingestion are shown for each detergent in Tables 4-7. The changes in white blood cell (WBC) counts of the dogs that ingested Tide, Sears Heavy Duty Detergent, and Electrosol are shown in Figs. 1 and 2. No significant changes in the WBC counts were observed in the dogs that ingested Tide NTA or in the control dogs. All times stated in this section are after ingestion unless otherwise indicated.

⁷ Model SMA 12/30, Technicon Instrument Corp., Tarrytown, NY.

TABLE 3
RESULTS OF DUPLICATE BASE-LINE SERUM CHEMISTRY
DETERMINATIONS OBTAINED FROM 114 BEAGLE DOGS

	Mean ^a	Normal range ^b
Total cholesterol (mg/100 ml)	149.9	91.3–208.5
Total bilirubin (mg/100 ml)	0.296	0.190–0.402
Total protein (g/100 ml)	5.89	4.55–6.95
Albumin (g/100 ml)	1.96	1.34–2.58
Inorganic phosphorus (mg/100 ml)	4.45	2.61–6.29
Uric acid (mg/100 ml)	0.669	0.389–0.949
Blood urea nitrogen (mg/100 ml)	14.44	7.88–21.0
Glucose (mg/100 ml)	91.2	65.8–116.6
LDH (Technicon units)	124.4	— ^c
Alkaline phosphatase (KAU)	10.13	4.33–15.93
SGOT (KU)	31.43	17.87–44.99
Calcium (mg/100 ml)	10.34	9.18–11.5
Sodium (mequiv./liter)	147.0	142.8–151.2
Potassium (mequiv./liter)	4.66	4.08–5.24
Chloride (mequiv./liter)	113.0	108.4–117.6

^a Means and normal ranges were calculated from two base line values from each of 114 dogs prior to ingestion of detergents.

^b Mean \pm 2 SD.

^c LDH activity values were not normally distributed and a normal range was not established.

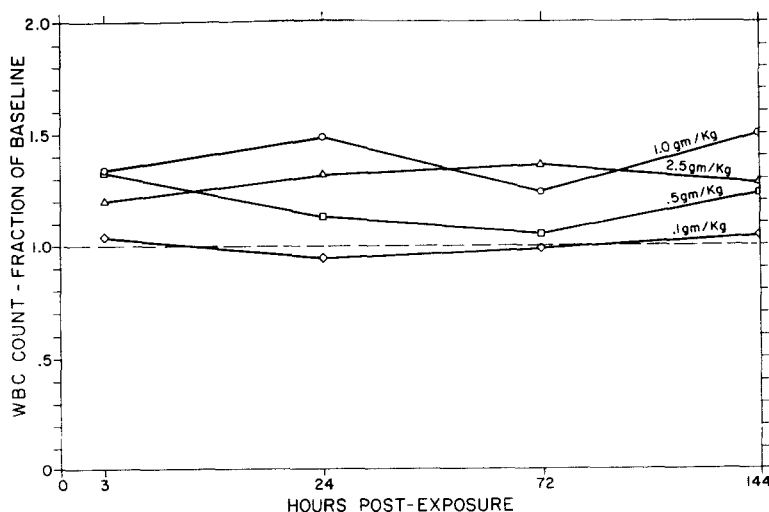


FIG. 1. Total white blood cell counts of venous blood of dogs at various times after ingestion of four dose levels of Tide Laundry Detergent given as fraction of base-line values. Each point is the mean value of three dogs.

Tide. All dogs given 2.5 and 1.0 g/kg and one of the three dogs given 0.5 g/kg Tide vomited detergent and gastric contents for 1–2 hr. No vomiting occurred at the 0.1 g/kg level. Vomiting was the only clinical sign observed in any of the dogs.

A slight increase in total WBC counts (Fig. 1) was observed at 3 hr after ingestion of 2.5, 1.0, and 0.5 g/kg. The WBCs remained elevated at 144 hr in the dogs that received 2.5 and 1.0 g/kg. Serum inorganic phosphorus was increased slightly at 3 hr in dogs receiving 2.5, 1.0, and 0.5 g/kg (Table 4). The BUN of the dogs given the highest dose was increased at 24 and 72 hr, but had returned to base line by 144 hr. Alkaline phosphatase activity was elevated at 24 hr in one dog at the highest dose level. The SGOT activity of one dog at the 1.0 g/kg level was elevated at 24 hr.

No significant gross lesions were observed in any of the dogs that ingested Tide. Proximal tubular nephrosis was found in the kidneys of two dogs that ingested 2.5 g/kg and in one dog ingesting 1.0 g/kg. No other significant histopathological lesions were noted.

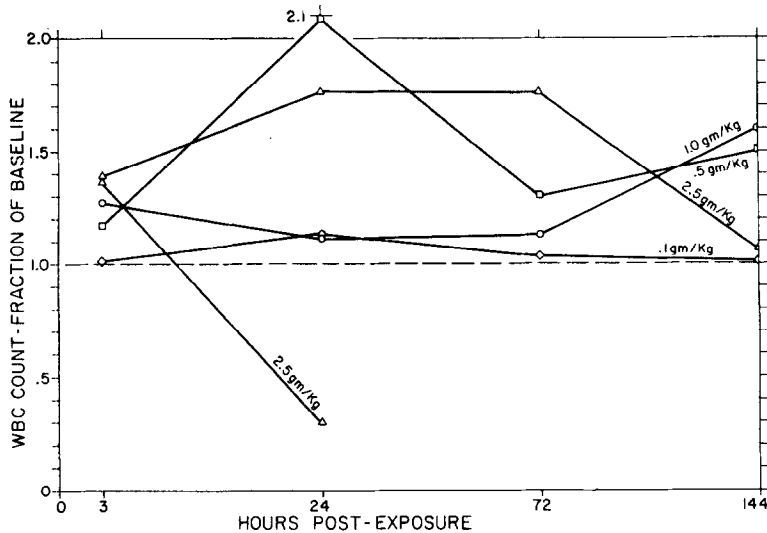


FIG. 2. Total white blood cell counts of venous blood of dogs at various times after ingestion of four dose levels of Sears Heavy Duty Laundry Detergent given as fraction of base-line values. Each point is a mean of three dogs except one dog at the 2.5-g/kg dose level is plotted separately.

Sears Heavy Duty Laundry Detergent. Emesis occurred for 2–3 hr in all dogs that ingested the Sears detergent. The vomitus of four dogs at the two highest dose levels contained blood, and all dogs at these two levels appeared depressed for 24 to 48 hr. One dog that received 2.5 g/kg died at 26 hr.

The WBC counts (Fig. 2) of all dogs that ingested 2.5 and 1.0 g/kg were elevated at 3 hr and remained elevated until 72 hr. The dog that died at 26 hr had a severely depressed WBC count when measured 2 hr before death. There was a small increase at 3 hr in the total bilirubin of one dog which received 2.5 g/kg. The BUN of all dogs that received 2.5 g/kg was moderately elevated at 24 and 72 hr, but had returned to base line by 144 hr. The serum alkaline phosphatase activity of dogs that received 2.5, 1.0, and 0.5 g/kg was elevated at 24 hr. The SGOT activity of dogs in the two highest dose levels was elevated at 3 hr and also at 24 hr for the highest dose level (Table 5).

TABLE 4
SERUM CHEMISTRY VALUES RELATIVE TO VARIOUS DOSES OF TIDE DETERGENT

	Time postexposure (hr)					
	3		24		72	
	Mean	Range ^a	Mean	Range	Mean	Range
2.5 g/kg						
Inorganic phosphorus (mg/100 ml)	6.85 ^b	4.55-9.16	4.74	2.93-6.55 ^c	5.54	3.92-6.78 ^c
BUN (mg/100 ml)	17.1	13.2-23.0	29.0	10.4-72.8	21.4	14.0-43.0
Alkaline phosphatase (KAU)	9.6	5.3-19.0	13.3	6.8-30.4	10.8	6.1-18.4
1.0 g/kg						
Inorganic phosphorus (mg/100 ml)	8.34 ^b	5.7-9.9	4.90	4.7-5.4	4.88	4.6-5.4
SGOT (KU)	39.0	37-43	72.0	26-158	35.7	32-43
0.5 g/kg						
Inorganic phosphorus (mg/100 ml)	8.00 ^b	6.99-8.72	4.31	3.20-5.22	4.75	4.50-4.93
					4.76	4.60-4.89

^a Range is the highest and lowest measured value.

^b Mean is higher than normal range (Table 3).

^c One or more measured values are higher than normal range.

TABLE 5
SERUM CHEMISTRY VALUES RELATIVE TO VARIOUS DOSES OF SEARS HEAVY DUTY LAUNDRY DETERGENT

	Time postexposure (hr)					
	3		24		72	
	Mean	Range ^a	Mean	Range	Mean	Range
2.5 g/kg						
Bilirubin (mg/100 ml)	0.41	0.20-0.90 ^b	0.39	0.24-0.52 ^b	0.29	0.25-0.30
BUN (mg/100 ml)	19.6	13.2-28.5 ^b	33.8 ^c	10.9-75.7	26.5 ^c	11.9-67.3
Alkaline phosphatase (KAU)	10.5	5.4-21.4 ^b	27.9 ^c	12.8-41.3	17.2 ^c	14.2-24.2
SGOT (KU)	84.3 ^c	37-226	70.4 ^c	33-155	27.8	22-35 ^b
1.0 g/kg						
Alkaline phosphatase (KAU)	11.3	9.9-12.3	31.1 ^c	23.0-40.3	22.4 ^c	16.5-28.8
SGOT (KU)	58.3 ^c	38-80	34.7	23-48 ^b	29.7	25-32
K (mequiv./liter)	4.7	4.5-4.9	4.6	4.5-4.7	5.0	4.8-5.2
0.5 g/kg						
Alkaline phosphatase (KAU)	13.6	7.3-22.8 ^b	26.6 ^c	14.0-38.8	20.2 ^c	10.9-30.4
					15.6	8.9-24.2 ^b

^a Range is the highest and lowest measured value.

^b One or more measured values higher than normal range (Table 3).

^c Mean is higher than normal range (Table 3).

Epithelial necrosis and ulceration into the submucosa were observed over the tongues, buccal surfaces, pharynges, larynges, and palates of the dogs receiving 2.5 and 1.0 g/kg. There was also necrosis and ulceration of the esophageal epithelium which was most pronounced in the anterior one-third of the esophagus. The stomachs were ulcerated and swollen with hemorrhage and edema, particularly in the fundic and cardiac regions. There were large consolidated, hemorrhagic foci in the dependent portions of the lungs. Foreign material and large numbers of bacteria and neutrophils were found in bronchioles microscopically, indicating aspiration pneumonia. No gross or microscopic lesions were found in dogs receiving 0.5 or 0.1 g/kg.

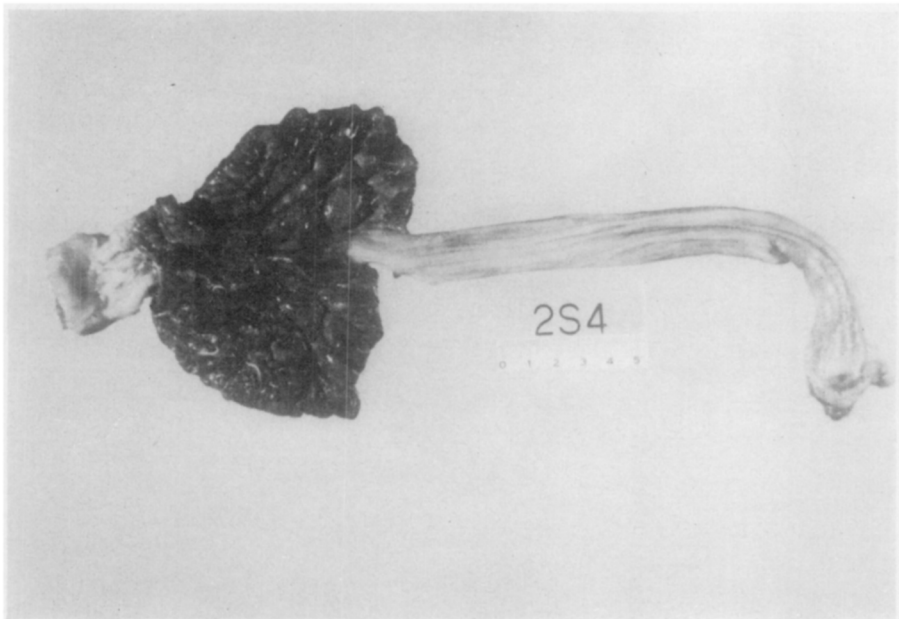


FIG. 3. Hemorrhage and edema of the stomach following ingestion of 2.5 g/kg Sears Heavy Duty Laundry Detergent.

Electrosol Dishwashing Detergent. All dogs receiving Electrosol vomited for 2–4 hr, and the vomitus from all except the 0.1-g/kg group contained blood. All of the 0.1-g/kg group and two of the three dogs in the 0.25-g/kg group survived to the 144-hr scheduled sacrifice. The other dogs died between 4 and 54 hr.

The WBC counts of all dogs were elevated at 3 hr and at 24 hr; WBC counts had fallen significantly before death in all dogs that died before sacrifice. Serum inorganic phosphorus of the dogs at the three highest dose levels was elevated at 3 and 24 hr (Table 6). The BUN of all dogs that died before sacrifice was elevated at 3 hr and was further increased at 24 hr. Alkaline phosphatase activity was increased at 24 hr, and SGOT activity was elevated at both 3 and 24 hr in all dogs except those at the 0.1-g/kg level. Serum potassium was elevated at 24 hr in the 2.5-g/kg dogs, all of which died during the ensuing 24 hr.

Gross lesions of variable severity were found in the oral cavity, pharynx, esophagus (principally upper one-third), stomach (Fig. 3), larynx, lung, and kidney of all dogs given

TABLE 6
SERUM CHEMISTRY VALUES RELATIVE TO VARIOUS DOSES OF ELECTROSOL DISHWASHER DETERGENT

	Time postexposure (hr)							
	3		24		72		144	
	Mean	Range ^a	Mean	Range	Mean	Range	Mean	Range
2.5 g/kg								
Inorganic phosphorus (mg/100 ml)	7.62 ^b	6.85–(999) ^c	7.19 ^b	7.19–(999) ^c				
BUN (mg/100 ml)	24.2 ^b	21.2–29.9	9.06 ^b	83.2–98				
Alkaline phosphatase (KAU)	14.7	12.2–17.5 ^d	40.0 ^b	41.8–38.1				
SGOT (KU)	71.5 ^b	56–(999)	50.5 ^b	47–54				
K (mequiv/liter)	5.2	4.8–6.0 ^d	7.05 ^b	5.8–8.3				
1.0 g/kg								
Inorganic phosphorus (mg/100 ml)	6.51 ^b	6.51–(999)	4.80	4.80–(999)				
BUN (mg/100 ml)	27.5 ^b	20–34.1	56.5 ^b	18.5–(999)				
Alkaline phosphatase (KAU)	12.5	10.5–15.0	37.4 ^b	33.6–42.5				
SGOT (KU)	124 ^b	68–(999)	89.5 ^b	42–(999)				
0.5 g/kg								
Inorganic phosphorus (mg/100 ml)	6.98	6.12–7.62 ^d	6.19	3.75–8.73 ^d				
BUN (mg/100 ml)	23.0 ^b	22.0–23.5	44.5 ^b	14.1–73.5				
Alkaline phosphatase (KAU)	11.6	9.9–14.8	36.8 ^b	33.2–40.5				
SGOT (KU)	91.3 ^b	72–125	92 ^b	52–148				
0.25 g/kg								
BUN (mg/100 ml)	17.7	12.5–22	37.2 ^b	9.6–74.5	38.6 ^b	15.0–88.5	17.0	16.0–18.0
Alkaline phosphatase (KAU)	8.54	4.8–11.2	29.7 ^b	13.8–40	21.7 ^b	16.6–(999)	12.7	10.9–14.5
SGOT (KU)	38.8	23–60 ^d	32.3	13–59 ^d	28.6	17–40	39	33–45

^a Range is the highest and lowest measured values.

^b Mean is higher than normal range (Table 3).

^c (999) is the symbol for value off scale and higher than the value the analytical technique could measure accurately.

^d One or more measured values higher than normal range (Table 3).

TABLE 7
SERUM CHEMISTRY VALUES RELATIVE TO VARIOUS DOSES OF TIDE NTA DETERGENT

	Time postexposure (hr)							
	3		24		72		144	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Inorganic phosphorus (mg/100 ml) BUN (mg/100 ml)	2.5 g/kg							
	6.24	4.92-9.30 ^a	3.84	2.61-5.15	4.52	3.03-5.60	4.33	4.01-4.88
	19.3	14.0-30.0 ^a	20.7	10.2-47.0 ^a	14.2	12.0-18.5	13.9	9.3-18.5
Inorganic phosphorus (mg/100 ml)	1.0 kg/g							
	6.59	5.40-7.71 ^a	4.69	4.38-5.19	5.03	4.59-5.30	4.59	4.35-4.90

^a One or more measured values higher than normal range.

2.5, 1.0, 0.5, and 0.25 g/kg. No gross lesions were found at 144 hr in dogs that received 0.1 g/kg.

Microscopic examination of tissues revealed an acute ulcerative necrosis of the epithelial lining of the digestive tracts from the oral cavity to the pyloric region of the stomach. These lesions included edema, hemorrhage, acute inflammatory cell infiltration, and occasional bacterial colonies. The larynges were necrotic, ulcerated, and edematous. The lungs were edematous with infiltrations of neutrophils and macrophages around bronchioles. Foci of foreign bodies and bacterial colonies were found in some bronchioles (Fig. 4). There was necrosis of the proximal renal tubules and cellular,

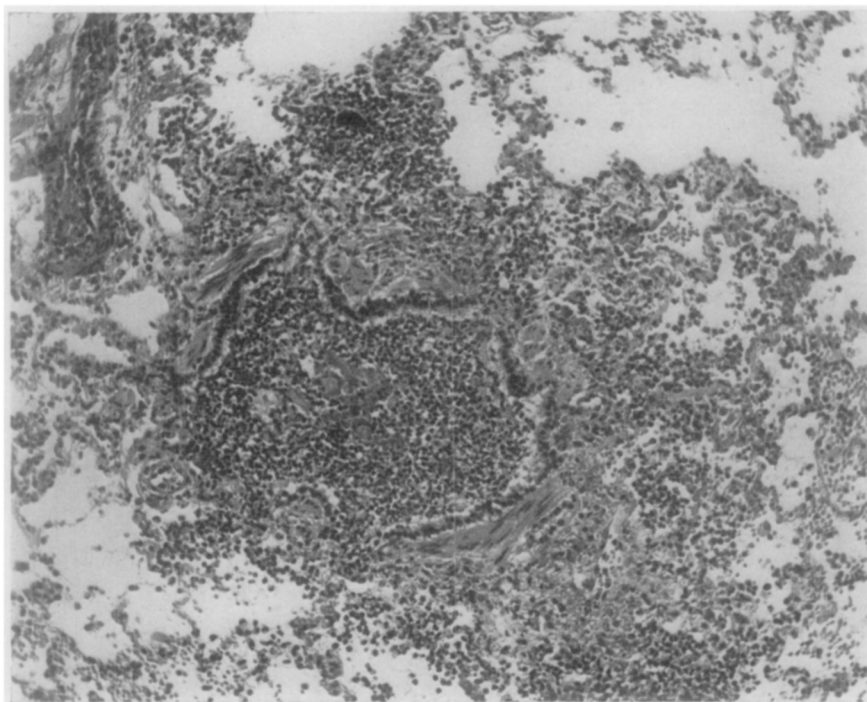


FIG. 4. Aspiration pneumonia after ingestion of 1 g/kg Electrosol Dishwashing Detergent. Note the foreign material in the bronchiole with intense inflammatory response. (H & E, $\times 140$).

hyaline, and mineralized tubular casts were scattered throughout the kidneys (Fig. 5). Only mild acute inflammatory changes, confined to the mouths and larynges, were found in the dogs given 0.1 g/kg Electrosol.

Tide NTA Detergent. Dogs that received Tide NTA vomited for times varying from 15 min to 2 hr; the severity of vomiting was related to dose.

No significant changes in WBC counts were found at any time after ingestion. The dogs that received 2.5 and 1.0 g/kg had an insignificant rise in serum inorganic phosphorus at 3 hr (Table 7). Some of the dogs that received 2.5 g/kg had small rises in BUN at 3 and 24 hr. No significant gross or histologic lesions were found in any of the dogs given Tide NTA.

Control dogs—wheat flour. The dogs that ingested 2.5 g/kg wheat flour had no abnormal clinical signs. All postingestion hematological and serum chemistry values were

within base-line ranges. A mild, chronic interstitial pneumonia and mild granulomatous hepatitis were found in most of the control dogs at necropsy. These lesions were probably related to lungworms which were found in a few dogs. Similar lesions were found in some of the exposed dogs, but were not considered to affect the pathogenesis of the detergent-induced lesions.

Species Comparison Study

There were no significant changes in the hematological or serum chemistry values obtained from pigs after ingestion of any of the detergents. Two pigs in each group that ingested Tide, Sears, and Electrosol detergents vomited several times during the first

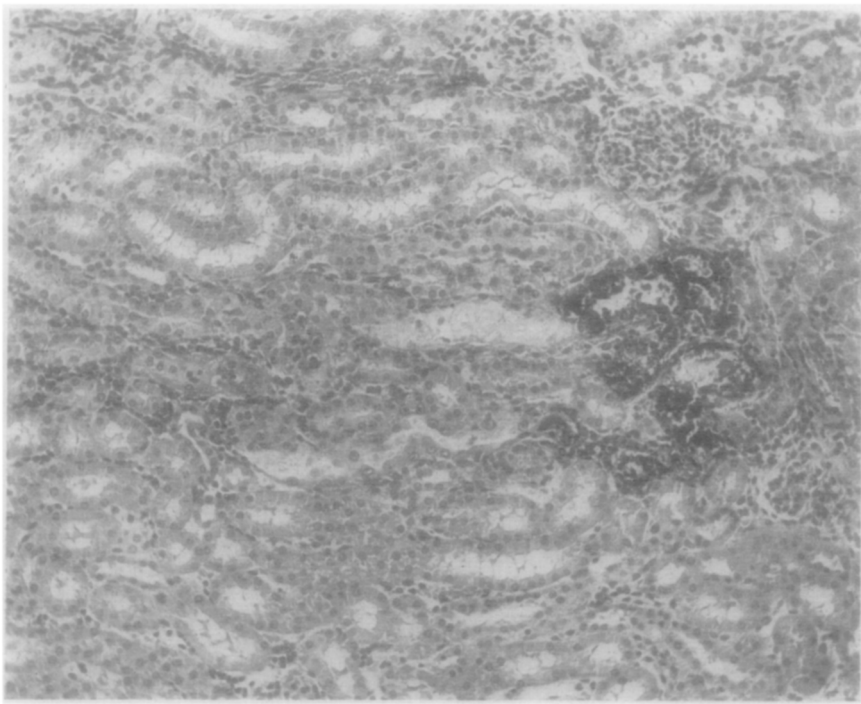


FIG. 5. Acute proximal tubular nephrosis after ingestion of Electrosol Dishwashing Detergent, 1 g/kg. Note the accumulation and mineralization of necrotic debris within the tubule. (H & E, $\times 140$)

30 min after ingestion. There was a small amount of blood in the vomitus in the Electrosol group. One pig died in each of the Sears and Electrosol detergent groups at 47 and 95 hr, respectively, after ingestion.

No gross or microscopic lesions were observed at necropsy in the pigs that ingested Tide or Tide with NTA. Epithelial necrosis and ulceration into the submucosa were observed over the tongues, buccal surfaces, pharynges, larynges, hard palates, and upper one-third of the esophagus after ingestion of Sears or Electrosol detergents. Aspiration pneumonia was found at sacrifice in one pig that ingested Sears detergent. No kidney lesions were observed in any of the pigs. No significant lesions were found at necropsy in any of the control animals.

DISCUSSION

The Beagle dog was selected as the experimental model for this study because (1) dogs will readily vomit in response to ingested irritants, (2) the dog is sufficiently large to allow its treatment as a clinical subject, (3) data concerning ranges of normal values for clinical and physiological parameters are available, and (4) the Beagle's tractable disposition facilitates its handling and the serial collection of experimental data. Pigs were selected because of the anatomy of its digestive tract, which is similar to that of man, its ability to vomit, and its size.

The method used for administering the detergents to the animals was intended to simulate accidental poisonings of children by ingestion. The intraesophageal administration of several detergents via stomach tube was reported by Lee *et al.* (1972). The method employed in this study, which was similar to that reported by Williams and Taber (1972), actually exposed the oral cavity and esophagus to the corrosive effects of the material ingested.

This study did not examine the toxicity of any single component of the products, but rather the combined effects of the entire formulation. Not only do the formulas of different products vary widely, but the composition of a single product may vary with the time and geographic area in which it is marketed. The results of this study must therefore be interpreted in view of the four products used and the time and location of their purchase.

Detergent ingestion primarily affected the epithelial surfaces of the mouth, tongue, pharynx, larynx, esophagus, and stomach, causing immediate coagulation necrosis and later ulceration. The types and distribution of lesions indicate that the damage resulted from direct contact and was probably related to the caustic properties of the detergents.

Aspiration pneumonia, a severe complication, frequently was the cause of death. The involvement of the respiratory system was thought to be secondary, resulting from the aspiration of vomitus. Laryngeal edema with loss of motor control was probably a predisposing factor leading to the high incidence of aspiration. Although the likelihood of the direct aspiration of detergent particles cannot be discounted, the presence of other foreign materials, large bacterial colonies, and necrotic gastric epithelium in the bronchioles associated with areas of severe pneumonia argues for the primary role of stomach contents in causing lung damage. Aspiration pneumonia was observed in only one of the pigs. This is possibly related to the observation that the pigs did not vomit for prolonged times and some not at all.

The proximal renal tubular nephrosis was morphologically similar in all dogs in which it was found. Although the contribution of these lesions to the death of the dogs is uncertain, an impairment in the renal function of subjects with fluid and electrolyte imbalances is not desirable. Nephrosis after detergent ingestion has not, to our knowledge, been previously reported. The cause is not known and may be either primary or secondary. There were no kidney lesions at death among the pigs, probably because they swallowed little of the detergent material and retained most of it in the pharyngeal diverticulum.

The serum chemistry alterations were indicative of the tissue damage occurring in the alimentary tract and kidneys. Increases in inorganic phosphorus and potassium can also be related to the nephrotic lesions. The increases in SGOT activity associated with the

higher doses of Electrosol and Sears detergents may have resulted from the red blood cell breakdown and muscle destruction which occurred in the stomachs of some dogs. Alkaline phosphatase activity can be increased by both gastric and renal damage in addition to other causes.

Electrosol Dishwashing Detergent was the most toxic, on a weight basis, of the products evaluated, causing destruction on contact of the surface of the upper alimentary tract. Sears Heavy Duty Laundry Detergent was the second most toxic product, also causing serious damage to the oral, esophageal, and gastric mucosa. Vomiting frequently led to aspiration following ingestion of both products, and aspiration pneumonia caused the death of several dogs. The high frequency of aspiration may suggest a possible interference with motor control of the pharynx and larynx. Renal lesions were found in many of the dogs, but it is not certain whether those lesions contributed significantly to the death of the dogs.

Tide caused irritation of the upper alimentary tract, which resulted in vomiting and discomfort, but no significant lesions were found, even as early as 3 hr after ingestion. Tide containing NTA appeared almost nontoxic at the dose levels evaluated, causing only a mild gastric irritation and no observable systemic effects.

The pigs appeared to swallow very little of the detergent material placed in the mouth, much of it being retained in the pharyngeal diverticulum. This leads to the speculation that the lack of gastric irritation resulted in less vomiting and reduced absorption of detergent material from the stomach into the blood and hence to other organs. This difference between pigs and dogs could account for differences in organs affected, principally the lung and kidney. Electrosol and Sears detergents were also the most toxic of the four detergents in the pigs with lesions similar to those in the dogs in areas of contact.

A study with 12-wk-old puppies was also conducted with results similar to those for the adult dogs. Age did not appear to influence the severity or distribution of lesions.

The results of this study indicate that the toxic effects of ingested household detergents can range from a mild, transient irritation to a severe, life-threatening destruction of tissue. It would be dangerous, therefore, to generalize when considering the clinical management of detergent ingestion. The varied findings among the four detergent products in this study indicate the importance of evaluating the toxicity of individual detergent formulations for appropriate therapeutic actions in the event of their ingestion.

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