

RELATIONSHIP OF NITRATES IN KANSAS GROUNDWATERS
TO ANIMAL AND HUMAN HEALTH

by

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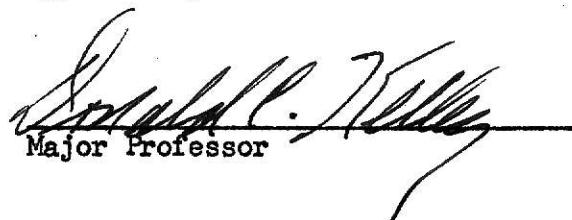
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INTRODUCTION

Nitrates have long been recognized as a problem in man and animals. Many studies have been conducted on the medical implications of nitrates; yet, the true significance of nitrates lacks thorough substantiation.

Nitrate poisoning occurs in man and animals from the ingestion of nitrates or nitrites. Signs of toxicity vary, depending upon the total level of nitrate-nitrite ingested, from acute death to chronic signs of impaired health and poor performance. Acute nitrate poisoning produces rapid onset of signs and acute death. This results when 1.5% of the feed on a dry weight basis or 500 ppm of the water is nitrate (1). Chronic nitrate poisoning occurs from ingesting low levels of nitrate, greater than 0.5% nitrate in feed or 125 ppm nitrate in the water, over a long period of time (2,3). An additive effect occurs in either form of the poisoning if the animal consumes both feed and water containing nitrate. Therefore, nitrate levels should be determined in both of these sources (4).

The clinical signs associated with chronic nitrate poisoning are numerous and controversial. Dyspnea, grinding of teeth, uneasiness, vasodilation, lowered blood pressure, abortion, reduction of milk secretion, avitaminosis A, and thyroid dysfunction are all reported (5). These signs are primarily related to impaired performance and health of animals, and are not easily differentiated from clinical signs due to other disease agents. Research on chronic nitrate poisoning in animals

is becoming physiological and biochemical in nature (6).

In humans, nitrate poisoning is seen in infants as infant methemoglobinemia (blue babies). Infant methemoglobinemia is an acute disease resulting from ingestion of well waters containing nitrates. The recommended nitrate limit in water for human consumption is 45 ppm (7). Consumption of water containing nitrates above this limit could result in acute poisoning in infants. Chronic nitrate poisoning with long-term effects has not as yet been recognized in humans, and there are no documented cases in the literature. However, physiologically it is known that nitrates will cause thyroid disturbances, vitamin A deficiency, and death (8,9). Recently, a possible causal relationship between nitrate levels in drinking water and the incidence of toxicological aspects were hypothesized by Shuval and Gruener (1972) (10).

As early as 1793, human health was recognized to be impaired when man was treated with nitrates (11). In animals, an early case reported intoxication from ingesting corn stalks containing excessive levels of nitrates. In both circumstances, the causative agent was not initially recognized (12). Since these early reports of nitrate intoxication, many cases have been reported in animals and humans and the causative agent has been determined.

Comly (1945) documented the first case of infant methemoglobinemia in the United States (13). Acting on a story told by the infant's skeptical father, Comly suggested that a sample of the well water used to make the infant's formula be tested for nitrates. An excessive level of nitrate was found. Bosch et al. (1950) reported that 139 cases of infant methemoglobinemia including 14 deaths occurred

in Minnesota (14). Walton (1951) surveyed the literature relating to infant methemoglobinemia due to nitrate-contaminated water and alluded to several other intrinsic and extrinsic factors associated with nitrate poisoning (15). The literature relating to nitrates reveals that the health hazard of nitrate-contaminated well waters has been thoroughly established (15). Thus, the recommended limit of nitrates in well waters for safe human consumption was established by the United States Public Health Service (7). However, the facts supporting the establishment of this limit need further investigation.

Nitrate intoxication, causing methemoglobinemia and impaired human health, is not only due to high nitrate well waters. Some processed foods and vegetables also have been known to contain excessive quantities of nitrates or nitrites and have been responsible for nitrate intoxication (12, 16, 17). Processed infant foods in the United States and Canada have not yet been implicated in infant methemoglobinemia (18). Recent research has shown that nitrites present in processed meat may result in carcinogenic compounds (19).

The study of nitrate intoxication in domestic animals has been extensive. Since the late 1930's, when cases of oat hay poisoning were reported and nitrates were found to be the causative agent (20), many reports of nitrate toxicity in animals have appeared. Work in laboratory animals involving the effect of nitrates on vitamin A metabolism and thyroid function caused concern throughout the livestock industry (6). The physiological effects and metabolism of nitrates have been studied in vitro (21) in sheep (22, 23, 24, 25, 26), swine (27, 28, 29), cattle (30, 31, 32, 33, 34, 35, 36), and poultry (37). Reports of nitrate

poisoning are frequently in conflict with the results of systematic research (5). Thus, the effects of nitrate consumption in domestic animals are confusing.

The environmental role and impact of nitrates is variable. The presence of nitrates in well waters is documented (10, 14, 15, 38, 39), and the movement and distribution of nitrates in groundwaters have been studied (38, 40). Nitrate movement occurs with water-flow, but nitrate concentrations at given distances from wells are not predictable. Localization of nitrates in the upper region of the aquifer has been observed and nitrate concentrations in well waters vary throughout the year (40).

The increased use of nitrogen-containing fertilizers and its relation with impaired health and performance in animals and humans is thought to occur at an alarming frequency (41), but no relationship between fertilization and poor animal performance due to nitrate consumption has been demonstrated (42). Nitrate contamination of drinking waters due to runoff from farms fertilized with inorganic nitrates cannot be adequately measured until more systematic surveys of nitrate and/or nitrite content of drinking water are undertaken in areas where such hazards exist (18).

This study was conducted to investigate the extent of nitrate problems on farmsteads using well waters containing excessive levels of nitrates. Particular attention was directed toward the relationship between inorganic fertilizer applied to the land and nitrate levels in well waters, other possible sources of nitrates, and the relationship of nitrate levels to animal and human health problems. The study

collected data on health problems on farmsteads and correlated these data with the nitrate levels found in respective well waters.

MATERIALS AND METHODS

Review of Records

The water chemical quality records compiled by the Sanitary Engineering Laboratory of the Kansas State Department of Health, Environmental Health Services, were reviewed to determine the status of nitrates in Kansas groundwaters. Test results for ground and surface waters were obtained for the period starting 1 January 1967 and ending 31 December, 1971. Water nitrate test results from the Veterinary Diagnostic and the Comparative Toxicology Laboratories, Kansas State University, were also reviewed for the period beginning 1 January 1969, and ending 31 December, 1971. Interviews were conducted with personnel of offices responsible for water testing. Further documentation of nitrates in Kansas groundwater was received from the Groundwater Division of the Kansas State Geological Survey.

Survey of Farmsteads with Well Waters High in Nitrates

Three areas in Kansas were selected for person-to-person interviews and on-site farmstead surveys. The areas were selected on the basis of having farmsteads with wells containing high levels of nitrates. Although several counties contained farmsteads with high levels of nitrates in wells, the three surveyed areas were specifically selected because of the interest of their residents.

County extension agents were asked to assist in scheduling interviews with farmstead owners or farm laborers. Although it was intended to discuss the nitrate problem with the person having specific

knowledge of the situation, this was not always possible. Questions were directed toward securing information on the following topics:

1. The location, type, depth, and casing of the well known to contain waters high in nitrates,
2. The health status of past and current livestock on the farm, type of feed fed, and sources of drinking water,
3. Past and current family health status, sources of drinking water,
4. Bacterial content of water, and
5. Fertilizer use.

Water Sampling and Testing

If possible, water samples were obtained from wells located on each farmstead surveyed to verify the existence of a current nitrate problem. At one farmstead, samples were obtained sporadically from March 1971 to March 1972 to analyze the cyclic fluctuation of the nitrate content. Samples were obtained at the closest outlet to the well. The water was permitted to run for several minutes before collection in order to flush the water lines. Testing of the samples was completed within 24 hours of collection. While samples were all placed under refrigeration if held overnight, little variation occurred in the test results if the samples were stored at room temperature prior to testing. All water samples were tested for nitrates, but samples were also sporadically tested for nitrites.

Nitrate levels were determined by using a Corning Model 10 Expanded Scale pH Meter and an Orion Nitrate-Ion Electrode. Concentrations are reported as parts per million (ppm) of the sample water. Nitrite was tested by diazotization using sulfanilic acid and alpha-naphthylamine

hydrochloride (3). The intensity of color development was directly related to the concentration of nitrite.

An arbitrary point system was devised to assign values to the physiological effects reported on each farmstead. Twenty points were assigned if an acute case of nitrate poisoning had been diagnosed by a veterinarian or physician. One point was assigned for each of the clinical signs of chronic nitrate poisoning present in the particular circumstances:

- (a) reduced rate of gain and poor growth
- (b) rough hair coat
- (c) xerophthalmia and related problems
- (d) diarrhea in animals and man
- (e) digestive disturbances associated with drinking water
- (f) loss of young animals
- (g) arthritic or related signs
- (h) hypothyroidism and associated signs
- (i) infertility, miscarriages, and abortions of late term fetuses, or birth of weak individuals.

If several different species of animals had the same clinical signs, 1 point was assigned for each species. One point was also assigned for other pertinent findings that supported a diagnosis of nitrate toxicosis. Such supportive findings included:

- (a) the feeding of vitamin A, D, and E complex, high carbohydrate diet, iodized and mineralized salt or antibiotics,
- (b) attempts at diagnosis by veterinarians or physicians, but only nitrates could be found, and
- (c) when the physician could not relate any specific cause except "something in the environment."

Five points were assigned if farmsteads had obtained a new source of water low in nitrates and the use of this water had resulted in abatement of the clinical signs.

The total points for each farmstead were correlated with the nitrate levels found in the water on the farmstead. If more than one water source was used, the arithmetic average was utilized. The total points were also correlated with the amount of inorganic fertilizer applied to the land on these farmsteads. The average of the application rate reported by the farmers was used. The average pounds of nitrogen applied per acre was also correlated with the nitrate concentration of the well water on each farmstead.

Statistical relationships of the data collected were analyzed by linear regression and coefficient of correlation analyses.

RESULTS

The review of the well waters tested by the Kansas State Department of Health, Environmental Health Services, from 1 January 1967 to 31 December 1971, afforded 1,938 nitrate test results (Figure 1). The results ranged from 0 - 1500 ppm nitrate. Twenty-five percent of the samples tested contained over 50 ppm nitrate. Concentrations of 175 ppm nitrate or above were found in 6% of the tested samples. Surface water samples tested for the same period totaled 193 ppm. The samples included surface water from mudholes, ponds, lakes, springs, streams, and reservoirs. The results ranged from 0.1 ppm to 69 ppm nitrate.

Thirty-seven municipal water supplies (43) were found to exceed the USPHS recommended maximum tolerance limit of 45 ppm nitrate. Three of the samples exceeded the 90 ppm nitrate tolerance limit for Kansas municipal waters. One water supply tested at 487 ppm nitrate.

A total of 607 well water samples were obtained from records compiled by the Diagnostic and the Comparative Toxicology Laboratories, Kansas State University for 1 January 1967 through 31 December 1971. Of these, 45.3% of the samples had levels in excess of 50 ppm nitrate. Concentrations of 175 ppm nitrate and above were found in 17.5% of the tested samples. Only 14 surface water samples were tested. They ranged from 3.0 to 106 ppm nitrate.

The survey conducted in three areas within the state involved 56 farmsteads (Figure 1). The northern area included Washington county, the eastern portion of Republic county, and the western portion of

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Figure 1--Geographic Areas of Kansas Selected for Nitrate Study and Water Test Samples From the Kansas State Department of Health From 1 January 1967 - 31 December 1971

Cheyenne	Rawlins	Decatur	Norton	Phillips	Smith	Jewell	Republic	Washington	Marshall	Nemaha	Brown	DO
+2	+1	+1	+2	+7	+27	+6	+13	+61	+42	+59	+21	+9
					-21	-1	-1	-17	-15	-47	-7	-4
					* 2		* 2	* 6	* 5	* 10	* 5	* 2
Sherman	Thomas	Sheridan	Graham	Rooks	Osborne	Mitchell	Cloud	Clay	Riley	Pottawatomie	Jackson	Alfons
	+1		+1	+10	+4	+4	+13	+31	+30	+25	+88	+10
				-1	-2	-1	-3	-2	-8	-17	-19	+35
								* 3	* 6	* 6	* 7	* 1
Wallace	Logan	Gove	Trego	Ellis	Russell	Lincoln	Ottawa	Dickinson	Geary	Wabaunsee	Shawnee	Jefferson
+6	+2		-1	+25	+23	+5	+28	+12	+15	+29	+76	+15
				-1	-3		-8	-4	-1	-8	-6	-1
				* 2			* 6	* 1	* 3	* 1	* 2	* 1
Greeley	Wichita	Scott	Lane	Rush	Barton	Ellsworth	Saline	McPherson	Morris	Lyon	Osage	Franklin
	+1	+1	+2	+120	+4	+17	+31	+11	+13	+7	-2	+2
				-21		* 2	-4	-5	-6	-2	* 1	+2
				* 5			* 2	* 3	* 3	* 1		-2
Hamilton	Reamy	Finney	Hodgeman	Pawnee	Stafford	Rice	Hayward	Butler	Chase	Coffey	Linn	Anderson
+3	+2	+1		+4	+8	+9	+33	+37	-1	+9	+8	+4
						-1	-32	-8		-5	-2	
						* 3	* 13	* 1				
Stanton	Grant	Haskell	Ford	Edwards	Pratt	Kingman	Sedgwick	Greenwood	Woodson	Wilson	Nosho	Crawford
+1	+4		+7	+3	+2	+4	+53	+8	* 1	+9	+14	+7
				+1		-2		Elk		-1	-6	-3
Morton	Stevens	Seward	Clark	Comanche	Barber	Harper	Sumner	Cowley	Montgomery	Labette		Cheokee
+1	+1	+1	+5	+13	+5	+20	+27	+7	+4	+5		+3
				-3		-4	-9	-1	* 1			-1
							* 3	* 1	* 1			* 1

General: +38; -10; *1.

- + Number of Samples 50 ppm NO_3^- and Below.
- Number of Samples 51 ppm - 175 ppm NO_3^- .
- * Number of Samples 176 ppm NO_3^- and Above.



Areas Selected for Study.

Marshall county, and incorporated 20 farmsteads. Eighteen farmsteads were surveyed in both Rush and McPherson counties in southern Kansas.

A total of 88 wells were observed on these 56 farmsteads. Some farmsteads had several wells in use within the past five years. Nineteen of the wells were no longer used as a source of drinking water for animals or humans. The type of wells found, their location and construction, and the range of nitrate concentration of their waters are outlined in Tables 1 and 2. All the dug wells ranged from 11 to 40 feet deep. Seventy-nine of the wells were 100 feet or less in depth. Only 5 wells were noted to be more than 100 feet deep. The depth of 4 wells was not reported.

Only 2 of the 88 wells were constructed according to recommendations of the Kansas State Department of Health (44). The location of 27 wells complied with the Kansas State Department of Health recommendations. Six currently used wells, containing water high in nitrate, were within 10 feet of abandoned wells. Three of these old wells were known to contain waters high in nitrate; the nitrate concentrations in the other 3 wells were unknown.

The bacteriological status of the well water was determined from testing performed by the Kansas State Department of Health and were reported as "safe" or "unsafe." Eleven wells were reported as safe and 23 wells were reported unsafe. The status of the remaining 54 wells was unknown. Five wells known to be unsafe and 22 wells in which the bacteriological quality of the water was unknown were used to supply drinking water for humans. Two wells, one bacteriologically unsafe and one of unknown status, had chlorination systems attached to their

Table 1--Type, Location, and Construction of Wells on 56 Kansas Farmsteads Reporting Well Waters High in Nitrates

Type	Number	Construction*		Location*	
		Proper	Improper	Proper	Improper
Dug	25	0	25	4	21
Drilled	59	2	57	23	36
Dug and Drilled	4	0	4	0	4
Total	88	2	86	27	61

* Per recommended standards for locating, constructing and equipping water wells for rural homes in Kansas (44).

Table 2--Use Made of Wells Containing Concentrations of Nitrate and Evaluation of Proper Construction and Location

Number of Wells	Percent	Nitrate Range (ppm)	Use*		Proper Construction (No.)	Proper Location (No.)
			Animal (No.)	Human (No.)		
6	6.9	Below 50	4	4	2	5
19	21.8	51 - 175	14	8	0	4
36	41.4	176 - 500	24	19	0	13
21	24.1	501 - 1000	12	3	0	4
5	5.7	Over 1000	4	1	0	1

* 19 wells were no longer used for animal or human drinking purposes.

pipelines. The addition of chlorine was intended to correct the high nitrate concentrations also found in the water.

The nitrate concentrations of the 88 wells ranged from a low of 6 ppm nitrate to a high of 1200 ppm nitrate. The number of wells with nitrate concentrations occurring at predesignated ranges of nitrate (in ppm) are given in Table 3.

The well waters from one farmstead in which nitrate poisoning was diagnosed as a health hazard were periodically tested for nitrate concentration during the 15-month period from April 1971 through July 1972 (Table 4). Samples from one dug and one drilled well were tested to determine the fluctuations of nitrate concentrations within the wells. Samples were also tested for nitrate concentrations after the drilled well water had passed through a water softener. The amount of nitrate removed varied from 0 to 142 ppm. Four of the 20 wells were positive when tested for nitrites, but all had less than 0.1 ppm nitrite levels. One stream with barnyard runoff tested negative for nitrite.

With the exception of one instance, all of the animal and human health problems occurred on 47 farmsteads using inorganic nitrogen fertilizers. Farmsteads reporting nitrogen fertilizer usage contained 79 of the 88 wells observed. The relationship between application of inorganic nitrogen fertilizer, adverse animal and human health, and the nitrate concentrations in wells therefore could be statistically analyzed.

The point values for health impairment on the 21 farmsteads ranged from 1 to 23. The mean value was 6.7619 points, with a standard deviation of ± 6.4179 .

Table 3--Relationship of Nitrates Found in Well Waters, Fertilizer Application, and Reported Health Impairment on Selected Farmsteads

Farmstead Wells by		Fertilizer Applied (lbs N/acre)		Reported Health Impairment	
Nitrate Levels (ppm NO ₃)	Nitrate Level (ppm NO ₃)	Range	Mean	Animal	Human
<u>Below 50</u>					
Neiberding*	26	80 - 100	90		
Neiberding*	6	80 - 100	90		
Bekeneyer	50	150 - 180	165		
Morey*	42	120 - 130	125		
Kruger*	45	50 - 100	75		
Kaufman	40	0 - 50	50		
<u>51 - 175</u>					
Ellenbecher	74	100 - 120	110	+	
Neiberding**	85	80 - 100	90		+
Dettke	140	80 - 120	100	+	
Randall	175	0	0		
Meyerhoff	100	100 - 150	125		
Morey J.**	170	120 - 130	125		
Vogts**	175	90 - 100	95	+	
Vogts	68	90 - 100	95		
Krehbiel	130	50 - 100	75	+	
Huxman	100	50 - 100	75		
Ediger	130	50 - 100	75		
Jacobs	155	0	0		
Grottinger	78	40 - 60	50	+	+
Perkins	105	-----	---		
Perkins	140	-----	---		
Train	60	210 - 275	243		
Kristine	100	0	0		
Chernak	115	80 - 90	85		
Kober	165	40	40		

Table 3--(continued)

Farmstead Wells by Nitrate Levels (ppm NO ₃ ⁻)		Nitrate Level (ppm NO ₃ ⁻)	Fertilizer Applied (lbs N/acre) Range Mean		Reported Health Impairment Animal Human	
<u>176 - 500</u>						
Ellenbecher	254	100 - 120	110	+		
Neiberding**	300	80 - 100	90	+		
Stevens	300	90 - 100	90	+		
Koss	375	90 - 100	95	+		
Finlayson	400	0	0	+		
Day	240	-----	---			+
Black	500	100 - 150	125			
Kruger	270	50 - 100	75			
Schaff	180	120 - 150	135	+		
Vathauer**	380	100 - 140	120			
Vathauer	430	100 - 140	120			
Vathauer	320	100 - 140	120			
Johnson	180	100 - 120	110			
Lindberg	330	60 - 120	90	+		
Gibson**	450	50 - 100	75			
Ostlind	370	50 - 70	60			
Kaufman**	315	0 - 50	50			
Kaufman	240	0 - 50	50			
Ediger	240	50 - 100	75			
Ediger	270	50 - 100	75			
Toews	335	50 - 100	75	+		
Bentson	330	50 - 75	63			
Malun	260	80 - 90	85			
Train	330	210 - 275	243			
Erb***	360	40 - 60	50	+		
Erb***	---	40 - 60	50			
Kober	240	40	40			
Williams	420	40	40			
Schoendaller	200	40 - 60	50			
Schoendaller	330	40 - 60	50			
Rogers	300	-----	---			
Boertz D.	240	40 - 60	50			
Boertz C.	255	40 - 60	50			
Boertz C.	380	40 - 60	50			
Boertz C**	280	40 - 60	50			
Craver	230	40	40			

Table 3--(concluded)

Farmstead Wells by		Fertilizer Applied	Reported Health	
Nitrate Levels	Nitrate Level	(lbs N/acre)	Impairment	
(ppm NO ₃ ⁻)	(ppm NO ₃ ⁻)	Range	Animal	Human
<u>501 - 1000</u>				
Herman**	580	0	0	+
House	540	0	0	
House	580	0	0	
Conner	740	-----	---	
Saunder**	760	40 - 60	50	
Baldwin***	640	40	40	
Baldwin***	---	40	40	+
Kaufman	600	0 - 50		
Nelson	590	-----	---	
Ostlind	600	50 - 70	60	
Buster	590	-----	---	+
Lindborg	780	60 - 120	90	+
Bullinger**	750	100 - 110	105	+
Goering**	890	-----	105	+
Morey**	600	120 - 130	125	
Kruger	780	50 - 100	75	
Meyerhoff	820	100 - 150	125	
Ohlde**	520	100 - 150	125	+
Ohlde	554	100 - 150	125	+
Hammerbecher**	950	-----	---	+
Neiberding**	700	80 - 100	90	+
 <u>Over 1000</u>				
Rhine**	1100	0	0	+
Bullinger	1175	100 - 110	105	+
Krehbiel	1100	50 - 100	75	+
Toews	1050	50 - 100	75	+
Sjoholm	1200	50 - 100	75	

* Newly dug wells to correct the nitrate problem.

** Wells discontinued or no longer used for drinking purposes for animal or humans.

*** Wells on these farmsteads were joined to form a common outlet.

Table 4--Variations in Nitrate Concentration in Two Wells Observed Over a 15-Month Period

Month	Dug Well (ppm NO ₃ ⁻)	Drilled Well	
		Before Softening (ppm NO ₃ ⁻)	After Softening (ppm NO ₃ ⁻)
April 1971	175	23	12
May 1971	450	50	28
May 1971	350	200	95
May 1971	360	220	78
September 1971	110	18	12
January 1972	220	40	27
March 1972	185	21	21
May 1972	100	11	8
July 1972	280	78	48
July 1972	310	74	50
Mean	254	73.5	37.9

Statistical analysis revealed the following coefficients of correlation: 0.12083 for health impairment vs. pounds of nitrogen applied per acre; 0.317331 for health impairment vs. well water nitrate concentration (in ppm); and -0.119618 for pounds of nitrogen applied per acre vs. well water nitrate concentration (in ppm).

The 21 farmsteads used in the comparative study for health effects reported health impairment in 6 different animal species: hogs (10 reports); cattle (8 reports); man (4 reports); dog (2 reports); rabbit (2 reports); and sheep (1 report). Both acute and chronic forms of nitrate poisoning were reported. One confirmed case of acute nitrate poisoning in feeder cattle was reported from ingesting well water high in nitrate.

Two of the farmsteads surveyed experienced apparent chronic nitrate toxicosis. Attempts to isolate other etiologic agents failed. Testing of water and feed showed that nitrate levels were sufficient to cause nitrate toxicity. The feeding of a high, good quality carbohydrate diet with vitamin and mineral supplement (3) seemed to lessen some of the clinical signs on one of the farms. The second farmstead had rabbits that were aborted, born weak and died, or born dead, and cattle with clinical signs of chronic nitrate toxicity. Histopathological and bacteriological studies were negative. When a new water supply with a safe nitrate level replaced the high nitrate water, the signs of chronic nitrate toxicity disappeared on both farmsteads within a few months.

Two other farmsteads reported previous signs of chronic nitrate toxicity in livestock. Both farmsteads had drilled new wells to obtain a supply of water low in nitrate. The use of the new water supply resulted in abatement of the clinical signs on both farmsteads within months.

Human health involvement from ingesting water high in nitrate was apparently minimal. Six farmsteads reported human health problems but only four instances were possibly due to nitrate toxicity. Several cases of health impairment thought to exist by county agents and health personnel were not reported when the farmsteads were surveyed. One confirmed case of infant methemoglobinemia was reported. Another three instances of human health involvement were investigated by family physicians. The causes of the health problems were not specifically determined. All three cases reported were related to an environmental agent frequently contacted by the patients; nitrates were not ruled out. Two additional farmsteads reporting human health impairment also reported animal health problems. Three of these six farmsteads are still using the high nitrate water for human drinking purposes.

Several of the farmsteads surveyed were approached by representatives from chemical companies. The representatives tested the water for nitrate and nitrite by a colorimetric spot-plate method and recommended the use of a chlorinator and water softening system to stabilize and to remove the nitrates found. Three farmsteads used some form of the recommended system, but only one reported satisfactory results. In the latter situation, the drilling of a new well and the resultant low nitrate water supply (a drop from 170 ppm to levels below 20 ppm nitrate) satisfactorily accounted for the reduction in clinical signs.

DISCUSSION

Review of the nitrate content of well waters tested by the Kansas State Department of Health and the Diagnostic and the Comparative Toxicology Laboratories of Kansas State University was necessary to develop an overview of the nitrate levels in well waters. However, the nitrate samples extracted from a certain county could have originated from neighboring counties. The samples do not accurately represent the number of wells sampled in the state, since some of the tests were repeats to determine if the first test was valid and/or to see if the nitrate level changed. Thus, the test samples indicate particular levels of nitrates rather than representing the absolute number of wells with these nitrate levels.

The same must be considered when evaluating the results from samples tested at Kansas State University. The percent of samples with high nitrate levels is expected to be large because the water samples were initially submitted to confirm suspected nitrate toxicoses. A higher percent of the samples obtained from Kansas State University occurred in the upper nitrate levels than was the case for samples obtained by the Kansas State Department of Health. Seventeen and one-half percent of the Kansas State University samples exceeded 175 ppm nitrate whereas only 6% of the Kansas State Department of Health exceeded this level.

Although nitrite (NO_2^-) may also be found in well waters, it is seldom analyzed (45). Of 5000 water samples tested in Missouri, only

1-4% were found to contain nitrites (46). A higher percentage was found to contain nitrites during the winter months. Nitrites are usually found at low concentrations since they are unstable and readily oxidized to nitrates. Metzler (1958) theorizes that the nitrate accumulation in well waters does not occur as a result of bacteriological or chemical reactions in the water itself (38). Surface waters normally have low nitrate levels because of denitrification and the presence of water biota that utilize nitrates as a nutrient source (47).

Nitrates in well waters may originate from many sources (14, 15, 47), but nitrates in well waters are thought to result primarily from improper well location and construction (14, 15, 38, 46, 47, 48). The location and construction of the 88 wells surveyed support this theory. Seventy-nine of the 88 wells were shallow wells more susceptible to contamination when improperly located and constructed. Improperly located and constructed deep wells are also vulnerable to pollution, but less so than the shallow type.

Nitrate levels cycled throughout the year on the farmstead where sporadic testing was conducted. Peaks occurring in the winter were not evident; perhaps increased frequency of sampling would have confirmed this earlier observation (40). Due to the fluctuation of nitrate levels in well waters, it is important that frequent (at least monthly) samplings be performed to adequately evaluate the nitrate levels found in well waters. The method by which the nitrates were removed is unknown. Mechanical filtering of particles which nitrate might be adhered may explain removal of a few ppm nitrates.

Although inorganic fertilizers have previously been implicated as

important sources of nitrates in well waters (41), inorganic fertilizers were not correlated with the nitrate levels in the 88 observed wells. Sixty-nine percent of the wells were improperly located and only two were properly constructed. These two wells were also properly located, and the waters contained 6 and 23 ppm nitrate. On two other farmsteads with wells containing water high in nitrate, new wells constructed in proper locations yielded water with nitrate levels below the hazardous limit. Properly located and constructed wells can provide sources of low nitrate water.

The length of time that a properly located but improperly constructed drilled well will provide water low in nitrates is difficult to determine. Runoff containing inorganic and organic matter may enter at anytime through an improperly grouted annulus around the well casing. If the casing is below ground level, as was the case in 26 of the 59 drilled wells examined, contamination may enter directly into the casing. A proper casing seal and concrete grouting of the annular space may prevent such occurrences.

Many farmsteads were found with multiple surface water sources available for animal drinking purposes. The existence of these waters were dependent upon the annual rainfall. These sources of water supplemented the well waters and thus affected the expression of nitrate toxicosis.

The reported nitrate problems tended to be seasonal, except for those operations (primarily hogs) where the animals were continually housed in pens. Although winter months are when the greatest incidences of nitrate poisoning would be expected in confined individuals, such

animals are usually fed a high carbohydrate diet with adequate vitamin and mineral supplement. This type of ration may mask the signs of chronic nitrate toxicosis (3).

Difficulty exists in evaluating the nonsignificant coefficients of correlation (r) found in the study because of: the numerous variables in nitrate toxicosis; the presence of bias in reporting of health problems; and the lack of definitive diagnostic means for chronic nitrate poisoning. The low levels of inorganic fertilizer utilized by the farmsteads studied does not substantiate that inorganic fertilizers contribute significant amounts of nitrate in runoff and groundwater percolates (49). It is doubtful that inorganic fertilizers are significant sources of nitrates found in the well waters. The concentrated sources of organic animal waste (barnyards, septic tanks, old pigpens, privies) near many of the wells and the improper construction and location of the wells suggests that these sources may be the most likely cause of the high levels of nitrates found in the water. The nonsignificant (r) of -0.1196 found when correlating the levels of inorganic nitrates applied to the land and the levels of nitrates found in farmstead well waters emulates the nonsignificant (r) of -0.0295 found by Keller and Smith (1967) when they correlated nitrogen fertilizer use with the percent of wells containing undesirable waters for livestock (49). Therefore, the inorganic fertilizers appear to be insignificant sources of the nitrates found in the farmstead well waters studied. If inorganic fertilizers are not significant sources of nitrates to the well waters, the nonsignificant (r) for the correlation of inorganic fertilizer applied to the land and reported animal health should also be valid.

It was theorized that the reported impaired health and the levels of nitrates found in well waters would be significantly correlated, rather than producing the nonsignificant (r) of 0.317331. A study of this nature may be incapable of documenting the actual relationship between these two variables.

To correlate health impairment on the farmsteads with well water nitrates, research should be conducted directly on the farmstead. Only the intake of the nitrate-containing waters should be varied; direct evaluation could be performed, and bias would be eliminated.

Few incidences of health problems possibly due to nitrates were reported by farmstead personnel. This was contrary to what was expected since unusually high nitrate levels were found in several well waters used for drinking purposes. Cattle and hogs were the most frequent species reported with health problems, although hogs are thought to be the species most susceptible to preformed nitrites (50). These nitrites may be formed in water in watering troughs (51). Many factors influence the occurrence of nitrate poisoning in animals (4, 6, 14, 15, 51) and animals vary in susceptibility to nitrate poisoning (7, 52, 53, 54, 55). In ruminants, cattle are reported the most susceptible species (53, 56). In general, monogastric animals are the least susceptible (7, 53).

Clinical signs in dogs were contrary to those reported in the literature (7, 12). Perhaps the environmental factors of the farm kennel as contrasted to the controlled housing of research facilities significantly affected the results. The relatively high incidence of nitrate poisoning in rabbits was also contradictory to the expected since rabbits are reported to have the highest concentrations of

methemoglobin-reducing enzymes (54).

The human incidences of nitrate poisoning reported in this study generally lack documentation. Acute infant methemoglobinemia due to nitrates in water is one exception. Infants are more susceptible than adults to methemoglobinemia from nitrate ingestion (15, 55). Research currently being conducted in Israel may provide evidence of the hazard from long-term low-level nitrate intake in humans (10). The toxic aspects of such nitrate intake in man and animals need further study.

Studies of the effect of chlorination on waters high in nitrates (57) probably stimulated the sale of chlorinating systems. Chlorination affects nitrate and nitrite concentrations in water by chemical and bacteriological means. Hypochlorite, the primary chemical agent employed in chlorinating systems, oxidizes nitrite to nitrate. It also destroys bacteria capable of reducing nitrate to nitrite. The use of chlorination to reduce nitrate and nitrite levels in farm waters is an unsound practice. Care should be employed in using chlorination for waters unusually high in nitrate since chloramines formed as a by-product may be of greater hazard than the original nitrates (58).

SUMMARY

Nitrate toxicity is a complex problem causing concern to the veterinarian and to the physician. The described study suggests that nitrate toxicity is a clinical reality in animals and man.

Farm wells with high levels of nitrate were observed. The source of nitrates appeared to be related to improper location and construction of wells. The low levels of applied inorganic nitrate fertilizer and statistical analysis suggested that fertilizer application was not related to nitrate levels in well waters.

Correlation of animal health problems with nitrate levels in well waters and with the use of inorganic fertilizers was nonsignificant. However, the many variables present in studying nitrate toxicity complicated the evaluation.

To adequately study the potential health effects of nitrates in drinking waters, the evaluation should be conducted on one farmstead where the nitrate source could be controlled and bias eliminated. Water samples should be repeatedly analyzed to adequately reflect fluctuating nitrate levels. The possible adverse health effects of chronic nitrate consumption in man and animals requires further research.

The prevention or removal of nitrates from water supplies are constant problems. Removal of nitrates by chlorination is not valid and other methods are economically unfeasible. Obtaining another low-nitrate water source may be impossible, since drilling a new well does not uniformly produce a satisfactory water supply. A properly located but

improperly constructed new well does not assure a continual supply of low-nitrate water.

The nitrate levels in many rural and domestic water supplies are sufficiently high to cause physiological impairment in animals drinking these waters. The occurrence of clinical signs may be masked by their complexity and subtleness. At present, the significance of nitrates in drinking water can only be measured by the incidence of acute nitrate poisoning.

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APPENDIXES

Appendix I. Review of Literature: Nitrates as an Environmental, Animal and Human Hazard.¹

The public's awareness of foreign chemicals polluting our environment during the previous decade has promoted the government's current high interest in the pollution problem. As a result, the applied fields of health (medicine, dentistry, veterinary medicine, nursing, public health, and others including social and psychological health) have been stimulated to increase their concern. We, as practicing scientists, must keep up-to-date in this area of applied health.

When considering our environment in regards to environmental pollution, we must consider three basic surroundings--air, water, and soil. Each of these constitutes a dynamic system incorporating sensitive and balanced ecological systems. In many instances, the biotic and abiotic entities of one biological system are interconnected, and the entities within the ecological systems of each biological system are cyclic and interrelated. The most studied relationship is that involved in the phases of the food chain cycle within an ecological system.

A disturbance in any one phase of the food chain results in an upset within this balanced system. Once stability is disrupted, the order of organisms within the system change and the system itself becomes less diversified. Even destruction of the system may occur. In nature this stability results as a function of time. All living things can alter the precise balance within these biological systems. However,

¹W. E. Ridder and F. W. Oehme. Comparative Toxicology Laboratory, Kansas State University, 1972. Presented by W. E. Ridder at the Symposium on Comparative Toxicology, Aspen, Colorado, 1972.

man is the only living creature that is capable of developing stability through technology.

Nitrogen is widespread in nature and is found in all three of the basic biological systems--air, water, and soil. Nitrate is an inorganic anion formed by oxidizing elemental nitrogen. The anion is a significant component of the nitrogen cycle of soil and water. It is found in the atmosphere (air) at a much smaller concentration (13) (23). Nitrate is an essential nutrient of plants and it is ultimately metabolized by plants to form plant protein. Whenever one of these biological systems is upset, nitrates may then accumulate in the soil, water, or plants. The accumulation of nitrates in our environment constitutes a potential public health hazard and environmental pollutant.

The levels of nitrates found in plants and surface waters have been steadily increasing (7) (37). In many rural areas of north-central United States excessive levels were reported in groundwaters (2) (44). In Kansas groundwater supplies, nitrates range from 0.0 ppm to over 1000 ppm. Results obtained by the Environmental Health Services of the Kansas State Department of Health, from groundwaters tested from January 1967 to 31 December, 1971 show that over 25% of the water samples exceed 50 ppm. Six percent of the groundwaters tested were in the toxic range. The Public Health Service Drinking Water Standards recommend 45 ppm nitrate as the limit in rural wells. The Kansas State Department of Health, Environmental Health Service 1965 publication concerning the Chemical Quality of Public Water Supplies in Kansas revealed 37 municipal water supplies that were above the 45 ppm nitrate tolerance limit. Three municipal water supplies exceeded the Kansas recommended tolerance limit

of 90 ppm nitrate. Surface waters, including ponds, lakes, streams, and reservoirs, carried nitrate levels ranging from 0.1 ppm to 69 ppm. Low nitrate levels in surface waters are expected since water biota rapidly utilize nitrates as a nutrient source and because of denitrification (24). However, if a small pond receives the runoff of a feedlot or a heavy fertilized cultivated field, it is apt to have a high nitrate content.

Nitrites are found infrequently in groundwaters. Only 1-4% of 5,000 samples tested in an extensive study in Missouri showed positive nitrites (26). The concentrations of nitrites varied between summer and winter. The infrequent finding of nitrites in groundwater results from the instability of the ion. Testing for nitrites in groundwater is infrequently performed (47).

Problems Associated with High Concentrations of Nitrates

Research studies of nitrate poisoning are inconsistent in their conclusions, but numerous clinical experiences have been reported. This may be caused by: (1) variations in research design; (2) biological variations in plants; (3) differences in nutrition, housing and care of experimental animals; (4) varying chemical and physical properties of the toxicant; (5) the route, method, and dosage of the toxicant; and (6) clinical inability to diagnose nitrate intoxication accurately (11).

Nitrate toxicity in animals results primarily from ingestion of nitrates in feed and water. Mayo, in Kansas in 1895, reported the first case of nitrate toxicity in animals (46). He diagnosed the disease as "cornstalk poisoning," since the cattle poisoned had ingested corn stalks.

Since then, many cases of poisoning from the ingestion of plants and water high in nitrates have been reported, and the etiological agent has been recognized.

Nitrate poisoning in humans was first documented by Comly (1945) in Iowa. In Minnesota, 139 cases of infant methemoglobinemia were reported from the ingestion of well waters high in nitrate (2). The mortality rate was 10%. In Kansas, 13 cases of infant methemoglobinemia with three deaths were reported during a period from the early 1940's to 1950 (44). Several other cases of acute nitrate poisoning no doubt have occurred; however, since it is not a reportable disease, they probably have gone unnoticed.

Early reported cases of nitrate poisoning in animals were related to acute toxicity. The clinical signs most generally seen were dyspnea, increased heart rate and respiration, excessive salivation, muscular tremors, incoordination, cyanotic mucous membranes, coma, and death. When blood samples were taken, the blood had a characteristic chocolate color, but this color was not pathognomonic. Chlorate herbicides have caused similar signs and chocolate-colored blood. In humans, primarily infants, the brownish-blue discoloration was first noticeable around the lips, spread to the fingers and toes and over the face, and eventually covered the entire body (44). Other signs included drowsiness, increased rate of respiration, and death.

The clinical signs of acute nitrate toxicity are attributed to anoxia and appear when methemoglobin levels reach 30 - 40%. Death occurs when methemoglobin levels reach 80 - 90%. The nitrate ion is reduced to nitrite, which then oxidizes the iron of the hemoglobin molecule from

the ferrous to the ferric form. The resultant methemoglobin (ferri-hemoglobin, ferriprotoporphyrin IX-globin) is incapable of reversibly binding molecular oxygen (2). The vasodilatory effect of nitrites on the cardiovascular system further induces tissue anoxia due to lowered circulatory volume.

Oxidation of oxyhemoglobin to methemoglobin by the nitrite ion occurs at a rate which is characteristically different for each animal species, and there is little difference between individuals of the same species (39). Similarly the reduction of methemoglobin is characteristically different for each animal species. These two physiological processes appear to be related, even though there is a large variation in the rate of formation of methemoglobin and its subsequent reduction. Thus, the imbalance of these two physiological processes may help explain the difference in species susceptibility and the variation in signs seen in nitrate poisoning.

Reports of chronic nitrate toxicity due to long-term, low-level nitrate intake in animals is recognized; however, documented reports are inconsistent. The controversial signs observed are: abortions; lowered milk production; reduced rate of gain; avitaminosis A, and a thyroid-interference syndrome. Several other signs, such as diarrhea, diuresis, arthritis in swine, and hydrocephalus in rabbits, have also been observed with sublethal levels of nitrates.

Ingestion of well waters high in nitrates is the primary cause of infant methemoglobinemia due to nitrate toxicity. However, Phillips (1971) cites several cases of infant methemoglobinemia due to the ingestion of vegetables high in nitrate. Vegetables may develop excessive

levels of nitrites due to various processing and storage techniques (33) (37). Although no cases of infant methemoglobinemia due to such foods have been reported in the United States, fatal cases have occurred in other countries (32). Orgeron (1957) reported a case of poisoning from the ingestion of wieners containing over 5000 ppm nitrite.

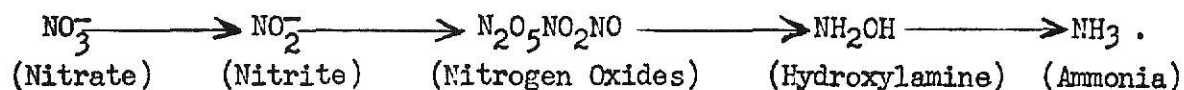
The use of nitrates and nitrites as curing ingredients in meat processing is being challenged by various consumer groups (42). Nitrosamines have been found in many processed meats (14) (40) (41). These substances, formed by the reaction between nitrites and secondary amines, are carcinogenic (27) (30). The present tolerance limits for processed meats are 500 ppm nitrate and 200 ppm nitrite (12).

"Silo Fillers' Disease," long recognized to be caused by silo gases, nitrogen oxides, is a result of ensiling plants high in nitrates. Cases of pulmonary adenomatosis have been observed in cattle ingesting feed and water high in nitrates (36). Research conducted with cattle using nitrogen dioxide caused severe methemoglobinemia and lung lesions (36).

Vasodilation, a pharmacological action of nitrites upon the cardiovascular system, is the cause of nitrite syncope and is known to occur in animals and man (37). Cases of this type have been observed experimentally and clinically in cattle and swine.

When ingested, nitrates are metabolized in the gastrointestinal tract by the microflora. Depending upon the organisms present, the pH, and the available nutrients (trace elements and carbohydrates), the

products that may be formed from nitrate reduction are:



Once formed, these products may be absorbed and can be toxic if allowed to accumulate. Experimentally, hydroxylamine can cause hemolytic anemia in cattle and sheep, in addition to being involved in methemoglobin formation (36) (44).

Eutrophication of lakes, ponds, and streams is an increasing problem (18). Nitrogen and phosphorus are thought to be the major limiting nutrients to water phytoplankton and plants. Excessive nitrate in these waters results in plant and animal life changes which usually interfere with the multiple uses of water, reduces its esthetic and economic values, and threatens the destruction of our water resources (8). Premature death of the body of water may be a serious consequence.

Physiological Effect in Animals

Ruminants. Ruminant animals, due to their physiology, are more susceptible to nitrate poisoning than monogastric animals (46) (39). Cattle are more susceptible to nitrate poisoning than sheep (38). The effect of nitrate in ruminants, as in all animals, is variable and depends upon several factors (9). The total nitrate intake, rather than just the content in water or feed, is the critical problem. Previous adaptation to nitrate feed, as well as feeding practices, will influence animal susceptibility. Nutritional status and proper rumen function is important. Hungry animals are less tolerant to nitrate since they will consume feed more rapidly.

The nutritional quality of the ration is very important. Rations high in vitamin A can reduce the toxic effects of nitrate. Furthermore, a good quality carbohydrate ration enables greater and more complete microbial action, resulting in reduced nitrate toxicity.

Nitrate toxicity occurs in ruminants in an acute and chronic form. The acute toxicity is the result of nitrates being reduced to nitrites, which then oxidize hemoglobin to methemoglobin, causing anoxia and death. Methemoglobin formation occurs most rapidly in ruminant animals (39). However, of all the ruminant animals, cattle have the slowest rate of methemoglobin reduction. This might explain why cattle are more susceptible to nitrate poisoning. Tillman et al. showed that nitrate reduction in the rumen was dependent upon pH and the Mo^{++} , Cu^{++} , and Fe^{++} concentration of the rumen content.

Acute nitrate toxicity may result from ingesting water containing 500 ppm nitrate or greater, or feed in excess of 5000 ppm (.5%) nitrate. Ingested nitrate is reduced by the rumen microflora to nitrite, which is 6-10 times more toxic than nitrate. However, high levels of nitrates alone may cause acute gastroenteritis, diarrhea, diuresis, and petechial hemorrhages on the pericardium.

Chronic nitrate toxicity may result with ingestion of sublethal levels of nitrate. The signs reported are primarily physiological interference effects. Some of these are vitamin A and E deficiencies, thyroid dysfunction, abortions, fetal resorptions, poor conceptions, decreased milk production, and decreased rate of gain. These physiological interference effects have been reported in other animal species. However, the occurrence of these effects in the ruminant are very

controversial, especially when considering the results of experimental research findings. Field cases of chronic toxicity may seem quite conclusive, but it is difficult to prove that all other variables capable of causing similar signs have been excluded.

Olson, et al. (1971) surveyed 25 different field cases involving livestock operations. Twenty percent of the surveyed operations revealed excessive nitrates present in feed and water sources. Herd health problems in 15% of the operations surveyed could be related to excessive nitrate intake.

Monogastric Animals. Monogastric animals are more tolerant to excessive levels of nitrate in their diet than are ruminants. Dogs have been fed up to 2% (20,000 ppm) nitrate in their diet without any adverse health effects (34) (31). Rats have been fed approximately 1% (10,000 ppm) nitrate for a life time without adverse effects (34). Healthy human adults are reported to be able to consume large quantities of nitrate in drinking water with relatively little, if any, effects (2) (32).

However, the physiological effects noted with ingestion of nitrates in food and water are variable. This may be explained by the metabolic and physiological differences existing between animals. Toxicity usually results when nitrate in the food is reduced to nitrite prior to ingestion. Under specific conditions, this reduction can occur in the stomach. Some tissues of all animals are able to reduce nitrate to nitrite.

In swine, larger doses of nitrites are required to produce the methemoglobin levels necessary for acute toxicity (10). The pig was found to have the slowest rates of methemoglobin formation and

methemoglobin reduction (39). A relative lack in response to treatment with methylene blue was also noted.

Swine are only susceptible to nitrite when the nitrite is pre-formed (1). This may occur when feed is mixed with water prior to feeding, and the bacteria in the ration reduce the nitrate to nitrite. Waters high in nitrate, left standing in metal troughs and automatic waterers, may also be sources of excessive nitrites (16). Reduction may occur by bacteria or by chemical reaction of the nitrate with the metal in the troughs. The toxic level of nitrites for pigs is listed as 88 mg/kg (1).

Some of the clinical signs of chronic nitrate toxicity in swine are vitamin A deficiency, thyroid dysfunction, decreased rate of gain, arthritic conditions, and abortions. Lymphocytic leukocytosis and erythrocytosis have also been reported (10). Perhaps some cases of iron deficient anemia are really a result of chronic nitrate toxicity.

Nitrate, when given orally to dogs was reduced to nitrite, but the amount reduced varied from practically none to a quantity sufficient to bring about methemoglobinemia (37). When given orally or intravenously, the nitrate ion caused over-excretion of chloride, resulting in hypochloremia, alkalosis, and digestive disturbances (15). Dehydration occurred due to the diuretic effect of nitrates (15). Hydrocephalus resulting from vitamin A deficiency has been noted in dogs with nitrate poisoning.

The physiological effects of nitrate toxicity in humans are largely unknown. Acute nitrate toxicity is most always seen in infants rather than adults, and results from ingestion of well waters and

vegetables high in nitrates. Increased susceptibility of infants to nitrate toxicity due to age, diet, and other factors has been speculated. Nitrate content and the amount of the food or water ingested daily, duration of exposure to food or formula, the presence of nitrate-reducing bacteria in the upper gastrointestinal tract, and the condition of the mucosa are all causative factors suggested by Walton (44).

Comly deduced that infants were prone to upset stomachs and achlorhydria. As a result, the stomach pH increased in alkalinity allowing nitrate-reducing organisms to enter and to reduce nitrates to nitrites. A gastric pH above 4 supports nitrate-reducing organisms (2) (8). Digestive disorders causing injury to the gastrointestinal mucosa and the resulting increased absorption was evident in several cases of infant methemoglobinemia reported in Minnesota (2).

Immature enzyme systems may also be of importance (6). Methemoglobin formation rate in human adults is close to the rate observed in cattle. However, in man, the rate of methemoglobin reduction occurred the fastest of all species studied (39). Approximately 1% of the adult hemoglobin is present as methemoglobin (21). This constant concentration exists as a result of the balance between the oxidation of hemoglobin and the reduction of methemoglobin. Fetal hemoglobin (hemoglobin F) is oxidized by nitrite to methemoglobin at a rate twice as rapid as adult hemoglobin (hemoglobin A). Furthermore, the enzymatic capacity of the erythrocytes of newborn infants to reduce methemoglobin to hemoglobin appears less than that of adults (21). The difference is probably due to a developmental deficiency in the activity of DPNH-methemoglobin reductase (diphosphopyridine nucleotide) (21). As opposed to adults,

several clinical, physiological, and metabolic factors predispose infants to development of methemoglobinemia and acute nitrate poisoning.

Sources of Nitrates

The sources of nitrates leading to contamination of ground and surface waters are thought to be numerous. Some of these are: atmospheric nitrogen (13); soils, and other geological sources, such as limestone rock, calcite, caves, and playa deposits (13) (23); concentrated organic animal wastes from pigpens, privies, cesspools, feedlots, and primary treated sewage; decayed plant matter and silo juices; inorganic fertilizers; and industrial wastes.

Much controversy exists in regard to the sources of nitrate pollution of our waters. Commoner (1968) feels that improper and excessive use of chemical fertilizers is the largest source. Kenney (1970) found that fertilizers are important contributors, but are apparently less involved than Commoner believes. Increased use of fertilizers has no doubt led to the increased levels of nitrates in some of our lakes, rivers, and streams.

Extensive research in Missouri revealed that excessive nitrates in groundwaters frequently resulted from organic animal wastes (25). In Minnesota, 83 of the 129 wells containing water high in nitrate were improperly located with respect to barnyards, pigpens, privies, cesspools, and other sources of animal organic wastes (2). Twelve of 22 states reporting to the Engineering Section of the Committee on Water Supply, American Public Health Association, reported similar findings (44).

Wide variations also exist in Kansas. Metzler (1958) reported that nitrogenous materials of animal origin, especially sewage and manure, may be the principle sources of nitrates. The Rush County Extension Service, Rush County Kansas (1971) reported that of 750 wells surveyed, barnyard runoff, septic tanks, cesspools, privies, sewer outlets, and silage seepage were the prominent sources of nitrates.

The accumulation of nitrates in forages, feeds, and vegetables is significantly correlated with the amount of chemical fertilizers applied to the land (23) (24) (25) (33). There is also a significant relationship between the amount of fertilizer used and the leaching and/or runoff of nitrates (23) (24). Crop yield and the application ratio of chemical fertilizers are directly related until a critical level of application is reached; beyond that, they are indirectly correlated. In areas of excessive nitrate application, plants tend to hold nitrates without metabolizing them and the crop yield decreases (23). Although the use of fertilizers by farmers may not always meet prescribed application procedures, the study completed indicates that judicious administration of fertilizers is being accomplished. The statistical relationship of fertilizer usage and the nitrate concentrations found in well waters on 47 farmsteads showed that no correlation existed between these two principal elements of the nitrate problem.

Detection of Nitrates

The analysis for nitrates in water and feedstuffs are usually conducted by colorimetric measurements or by use of an ion-specific electrode.

The phenol disulfonic acid method and the brucine method are the two colorimetric procedures more frequently used in water nitrate analysis (28). In the former test, color reaction develops proportionate to the amount of nitrate present and is read spectrometrically. In the latter, since the color intensity changes with time, it is necessary to develop the color of standards and samples simultaneously and compare them at maximum intensity (28). Both tests are quantitative and interference by nitrites and chlorides may occur.

Several other tests have been reported for testing nitrates in natural waters and waste waters (28). Nitrate analysis by reduction, either to ammonia which is then detected by Nesslerization or to nitrites which are then detected by Griess-Ilsovoy method, has been used. Ultra-violet and infrared techniques have been reported for use in testing waters for nitrate. Polarographic analysis of nitrate offers the advantage of being adaptable to continuous monitoring.

The ion-specific electrode is a quick and reliable test (28). The electrode responds to anions other than nitrate, but it does not respond to cations. It is more selective for chlorate, periodide, and chloride ions than for nitrate. Thus, interference may be expected. To test samples, the electrode is calibrated with standardized nitrate solutions and a standard curve is prepared. The sample is then tested, and the results are obtained by extrapolation from the calibration curve. The ion-specific electrode can be used for testing nitrates in both water and feedstuffs.

Nitrites may be analyzed in waters, serum, plasma, blood, and feedstuffs by diazotization, using either sulfonilic acid and alpha-

naphthylamine hydrochloride to produce a reddish-purple color or sulfanilamide and 1-naphthylethylene-diamine dihydrochloride forming a red color. These color reactions may be evaluated visually or with a spectrophotometer.

Several screening tests (spot plate tests) for nitrate or nitrite are also available. These tests are qualitative and reveal the amounts of the ions present through the intensity of color developed. The diphenylamine test has been recognized as very useful. An adaptation has been made to test for nitrates in body fluids (19). The disulfanilic acid test, another spotplate test, is probably used most widely for testing feedstuffs and water.

Treatment of Toxicity

The treatment of acute nitrate toxicity in all animals, including man, is by the administration of methylene blue as a 1% solution. The exact mechanism of action of the dye is not known. It is postulated that methylene blue opens a new methemoglobin reducing pathway requiring TPNH (triphosphopyridine nucleotide methemoglobin reductase) and coenzyme factor II (21). However, the injection of too much methylene blue may compound the problem by causing further methemoglobin formation (44). Recovery of acute cases, when diagnosed early and treated with methylene blue, occurs within one-half hour after treatment. Prompt removal of the causative water has resulted in spontaneous recovery in infants (44) (2).

Treatment of chronic nitrate toxicity, resulting in signs of physiological interference, primarily employs replacement therapy.

Vitamins A, D, and E in the ration and added iodized salt and trace minerals are recommended. Vitamin A supplement alone has reversed the signs of chronic nitrate toxicity in cattle and swine (4).

A good quality ration high in carbohydrates also assists in treating chronic nitrate poisoning. Removal of the dietary source of nitrates is necessary for complete success.

Current Status

It is known that nitrates can and do accumulate in our foods and water. This occurs largely as a result of man's own actions. Ingestion of these nutrients by animals, including man, can be hazardous to health in many ways. The accumulation of nitrates in surface waters may also lead to destruction of these waters. Many government regulations regarding sewage treatment, pollution control, and use of nitrates in foods are currently in effect. Regulations are also pending to enforce pollution taxes on large industries and feedlots. Intense concern is being directed at restricting the use of nitrates in processed foods.

Although much is known about nitrates in our environment, more is still required. What are the biochemical lesions occurring from the chronic consumption of nitrates? Once nitrates are ingested, the effect and excretion of various metabolites needs further research. These compounds may be precursors of common diseases, such as anemia, neoplasia, collagen disease, miscarriages, and other idiopathic disorders.

Specific research is needed to determine other undetected nitrate sources. Soil borne sources are now being studied. Since nitrates are eliminated in the milk of cattle and women, some workers suggest that

sufficient concentrations may occur in milk to cause acute infant toxicity. Ammonia from feedlots may be absorbed by nearby lakes and lead to pollution and eutrophication (20).

Information is needed about the levels of nitrates that constitute hazards to the human body. It is known that infants under three months of age and pregnant mothers are most susceptible to nitrate toxicity. But what about persons with chronic digestive or respiratory problems? Nitrate poisoning has developed from excessive nitrates in water used in dialysis machines and from silver nitrate applied to burn patients.

The occurrence of nitrosamines in processed meats and their role in producing cancer in rats has stimulated additional research. The United States Department of Agriculture and the Food and Drug Administration are under increased pressure to reevaluate their recommendations concerning the use of nitrates and nitrites in foods.

The removal of nitrates from water is currently economically unfeasible. New methods of water purification need investigation, since the concentrations of nitrates appear to be steadily increasing in our water supplies.

Practical solutions to the environmental nitrate problems, which can be initiated on farmsteads reporting high nitrate levels in well water, are greatly needed. At the present, the most practical solution--obtaining another water source--is most difficult to accomplish. When costs and attitudes are favorable for seeking another source of water, water cannot be found.

Only after these basic problems are solved can further energies be directed through public education and rational governmental policies

at controlling the nitrate contamination of our food and water. However, a conformable understanding between the environmental and agricultural agencies is necessary if rational policies are to result.

SUMMARY

Man's environment encompasses several biological systems composed of various ecosystems. These ecosystems are stable or are balanced with naturally occurring cyclic patterns of movement by biotic and abiotic entities. The nitrogen cycle is one whereby nitrates can become an environmental pollution problem if allowed to accumulate in our waters and food. The physiological effects of acute and chronic nitrate toxicity on ruminant and monogastric animals is both simple and complex, and its sources, detection in foods, and the treatment of poisoned animals present continuing confusion. Much is still to be learned about nitrates in our environment. Through knowledge and technology, man can establish stability and solve the problems of nitrates in his environment.

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Appendix II. Individual Results of Surveying Wells on Selected Kansas Farmsteads

Farmstead Wells	Description of Well			Content of Well Water			
	Location	Type	Depth (ft)	Casing Construction	NO ₂ (ppm)	NO ₃ (ppm)	Bacterial Status ¹
Ellenbecher (#1)	Within 50' of septic tank, old trees nearby, 20' from septic tank lateral	16' Dug 20' Drilled	36	Nonapplicable	0	100-300	Unsafe
(#2)	Uphill from #1 and septic tank, 50' from old pigpen and privy	Drilled	60	Below ground surface	1	10-90	Safe
Neiberding (#1)	Used in house, 50-75' from septic tank	Drilled	60	Below ground surface	0	80	Safe
(#2)	Lower corner of barnyard, catches runoff	Drilled	40	Above ground surface	Not Tested	300	Unknown
(#3)	Middle of old barnyard by trees	Dug	30-40	Nonapplicable	Not Tested	700	Unknown
(#4)	New, uphill from buildings, used for cows	Drilled	90	Above ground surface	1	27	Safe

Appendix II. (continued)

Neiberding (#5)	New, 500' out in pasture, built grade A milk specifications	Drilled	90	Above ground surface	0	6	Safe
Dettke* (#1)	Within 50' of old chicken house	Drilled	128	Above ground surface	Not Tested	140	Unsafe
Chermak (#1)	Within 50' of chicken house	Drilled	190	Above ground surface	Not Tested	115	Unsafe
Hammerbecher (#1)	Downhill at corner of barnyard now plowed	Dug	35	Nonapplicable	Not Tested	950	Unknown
Stevens (#1)	100' from barnyard, trees close by, silo 100' away	Dug	40	Nonapplicable	Not Tested	300	Unsafe
Koss (#1)	50' from old chicken house, downhill from septic tank	Drilled	40	Above ground surface	1	375	Unknown
Finlayson (#1)	Middle of garden, old privy 100' away	Drilled	100	Below ground surface	Not Tested	400	Safe
Ohlde (#1)	Middle of barnyard and old pigpen, 6' from abandoned well high in nitrate and bacteria	Drilled	100	Below ground surface	Not Tested	520	Safe

* House sewage drains to surface and collects in low area behind barn where barnyard and feedlot also drain to common area. This area is approximately 100' below surface of hill. Perhaps this area drains into the 128' deep well.

Appendix II. (continued)

Ohlde (#2)	Abandoned well	Drilled	100	Below ground surface	Not Tested	554	Unsafe
Randall (#1)	50' downhill of barnyard	Dug	35	Nonapplicable	Not Tested	175	Unknown
Day (#1)	75' from barnyard, adjacent to old cistern	Drilled	30	Below ground surface	Not Tested	240	Safe
Meyerhoff (#1)	Middle of barnyard	Dug and Drilled	100	Nonapplicable	Not Tested	820	Unknown
(#2)	500-1000' out in pasture	Drilled	100	Below ground surface	Not Tested	100	Unknown
Kruger (#1)	Corner of barnyard	Dug	40	Nonapplicable	Not Tested	270	Unknown
(#2)	Middle of barnyard	Dug	35	Nonapplicable	Not Tested	780	Unknown
(#3*	Across road in cultivated field, for house use	Drilled	38	Above ground surface	Not Tested	45	Safe
Schaff (#1)	25-50' from pigpens, 10' from abandoned well and cistern, Purchased chlorinator	Drilled	120	Above ground surface	Not Tested	180	Unknown
Bekemeyer (#1)	50-75' from house, tree roots in well	Drilled	90	Below ground surface	Not Tested	50	Unknown

Appendix II. (continued)

Morey, Jr. (#1)	Middle of old pigpen, sewage from septic tank flows to well. No longer used.	Dug and Drilled	10 30-40	Nonapplicable	Not Tested	170	Unsafe
(#2)	New well in hayfield.	Drilled	60	Above Ground surface	Not Tested	42	Safe
Rhine (#1)	Downhill at corner of barnyard, creek 100' beyond. No longer used.	Drilled	40-60	Above ground surface	Not Tested	1100	Unknown
Vatthauer (#1)	Downhill from pigpens, 20' from pens, washoff from pens runs to well. No longer used.	Drilled	60	Above ground surface	0	380	Unknown
(#2)	Beside house, downhill from pigpens, 75-100' from septic tank	Drilled	60	Below ground surface	0	270	Unknown
(#3)	New well, drilled within 6' of #1	Drilled	100	Above ground surface	Not Tested	320	Unknown
Vogts (#1)	30' from cesspool that does not have bottom.	Drilled	60	Above ground surface	Not Tested	175	Unsafe
(#2)	60-70' from cesspool, Purchased chlorinator.	Drilled	95	Above ground surface	Not Tested	68	Unsafe
Goering (#1)	Beside barnyard, No longer used.	Drilled	Unknown	Above ground surface	Not Tested	890	Unsafe

Appendix II. (continued)

Johnson (#1)	In yard between trees, another well capped off 10' away.	Drilled	37	Above ground surface	Not Tested	180	Safe
Bullinger (#1)	Behind house in middle of old pig and chicken pens.	Drilled	28	Above ground surface	Not Tested	1175	Unsafe
(#2)	Adjacent to barnyard, No longer used.	Drilled	40	Unknown	Not Tested	750	Unsafe
Lindberg (#1)	Adjacent to feedlot, within 50' of silo.	Dug	40	Nonapplicable	Not Tested	330	Unknown
(#2)	Adjacent to feedlot, 50' from silo, 28" drilled hole with 8" casing and gravel and dirt packed.	Drilled	60	Above ground surface	Not Tested	780	Unsafe
Krehbiel (#1)	Middle of barnyard.	Drilled	48	Above ground surface	Not Tested	1100	Unsafe
(#2)	Behind shed in orchard.	Drilled	40	Below ground surface	Not Tested	130	Unsafe
Gibson (#1)	Corner of barnyard next to silo.	Drilled	50	Below ground surface	Not Tested	450	Unsafe
Buster (#1)	In small lot 50-75' from barnyard, Used to be old pigpen.	Drilled	35	Above ground surface	Not Tested	590	Unsafe

Appendix II. (continued)

		Dug	36	Nonapplicable	Not Tested	600	Unsafe
Ostlind (#1)	Edge of feedlot.	Dug	36	Nonapplicable	Not Tested	600	Unsafe
(#2)	20" from feedlot, 100-150' from #1, middle of barnyard.	Drilled	62	Above ground surface	Not Tested	370	Unsafe
Nelson (#1)	Edge of feedlot adjacent to orchard, 75-100' from old dug well no longer in use; Old pigpen used to be where orchard is now.	Drilled	60	Above ground surface	0	590	Unsafe
Huxman (#1)	Between pigpen and barnyard, below barnyard toward creek.	Drilled	40	Below ground surface	Not Tested	100	Unknown
Kaufman (#1)	Edge of garden.	Drilled	28	Below ground surface	Not Tested	315	Unknown
(#2)	Basement of house.	Drilled	40	Below ground surface	Not Tested	240	Unknown
(#3)	Corner of barnyard; Now under roof of shed.	Dug	40	Nonapplicable	Not Tested	600	Unknown
(#4)	In corner of chicken house; New well.	Drilled	75	Above ground surface	Not Tested	40	Unknown
Ediger (#1)	Basement of house 50' from septic tank.	Dug	30	Nonapplicable	Not Tested	240	Unsafe
(#2)	20' from pigpen.	Drilled	Unknown	Above ground surface	Not Tested	130	Unknown

Appendix II. (continued)

Ediger (#3)	Edge of barnyard.	Dug	20	Nonapplicable	Not Tested	270	Unknown
Toews, Sr. (#1)	Middle of barnyard, barn roof now built over it.	Dug	20	Nonapplicable	Not Tested	1050	Unknown
(#2)	Yard, 30' from house and garage	Drilled	75	Below ground surface	Not Tested	335	Unknown
Toews, Jr. (#1)	Peside barnyard.	Dug and Drilled	Unknown	Nonapplicable	Not Tested	Unknown	Unknown
Pentson (#1)	Next to barnyard.	Drilled	30	Below ground surface	Not Tested	330	Safe
Malm (#1)	Old barnyard adjacent to well, old well 10' away (dug); septic tank 60' from well.	Drilled	35	Below ground surface	Not Tested	260	Safe
Train (#1)	Stock well, edge of barnyard.	Dug	30-40	Nonapplicable	Not Tested	60	Unsafe
(#2)	At corner of house, 15' from old well which developed problems, 15' from old filled-in cistern.	Drilled	Unknown	Below ground surface	Not Tested	330	Unsafe
Sjoholm (#1)	20-30' from house, 70' from barnyard, roots removed from casing this year.	Dug	35	Nonapplicable	Not Tested	1200	Unknown

Appendix II. (continued)

Erb (#1)*	Downgrade from pigpens 100-150', also 25-50' from cesspool, 50-75' from old privy.	Drilled	30	Below ground surface	Not Tested	360	Unknown
(#2)*	100-150' from house.	Drilled	40	Below ground surface	Not Tested	360	Unknown
Kristine (#1)	Beside barnyard.	Drilled	40	Above ground surface	Not Tested	100	Unknown
Jacobs (#1)	100' downhill from old privy.	Drilled	30	Above ground surface	Not Tested	155	Unknown
Kober (#1)	In a draw catching runoff of feedlot, downhill of two old abandoned wells.	Dug	11	Nonapplicable	Not Tested	240	Unknown
(#2)	Edge of pasture, 50-75' from old pigpen, downhill 200-300' of barn.	Dug	13	Nonapplicable	Not Tested	165	Unknown
Williams (#1)	In field in a draw, septic tank drains to surface and runs to well; barnyard runoff drains to well.	Dug	16	Nonapplicable	Not Tested	420	Unknown

* Wells #1 and #2 joined together.

Appendix II. (continued)

Baldwin (#1)*	Edge of yard, 70' from old privy, 150-175' from septic tank, tree roots a problem in well.	Drilled	30	Below ground surface	Not Tested	640	Unknown
(#2)*	Basement of house.	Drilled	30	Below ground surface	Not Tested	640	Unknown
Saunders (#1)	Low area between barn, feedlot and silo, all 3 within 50' of well.	Dug	30	Below ground surface	1	760	Unknown
Conner (#1)	Old feedlot.	Drilled	30-40	Below ground surface	0	740	Unknown
Schoendaller (#1)	50' downhill of barn and barnyard, in low area.	Dug	30	Nonapplicable	0	430	Unknown
(#2)	Near house, 50-75' from old privy, 75-100' from old pigpen.	Drilled (12" with 10" casing)	28	Above ground surface	0	200	Unknown
Rogers (#1)	Edge of barnyard.	Dug	30	Nonapplicable	Not Tested	330	Unknown
Boertz D. (#1)	20' from barnyard.	Dug	35	Nonapplicable	0	240	Unknown
Boertz C. (#1)	In garden that was previously an old alfalfa field.	Drilled	25	Above ground surface	0	280	Unknown

* Wells #1 and #2 joined together.

Appendix II. (continued)

Boertz C. (#2)	Edge of barnyard and garden.	Drilled	25	Below ground surface	0	380	Unknown
(#3)	In yard 100' from septic tank, dug well, then put in casing and filled in. Many roots in water.	Dug	28	Nonapplicable	0	255	Unknown
Graver (#1)	In pasture field, 30-50' uphill from stream that holds stagnant water and catches all runoff from barnyard.	Drilled	20	Above ground surface	0	230	Unknown
Herman (#1)	50' from cesspool.	Dug	23	Nonapplicable	Not Tested	580	Unsafe
House (#1)	75' from old privy, 2 abandoned wells 10' away.	Drilled	40	Above ground surface	Not Tested	540	Unknown
(#2)	Edge of barnyard and between shelter houses.	Drilled	40	Above ground surface	Not Tested	580	Unknown
Perkins (#1)	Downhill of septic tank and old house site and old well.	Drilled	210	Below ground surface	0	140	Unknown
(#2)	In pasture field, pigpen 50' up hill.	Dug	15	Nonapplicable	0	105	Unknown

Appendix II. (concluded)

Morey, Sr. (#1)	30' from house, old cistern 50' away, 75' from septic tank, Trees nearby, No longer used.	Dug	40	Nonapplicable	Not Tested	600	Unknown
Crottinger (#1)	50' from barnyard.	Drilled	400	Above ground surface	Not Tested	78	Unknown
Elack (#1)	Middle of barnyard.	Drilled	66	Below ground surface	Not Tested	500	Unknown

¹The bacteriological testing of wells was reported as "Safe," no coliform organisms found or "Unsafe," coliform organisms found.

Appendix III. Reported Health Problems, Fertilizer Application, and Feeding Program on Surveyed Farmsteads

Farmstead	Reported Health Problems	Fertilizer Application (lbs N/acre)	Feeding Program
Ellenbecher	Rabbit abortions, weak and dead calves, pink eye in cattle	100-120	Grain and hay to cattle, commercial pellets to rabbits
Neiberding	Stopped hog farming 12 years ago, infertility and poor growth in hogs. Cattle had birth of weak and dead calves, rough hair coat, poor rate of gain, excessive pink eye. Wife has had 2 miscarriages.	80-100	Vitamin supplement, minerals, iodized salt, concentrate
Dettke	Frequent abortions in cattle delayed time to get to market weight, decreased weight gain in feeder pigs. Carried water for home use.	80-120	Vitamins, iodized salt, grain in winter
Chermak	Sheep have diarrhea problem. Carried water for home use.	80-90	Grain, vitamins, iodized salt.
Hammerbecher	Discontinued raising hogs in 1964 because of infertility in sows, birth of weak and dead pigs. Carried water for home use.	Not Reported	Commercial ration
Stevens	Constant diarrhea in feeder pigs, pink eye in cattle. Carried water for home use.	80-100	Vitamins, iodized salt, concentrate, silage
Koss	Pink eye in cattle, decreased weight gain in pigs, constant scours in pigs. Carried water for home use.	90-100	Milo concentrate, iodized salt

Appendix III. (continued)

Finlayson	Dog abortions, birth of weak and dead pups, discontinued raising dogs, veterinarian unable to determine problem.	None	Commercial ration
Ohlde	Abortions in dogs and rabbits, birth of weak and dead pups, loss of 11 out of 13 bucket fed calves, poor growth in hogs.	100-150	Commercial ration for all animals
Randall	No reported problems.	None	Iodized salt for cattle
Day	Wife has continuous kidney problems of an unknown cause, wife constantly fatigued. No problems in swine	None	Vitamins, minerals, iodized salt
Meyerhoff	No reported problems.	100-150	Concentrate, vitamins, iodized salt
Kruger	No reported problems.	50-100	Concentrate, vitamins, iodized salt
Schaff	Scours in hogs, no reported problems in cattle, have another source of water.	120-150	Concentrate, vitamins, iodized salt
Bekemeyer	No reported problems.	150-180	Vitamins, iodized salt
Morey, Jr.	Calf scours, infertility in heifers, loss of 2 dogs, poor conception in 1 bitch, veterinarian unable to determine problem; no problems in calves since new well.	120-130	Concentrate, vitamins, and iodized salt for cattle
Morey, Sr.	No reported problems. Carried water for home use.	120-130	Not reported
Rhine	Three animals acutely poisoned, 2 died, 1 treated with methylene blue and lived.	None used nearby	Vitamins used after poisoning

Appendix III. (continued)

Vatthauer	No reported problems, pig scours ceased when treated with tylosin.	100-140	Commerical ration, vitamins, minerals, antibiotics
Vogts	Infertility in sows, birth of weak and dead pigs, pig scours from use with this well. Use of second drilled well solved problem.	90-100	Vitamins after problem occurred
Goering	No reported problems, No longer use well.	Not Reported	Not reported
Johnson	No reported problems in dairy herd.	100-120	Commercial ration
Bullinger	Infant son acutely poisoned, Survived with methylene blue treatment, no longer use well for drinking purposes. Decrease weight gain in sheep.	100-110	Vitamins and iodized salt after problem occurred in sheep
Lindberg	Reduce rate of gain in cattle. Water not used in house.	60-120 (only used 10 years)	Vitamins and iodized salt
Krehbiel	Scours in pigs, splayleg syndrome.	50-100	Commercial ration, vitamins and minerals, antibiotics
Gibson	Excessive watering of eyes in feeder cattle, no longer use well.	50-100	Concentrate, vitamins
Buster	Discontinued hog operation due to infertility and birth of dead and weak pigs. Poor rate of gain in sheep.	Not Reported	Not reported
Ostlind	No reported problems. Water for house use obtained from another well.	50-70	Iodized salt, grain in winter
Nelson	No reported problems. Carry water for house use.	Not Reported	Not reported

Appendix III. (continued)

Huxman	No reported problems. Use another well for house use, safe in nitrates.	50-100	Concentrate, vitamins
Kaufman	No reported problems in chickens and sheep.	50	Commercial ration
Ediger	No reported problems in sheep, have creek and pond water. Carried water for house use.	50-100	Iodized salt
Toews, Sr.	Infertility in sows, birth of weak and dead pigs.	50-100	Commercial ration, vitamins, iodized salt, antibiotics
Toews, Jr.	Infertility in sows, birth of weak and dead pigs, well reported to be high in nitrates.	Not Reported	Not reported
Bentson	No reported problems.	50-75	Hay
Malm	No reported problems. Creek water available.	80-90	Commercial ration, iodized salt
Train	No reported problems, No livestock raised now.	210-275	Not reported
Sjoholm	No reported problems.	50-100 (only used 7 years)	Not reported
Erb	Scours in pigs, splayleg syndrome, many deaths.	40-60	Commercial ration, vitamins, iodized salt, antibiotics
Kristine	No reported problems, cattle have other sources of water.	None	Hay in winter
Jacobs	No reported problems in livestock, wife has high blood pressure	None	Hay in winter

Appendix III. (continued)

Kober	No reported problems, many other sources of water for livestock.	None nearby, 40 when applied	Grain and hay in winter
Williams	No reported problems, pond water available.	40 or less	Not reported
Baldwin	No reported problems in cattle, husband has persistent lung condition of unknown cause.	40	Iodized salt
Saunders	No reported problems, no livestock now.	40-60 (Used only in last 5 years)	Not reported
Conner	No reported problems.	Not Reported	Hay for cattle
Schoendaller	No reported problems for one well. Sister, high blood pressure and ulcers	40-60 (Used only in last 2 years)	Mineral mix for pigs
Rogers	No reported problems.	Not Reported	Not reported
Boertz, D.	No reported problems, occasional creek water used.	40-60	Grain in winter, iodized salt
Boertz, C.	No reported problems, other sources of water for cattle.	40-60 (First used in 1972)	Not reported
Graver	No reported problems, other sources of water for cattle and sheep, (stream water 37 ppm nitrate, negative nitrite)	40	Commercial ration
Herman	No reported problems in livestock, pond and creek water available, wife - rheumatoid arthritis thought due to use of water	None	Iodized salt

Appendix III. (concluded)

House	No reported problems, other source of water for cattle.	None	Grain in winter, mineral salt block
Perkins	No reported problems.	Not Reported	Not reported
Grotinger	Infertility in hogs, poor growth and weight gain in feeder pigs, hypothyroidism in husband and husband's father	40-60 (Used only in last 2 years)	Commercial ration, cattle - grain in winter and iodized salt
Black	No reported problems in dairy herd.	100-150	Commercial ration

RELATIONSHIP OF NITRATES IN KANSAS GROUNDWATERS
TO ANIMAL AND HUMAN HEALTH

by

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ABSTRACT

A study was conducted to determine the health effects of animals and humans ingesting groundwater containing high levels of nitrates. The study involved collecting previous test results of the groundwaters in the state of Kansas and surveying wells on selected Kansas farmsteads.

Previous test results of Kansas groundwaters were collected to determine if nitrate levels were significantly high and to determine which geographical areas of the state should be studied as a result of high nitrate levels.

Eighty-eight wells on 58 selected Kansas farmsteads were surveyed in 3 different geographical areas of the state. The survey revealed levels of 6 to 1,200 ppm nitrates in groundwaters of the selected wells. Sixty-three of the 88 wells contained water with concentrations of nitrates exceeding 175 ppm. Impaired animal and human health was reported from 21 farmsteads and involved 30 wells.

Point values were assigned to the clinical signs of health impairment in man and animals ingesting groundwaters containing nitrates. The assigned values were then used to statistically study the linear correlation between these values and the level of nitrates found in the respective well water. If more than one well existed on the farmstead, an average of the water nitrate levels was utilized. No statistical relationship was observed between the compared data.

Water nitrate levels observed in the 88 wells were also correlated with the average pounds of nitrogen fertilizer applied to the land of the farmsteads. No statistical relationship was found between the compared

data. Applied inorganic nitrogen fertilizer used on these farmsteads had little relationship to the levels of nitrates found in the wells and to the reported health effects of the animals and humans. The improper construction and location of the wells was thought to be the fundamental cause of the high levels of nitrates found in waters of the selected wells.

It was concluded that many variables contribute to the occurrence of nitrate toxicity. A study which involves the collecting of previous water test results and the surveying of numerous selected wells may not adequately contend with these variables. The existing variables and sources of error can only be excluded by identifying the factual relationship between the ingestion of nitrates in well waters and adverse health effects. Such a relationship may only be found if a study was conducted at one farmstead where the variables and sources of error could be controlled and minimized.