Physical and Chemical Properties of Outdoor Beef Cattle Feedlot Runoff

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SUMMARY

1. Total, fixed, and volatile solids transported in rainfall runoff averaged 1.52, 0.84, and 0.68 (% w.b.), respectively.

2. Solids transported in rainfall runoff were 28% filtrable solids, 41% within the range of 14-44 microns, and 31% between 44 and 2000 microns.

3. The volatile solids portion decreased with a decrease in particle size while the particle density increased with a decrease in particle size. Seventy-two percent of the total solids transported passed the 44-micron sieve and 48% of the solids removed from a debris basin passed the 53-micron sieve. The average particle density of the total solids transported was 1.95 and 2.56 gm/cc for fixed solids (ash).

4. The unit weight of runoff was 63.02 lb per cu ft (1.01 gm/cc).

5. Settleable solids transported in runoff and discharged from the debris basin to the holding pond averaged 217 and 63 cu ft per acre-inch (60, 760 and 17,640 ppm) respectively. The bulk density of the settleable solids in runoff and discharged from the debris basin to the holding pond averaged 10.72 and 8.03 lb per cu ft (0.17 and 0.13 gm/cc) respectively. Seventy-one percent (by weight) of the settleable solids settled within the first 15 minutes under static conditions. Thirty-seven percent of the runoff samples tested were categorized as rapid settling, 45% moderate settling, and 18% slow settling.

6. The COD in runoff ranged from 14,100 to 77,100 mg/l in snowmelt runoff and 1300 to 8200 mg/l for rainfall runoff.

7. Total N and P concentration in rainfall runoff averaged 916 and 361 ppm, respectively. Average values were 2105 and 292 ppm for snowmelt runoff.

8. The runoff data indicate that the variability is too great to determine the effect of feedlot slope on runoff quantity and quality.

9. Solids transport and settling characteristics data may be valuable in calculating detention times and storage capacities for solids settling facility design. Results can also be used to calculate solids accumulations in holding ponds to estimate maintenance requirements.

10. Feedlot runoff, because it has pollutional characteristics, should be restricted from freely flowing into streams.

Physical and Chemical Properties of Outdoor Beef Cattle Feedlot Runoff

C. B. Gilbertson, J. R. Ellis, J. A. Nienaber, T. M. McCalla and T. J. Klopfenstein[1]

INTRODUCTION

Within the past decade, emphasis has been placed on the quality of our environment. Beef cattle feedlots have been singled out as a significant source of environmental pollution (3, 4, 5, 12, 16).

Environmental protection provided by control facilities requires basic knowledge of the physical and chemical properties of feedlot runoff. Hart (9) in 1964 and Kumar (11) in 1970 characterized animal manures for design of materials handling equipment. Recently, physical properties of feedlot runoff were reported by Gilbertson (7, 8). In 1971, pollution potential of feedlot runoff was summarized by EPA (3). Gilbertson (4, 6) and Swanson (16) reported the characteristics of solids transported in feedlot runoff. In 1972, McCalla (12) reported on chemical studies of solids, runoff, soil profile and groundwater from beef cattle feedlots.

This bulletin summarizes studies of physical and chemical properties of beef cattle feedlot runoff completed from August, 1968 through December, 1972.

PROCEDURE

Runoff Control Systems

In August 1968, systems to study feedlot runoff and its control were constructed at the University of Nebraska Field Laboratory, near Mead, Nebraska on a Sharpsburg silty clay loam, a soil formed in Peoria Loess that overlies the Todd Valley sand formation.

A continuous-flow system consisting of a gravity drained settling channel with a liquid detention pond, and a batch system consisting of a deep settling basin with a detention pond were installed (5).

The quantity of runoff was measured volumetrically using a water level recorder in the detention pond of the continuous-flow system and in the primary and secondary basins of the batch system.

Other facilities included pairs of feedlots with 3%, 6%, and 9% slopes with a 20 ft wide (6.1m) buffer strip between each pair. Each

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lot was 100′ (30.5 m) x 20′ (6.1 m) wide. Cattle were stocked in each pair of lots at cattle densities of 100 and 200 sq ft (9.3 and 18.6 sq m) per animal. In November 1970, densities were changed to 200 sq ft (18.6 sq m) per animal on all lots to replicate treatments. Cattle in all pairs of lots were fed identical rations of chopped alfalfa-brome hay, rolled corn, and supplement.

Continuous flow runoff control facilities were also installed on two 1,000-head cooperator feedlots in 1970.[2]

Sampling

Automatic samplers were installed at all locations to obtain composite samples of runoff from each feedlot and of effluent discharged from each debris basin (15). The 5-gallon (18.9 liter) containers used to collect the runoff were transported to the laboratory the day of the runoff event, subsampled, then stored at 0 Centrigrade until analyzed for physical and chemical analysis.

Physical Analysis

Total solids (T.S.) concentration transported in runoff was determined by drying three subsamples to constant weight at a temperature of 75C. Fixed solids (F.S.) were the weight of ash remaining after ignition at 600C (14). Volatile solids concentration was determined by weight loss on ignition.

Settleable solids (volumetric) for runoff and debris basin effluent were determined by using the standard Imhoff cone test (14). Settleable solids volumes were recorded after 0.25, 0.5, 1, 6, 24, and 48 hours of settling. Total and fixed solids of the Imhoff cone supernatant were determined on samples obtained from a depth of 10 cm after 0.5, 1, 6, and 24 hours of settling.

Settling characteristics of solids were determined by pouring a sample of runoff (agitated) into a one liter settling cylinder. Ten-milliliter samples were obtained by pipette from a depth of 10 cm below the liquid level at 0.25, 0.5, 1, 6, 24, and 48 hours of settling to obtain the total and fixed solids content.

About 100 ml of runoff was removed from an agitated sample, then poured through standard sieves with 2000, 1000, 500, 250, 125, 105, 53, 44, and 37 micron screen openings. Distilled water was used to rinse the solids through each sieve. The sieves were hand agitated while submerged to allow particles to pass the sieve. Particle size distribution was calculated as a percent of the total and volatile solids retained on and finer than indicated sieve openings.

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[2] One cooperator site was the Otoe County National Bank Research farm near Nebraska City; the other, the Eldon Wesley farm near Oakland, Nebraska. Both facilities were constructed on a 6% surface slope exposed to the east with animals stocked at 300 sq ft.

Nonfiltrable solids were determined by procedures outlined in Standard Methods (14). A 14-micron-diameter pore size Millipore filter[3] was used with a 47-mm-diameter filter assembly. Distilled water was used to rinse residue from the sides of the filter assembly. The solids retained on the filter (nonfiltrable solids) were calculated on a percent wet basis (% w.b.) and as a percent of the original total solids. The fixed solids content was the weight of ash remaining after ignition at 600C (14). The solids content of the dry filters was determined to be 100% volatile.

Unit weight of runoff was determined by the wet weight per unit volume. The bulk density of settleable solids was calculated as the dry weight of settled solids per unit volume of settleable solids.

Particle density of the solids transported in runoff and solids retained on the sieves was determined by the pycnometer bottle method (1). Particle density was calculated as the weight of the dry solids per unit volume of displaced water (gm/cc).

Gross energy was determined for solids transported in runoff and those solids retained on the 500, 250, 125, and 44 micron sieves, by use of a bomb calorimeter. Operating procedures recommended by the bomb calorimeter manufacturer were followed (13).

Chemical Analysis

The samples were blended and analyzed for water content, total N, NO_3–N, NH_4–N, chemical oxygen demand (COD), pH, electrical conductivity (EC), and elements sodium (Na), potassium (K) calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu) iron (Fe), and manganese (Mn).

Ashed samples were dissolved in 6N hydrochloric acid (HCl) and the total P content determined by the vanadomolybdophosphoric yellow method (2, 10). Total N was determined using micro-Kjeldahl procedure (2). Steam-distillation techniques were used to determine NO_3–N and NH_4–N (2). Standard procedures were used on diluted samples of manure to determine COD (14). Chemical elements were determined by atomic absorption procedures on a dry ash sample dissolved in nitric acid.

RESULTS AND DISCUSSION

Runoff Volume

Table 1 shows climatic conditions at the University of Nebraska Field Lab for the period 1968 through December 1972. Runoff (R)

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[3] Mention of trade names is for identification purposes only and does not imply product endorsement by the U.S. Department of Agriculture or the University of Nebraska.

Table 1. Monthly summary of climatic data for the University of Nebraska Field Laboratory near Mead, Nebraska.

	Ambient temperature (F)						Precipitation (in)					
	Normal	1968	1969	1970	1971	1972	Normal	1968	1969	1970	1971	1972
January	21.3	21.3	16.1	13.6	15.0	18.6	1.0	......	0.3	0.0	0.7	0.0
February	24.8	25.3	25.5	29.8	21.0	23.7	1.5	......	0.7	0.1	1.1	0.0
March	34.7	43.8	28.7	33.2	33.8	39.0	2.5	......	0.5	0.3	0.3	0.3
April	49.4	51.2	51.8	51.0	50.0	49.6	2.5	......	2.7	2.5	0.5	6.8
May	60.6	56.8	62.4	66.0	59.1	61.5	3.5	......	3.1	4.6	8.3	6.8
June	71.2	72.5	66.9	72.1	73.9	71.4	4.5	......	2.9	3.8	2.0	2.5
July	76.6	74.8	76.2	74.8	72.1	73.0	2.9	2.0	2.2	0.9	1.1	2.2
August	74.4	73.4	73.9	74.6	73.0	72.1	4.0	4.0	2.0	2.4	1.4	2.2
September	65.6	63.6	66.2	64.4	68.3	64.4	2.6	3.3	1.1	4.0	0.1	2.2
October	54.3	54.3	48.2	50.3	59.0	49.1	2.5	3.7	2.2	3.1	3.3	3.7
November	37.4	36.1	39.7	36.1	44.9	35.6	1.1	1.2	.0	1.1	2.2	3.5
December	27.1	21.7	23.1	26.9	26.0	20.1	0.7	1.2	1.1	0.0	0.3	1.4

from the feedlots followed the precipitation (P) pattern. The equation $R = 0.71P^{2P} - 0.23$ may be used to estimate runoff yield from a feedlot for a storm event (7). About 40% of the annual precipitation runs off the University of Nebraska feedlots. Snowmelt resulted in slurry type runoff for three out of the five winters. These conditions can inundate runoff control facilities, making maintenance difficult.

Solids Concentration

The total solids transported in rainfall runoff ranged from 0.66% to 3.30% w.b. (Table 2). Total solids transported varied with duration and intensity of precipitation, temperature, antecedent water content of the feedlot surface, number of animals per unit area, length of time animals were confined, and the ration fed (4). The total solids concentration of runoff from all feedlots studied averaged 1.52% compared to 0.99% for the period August 1968 through December 1970 for a single research feedlot (7). The total solids transported were 45% volatile for all systems.

Settleable Solids

Table 3 summarizes the quantities of settleable solids transported for 1970, 1971, and 1972 for the runoff and the effluent discharged

Table 2. Average concentration of solids transported in 55 composite rainfall runoff samples from unpaved beef cattle feedlots near Mead, Oakland, and Nebraska City, Nebraska for the period January through November, 1972.

	Average	Range (% w.b.)	Standard deviation
Total solids	1.52	0.66-3.30	0.53
Fixed solids	0.84	0.26-2.21	0.35
Volatile solids	0.68	0.36-1.68	0.27

Table 3. Settleable solids transported in feedlot runoff and discharged from debris basins to holding ponds.

	Settleable solids (ft^3/ac-in)[a]			
	Rainfall runoff		Debris basin effluent	
	Average	St. deviation	Average	St. deviation
1970	179.0	68.3	3.6	4.7
1971	287.0	167.1	27.4	37.8
Average (70-71)[b]	246.2	147.1	18.1	31.6
1972[c]	216.9	71.5	62.9	38.5

[a] Convert listed English units (ft^3/ac-in) to metric units (m^3/m^3) by multiplying by 0.028.

[b] Average of 45 runoff samples and 23 debris basin effluent samples from Mead, Nebraska after one hour of settling.

[c] Average of 64 runoff samples and 49 debris basin effluent samples after 24 hours of settling for the period January through November, 1972 from research feedlots located near Mead, Nebraska, and a cooperator site near Nebraska City, Nebraska.

from debris basins. The quantity of solids that settled in one hour was more variable than for solids allowed to settle for 24 hours (7). Variability was assumed to be due to the duration and intensity of precipitation with secondary factors of feedlot surface, antecedent moisture conditions, and ration fed. Debris basins removed 71% (by weight) of the settleable solids transported in runoff. Settled solids measured volumetrically indicated that 97% of the settleable solids can be removed within 15 minutes. This removal is equivalent to 75% total solids reduction by weight. The difference between volumetric and gravametric results is due to compaction of settled solids.

Suspended Solids

Total solids content of the batch system secondary pond supernatant was determined periodically during the summer months of 1970 and 1971. The total suspended solids in the pond liquid were 0.39, 0.52, 0.63, 0.66 and 0.83 (% w.b.) for April, June, July, August, and September, respectively.

Settling Rate

The concentration of total and volatile solids in the supernatant at a depth of 10 cm below the surface is shown in Figure 1. The rate of settling was quite variable. However, variability was reduced by grouping data into three categories: rapid, moderate, and slow settling. The three categories were defined by the quantity of total solids in suspension after 24 hours as follows:

Rapid settling—less than 30% of the original total solids in suspension.

Slow settling—more than 50% of the original total solids in suspension.

Moderate settling—30 to 50% of the original total solids in suspension.

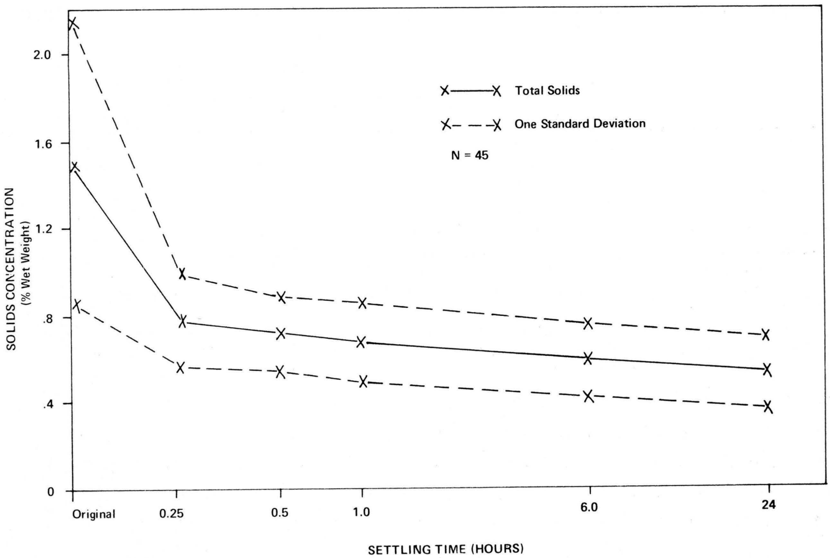

Figure 1. Rainfall runoff solids concentration as a function of settling time for 45 samples from runoff from beef cattle feedlots near Mead, Oakland, and Nebraska City, Nebraska (1972).

Table 4 shows the average concentration of total and volatile solids in the supernatant for the rapid, moderate, and slow settling categories. The rapid settling category had the highest initial and the lowest 24 hour total solids concentration. The slow settling category had the lowest initial and the highest 24 hour total solids concentrations. The volatile solids concentration did not appear to affect the rate of settling of any of the categories.

Particle Size Distribution

The quantity of solids retained on each respective sieve for those solids transported in runoff and removed from debris basins decreased with particle size (Figure 2). The difference between the solids transported in runoff and the solids removed from the debris basin during cleaning represents the approximate amount of materials that entered the holding pond. However, the amount and effect of biological degradation on accumulated solids within the debris basin and holding pond are not known. The total solids removed from debris basins were less volatile than the total solids transported in runoff, indicating that more soil than manure settled or that biologically decomposition occurred in the debris basin.

The particle size distribution of solids transported by runoff is

Table 4. Average total (T.S.) and volatile solids (V.S.) as a function of settling time for runoff samples obtained from research feedlots near Mead, Oakland, and Nebraska City, Nebraska.

	Settling time (hours)											
	Initial		0.25		0.5		1.0		6.0		24	
	T.S. (% w.b.)	V.S.	T.S. (% w.b.)	V.S.	T.S. (% w.b.)	V.S.	T.S. (% w.b.)	V.S.	T.S. (% w.b.)	V.S.	T.S. (% w.b.)	V.S.
Rapid settling (less than 30% of the original total solids remaining at depth of 10 cm after 24 hours N=21)												
Average	1.97	0.78	0.72	0.34	0.66	0.32	0.61	0.31	0.51	0.26	0.42	0.25
Range												
High	3.30	1.11	0.98	0.52	0.90	0.45	0.82	0.47	0.76	0.47	0.65	0.35
Low	1.15	0.36	0.51	0.19	0.48	0.18	0.45	0.18	0.29	0.11	0.24	0.13
Std. Dev.	0.77	0.33	0.19	0.10	0.16	0.09	0.12	0.07	0.14	0.10	0.12	0.07
Moderate settling (30 to 50% of the original total solids remaining at depth of 10 cm after 24 hours N=25)												
Average	1.44	0.67	0.81	0.42	0.76	0.40	0.72	0.38	0.59	0.34	0.55	0.33
Range												
High	2.59	1.68	1.25	0.67	1.12	0.71	1.04	0.67	0.97	0.61	0.84	0.58
Low	0.79	0.36	0.45	0.25	0.45	0.24	0.43	0.19	0.36	0.24	0.36	0.19
Std. Dev.	0.43	0.28	0.20	0.12	0.19	0.12	0.18	0.11	0.19	0.13	0.12	0.10
Slow settling (greater than 50% of the original total solids remaining at depth of 10 cm after 24 hours N=10)												
Average	1.16	0.62	0.89	0.51	0.85	0.48	0.81	0.47	0.75	0.47	0.67	0.42
Range												
High	1.59	0.92	1.30	0.79	1.20	0.77	1.13	0.70	0.98	0.71	0.96	0.64
Low	0.66	0.38	0.43	0.29	0.43	0.29	0.41	0.30	0.53	0.27	0.33	0.23
Std. Dev.	0.28	0.18	0.27	0.18	0.25	0.16	0.23	0.15	0.17	0.18	0.21	0.16

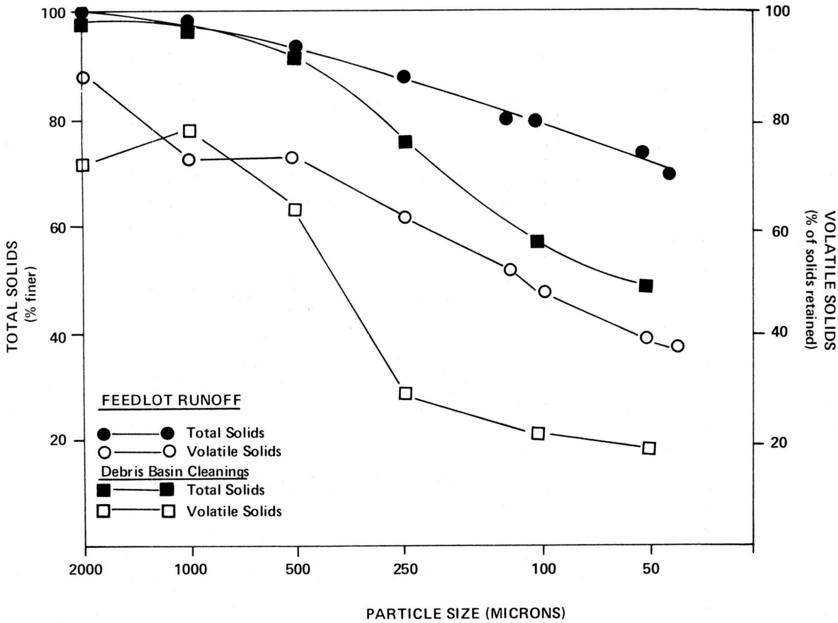

Figure 2. Average particle size distribution of solids transported in rainfall runoff from feedlots located near Mead, Oakland, and Nebraska City, Nebraska (January through October, 1972).

expressed on a wet weight basis in Table 5. Forty-eight percent of the materials trapped in the debris basins and 72% of the solids transported in rainfall runoff passed the 53-micron sieve. The filtrable solids (0.39% w.b.) approximated the total solids concentration of liquid in holding ponds used for feedlot runoff control (7). The original runoff, nonfiltrable, and filtrable solids concentration in runoff were 1.52, 1.13, and 0.39 (% w.b.) respectively. The loss

Table 5. Particle size distribution of solids transported in runoff from beef cattle feedlots located near Mead, Oakland, and Nebraska City, Nebraska (January through December 1972).

Particle size (micron)	Average solids concentration (% w.b.)	Standard deviation	Number of samples
> 2000	0.02	0.01	10
1000 to 1999	0.03	0.02	10
500 to 999	0.06	0.03	28
250 to 499	0.10	0.04	28
125 to 249	0.12	0.02	17
105 to 124	0.02	0.02	10
53 to 104	0.08	0.01	10
44 to 52	0.08	0.03	18
< 44	1.14	0.18	28
Filtrable (< 14 micron) Solids	0.39	0.04	22

on ignition was 45%, 33%, and 67% for the initial, nonfiltrable, and filtrable solids transported in runoff, respectively.

Nonfiltrable solids were 71.9% and 59.5% of the total and volatile solids retained on a 14-micron Millipore filter, respectively. The average concentration of nonfiltrable solids was 1.14 (% w.b.) while the volatile solids was 0.39 (% w.b.). Solids distribution in runoff were: 28% less than 14 microns, 41% within the range of 14 to 44 microns, and 31% within the range of 44 to 2000 microns. The values are approximate, since it was assumed that the 14-micron Millipore filter passed all the particles of that size and smaller. Any plugging of the pores would tend to restrain some of the finer particles from passing the filter.

Unit Weight and Bulk Density

The unit weight of runoff averaged 63.02 lb/ft^3 (1.01 gm/cc) for all runoff. The bulk density of settleable solids transported in runoff and discharged from debris basins to holding ponds was calculated from Imhoff cone data (Table 6). The bulk density of settleable solids transported in 1972 rainfall runoff was 1.7 times greater than settleable solids transported in 1971 rainfall runoff. Some of this difference may be due to settling times of one hour in 1971 and 24 hours in 1972. The bulk density of settleable solids transported in runoff was 1.3 times greater than the bulk density of the settleable solids discharged from the debris basin to the holding pond in 1972. The settleable solids discharged from the debris basin appeared fluffy and would return to a suspended form with a slight agitation or jarring of the Imhoff cone. The effect of head on settleable solids bulk density in the bottom of holding ponds or debris basins is not known. The calculated average in Table 6 may be used for estimating

Table 6. Unit weight of runoff and bulk density of settleable solids transported from feedlots near Mead (1971) and Oakland, and Nebraska City, Nebraska (1972).[a]

	Unit weight[b] (lb/cu. ft.)			Bulk density (lb/cu. ft.)[b]					
	Runoff			Settleable solids transported in runoff			Settleable solids discharged from debris basins		
Year	Average	St. Dev.	No. of samples	Average	St. Dev.	No. of samples	Average	St. Dev.	No. of samples
1971	63.02	0.13	49	6.40	2.94	15	10.72	8.37	14
1972	....	....	....	10.72	3.44	55	8.03	2.31	34

[a] The dry weight of settleable solids was calculated by the difference between initial solids concentration and supernatant solids concentration after one hour (1971) and 24 hours (1972) of settling time in Imhoff cones. The volume of settleable solids was recorded directly from the Imhoff cone. Snowmelt settleable solids are not included.

[b] The unit weight of runoff is expressed as the weight of runoff per unit volume. Bulk density is expressed as the weight of dry solids per unit weight of solids and voids. Convert English units (lb/cu ft) to metric units (kg/m^3) by multiplying listed values by 16.02.

Table 7. **Average particle density of solids transported in 28 samples of beef cattle feedlot runoff.**

	Particle density (gm/cc)		
	Average	N	Standard deviation
Total solids	1.95	33	0.18
Fixed solids (Ash)	2.56	7	0.14
Particle size (micron)[a]			
500-999	1.77	3	......
250-499	1.96	3	......
105-249	2.34	3	......
< 37	2.38	3	......

[a] Particle density was determined on accumulated solids retained on the 500, 250, and 105 micron sieves and solids passing the 37 micron sieve. Insufficient quantities of solids were retained on the 2000, 1000, 53, and 37 micron sieves to determine particle density.

the volume reduction in holding ponds due to settleable solids accumulations.

Particle Density

Particle densities for the total and fixed solids transported and particles retained on the 500-, 250-, and 105-micron sieves and materials passing the 37-micron sieve are shown in Table 7. The average particle density increased as the particle size decreased. The particle density of the total solids and fixed solids (ash) transported was 1.95 and 2.56 gm/cc, respectively. The particle density of the ash approached that of sand and clay. The increase in particle density with decreased particle size is somewhat a function of the volatile solids (Figure 2). Particles less than 250 microns apparently are mostly soil and larger particles are undigested feed.

Gross Energy

Gross energy of solids transported in runoff and removed from feedlot surfaces and debris basins during cleaning decreased with decreased particle size (Table 8). Gross energy could not be deter-

Table 8. **Gross energy of solids in beef cattle feedlot waste at Mead and Nebraska City, Nebraska (1972).**

	Gross energy (cal/gm)[a]		
Particle size microns	Runoff transported solids	Debris basin solids	Feedlot surface solids
Initial	....	1149	979
1000-2000	....	....	3110
500- 999	....	....	3055
250- 499	....	....	2133
105- 249	....	2146	1246
53- 104	1273	635	426
Other	1658[c]	895[b]	........[d]

[a] Gross energy was determined by use of a bomb calorimeter, reported as the average of two replications.

[b] Solids passing the 53 micron sieve.

[c] Solids passing the 44 micron sieve.

[d] Solids retained on the 37 micron sieve would not ignite.

mined for solids retained on the 37-micron sieve from feedlot surface cleanings because the solids would not ignite. This indicates inert soil fractions constitute the majority of material retained on the 37 micron sieve.

The gross energy of solids transported in feedlot runoff, or removed from a settling area were about one-fourth that of lignite coal, therefore could be classified as a low energy fuel source.

Chemical Characteristics

Chemical contents and characteristics of feedlot runoff are highly variable (Table 9). There is considerable difference in the quality of snowmelt and rainstorm runoff. Snowmelt runoff contains greater quantities of all elements examined. The pH of snowmelt runoff averaged less than the rainstorm runoff pH of 7.0. The range for all samples was 4.1 to 9.4. In most average values, however, the snowmelt runoff had about four times more nutrients than rainstorm runoff. The greatest difference in values between snowmelt and rainstorm runoff was the COD. The much larger COD indicates that the materials contained in snowmelt runoff are composed primarily of undecomposed manure.

Electrical conductivity was as high as 5.3 and 19.8 millimhos/cm in summer and snowmelt runoff, respectively.

The maximum quantity of solids from the snowmelt was 21.8 (% w.b.) (Table 9). Almost 67% of the material was volatile when ashed, which indicates the large quantity of organic matter in the snowmelt material. When thaws occurred during some winters, a slurry of undecomposed manure flowed from the lot. The snowmelt runoff that contained high solids content occurred from lots of cattle which were on a high-concentrate ration. In this type of sample, total nitrogen was as high as 6,528 ppm. and NH_4–N 2,028 ppm. The average quantity of NO_3–N in the runoff was consistently low, but was as high as 280 and 217 ppm in snowmelt and runoff, respectively.

Table 9. Ranges in the characteristics and chemical values of runoff from beef cattle feedlots at Mead, Nebraska (1968-72).

	Snowmelt runoff			Rainstorm runoff		
	Low	High	Mean	Low	High	Mean
pH	4.1	9.0	6.3	4.8	9.4	7.0
Conductivity (mmhos/cm)	3.0	19.8	7.1	0.9	5.3	3.2
Total solids (%)	0.8	21.8	7.7	0.24	3.3	1.93
Volatile solids (%)	0.6	14.3	3.9	0.12	1.5	0.82
Ash (%)	0.2	9.2	3.8	0.12	2.8	1.11
COD (mg/1)	14,100	77,100	41,000	1,300	8,200	3,100
P (ppm)	5	917	292	4	5,200	300
NH_4-N (ppm)	6.0	2,028	780	2	1,425	151
NO_3-N (ppm)	0	280	17.5	0	217	10
Total nitrogen (ppm)	190	6,528	2,105	11	8,593	854

In 1969, an appreciable amount of material was removed in the snowmelt; 53.1 and 12.6 t/ac (119 and 28 metric t/ha) for the 100 and 200 sq ft (9.3 and 18.6 sq m) per animal densities, respectively. Approximately 50% of the solids were volatile. Significant amounts of nitrogen and phosphorus also left the feedlot in snowmelt runoff (Table 10). The runoff varied from year to year; two to three times as much material was removed from the 100 sq ft (9.3 sq m) per animal lot as from the 200 sq ft (18.6 sq m) per animal lot for 1969 and 1970. Quantity of solids for 1971 and 1972 removed in runoff increased over the previous year's. There were 33% more solids removed these two years. Rainfalls producing runoff had not signifi-

Table 10. Quantity of materials removed in runoff from beef cattle feedlot located near Mead, Nebraska, 1969-1972.

	Total year		Snowmelt		Rainstorm	
	Jan. 1	Dec. 1	Jan. 1	Apr. 4	Apr. 5	Dec. 31
	100	200	100	200	100	200
	ft² per animal					
1969						
Precipitation (in)[a]	14.21	14.21	3.30	3.30	10.90	10.90
Runoff (in)[b]	6.73	6.53	2.66	1.79	4.05	4.72
Total solids (t/ac)[b]	60.30	19.17	53.55	12.60	6.75	6.52
Volatile solids (t/ac)[b]	31.27	9.54	28.17	6.43	3.10	3.06
Ash (t/ac)[b]	29.20	9.63	25.56	6.16	3.63	3.46
Total N (t/ac)[b]	1.72	.56	1.42	.39	.30	.17
Total P (t/ac)[b]	.58	.21	.56	.18	.01	.03
1970						
Precipitation (in)	14.48	14.48	1.17	1.17	13.30	13.30
Runoff (in)	5.78	7.59	.62	.79	5.15	6.81
Total solids (t/ac)[b]	25.24	17.19	.94	.57	24.30	16.65
Volatile solids (t/ac)[b]	14.94	9.22	.69	.39	14.22	8.82
Ash (t/ac)[b]	10.30	7.96	.21	.18	10.08	7.78
Total N (t/ac)[b]	.09	.64	.09	.33	.81	.31
Total P (t/ac)[b]	.13	.10	.00	.05	.12	.06
1971[c]						
Precipitation (in)	....	16.77	....	....	....	16.77
Runoff (in)	....	9.68	....	....	....	9.68
Total solids (t/ac)[b]	....	24.07	....	....	....	24.07
Volatile solids (t/ac)[b]	....	8.59	....	....	....	8.59
Ash (t/ac)[b]	....	15.48	....	....	....	15.48
Total (N (t/ac)[b]	....	.62	....	....	....	.62
Total P (t/ac)[b]	....	.14	....	....	....	.14
1972[c]						
Precipitation (in)	....	15.07	....	....	....	15.07
Runoff (in)	....	9.96	....	....	....	9.96
Total solids (t/ac)[b]	....	29.16	....	....	....	29.16
Volatile solids (t/ac)[b]	....	12.64	....	....	....	12.64
Ash (t/ac)[b]	....	16.51	....	....	....	16.51
Total (N (t/ac)[b]	....	.98	....	....	....	.98
Total P (t/ac)[b]	....	.06	....	....	....	.06

[a] Precipitation causing a runoff event.

[b] 1 t/Ac = 2.22 metric t/ha.

[c] 100 ft² per animal stocking rate was discontinued in 1971. Snowmelt runoff was not significant and detailed analyses were not completed in 1971-72.

Table 11, Chemical elements in runoff from beef cattle feedlots located near Mead, Nebraska.

Chemical	Concentration range (ppm)		
	Low	High	Mean
Digested samples[a]			
Na	90	2750	840
K	50	8250	2519
Ca	75	3460	794
Mg	30	2350	494
Zn	1	415	107
Cu	0.6	28	7.6
Fe	24	4170	764
Mn	0.5	146	26.7
Solution samples[b]			
Na	78	478	208
K	504	1864	1029
Ca	33	181	73
Mg	5.2	146	49.4
Zn	0.3	1.1	0.64
Cu	<0.1	<0.1	<0.1
Fe	1.5	31.5	12.5
Mn	0.1	2.51	1.13

[a] Ashed at 550 C; ash dissolved in 6*N* HCl; selected samples from all feedlots, 1968-1970.

[b] Elements in solution; selected samples from feedlots with animal densities of 200 sq ft (18.6 sq m) per animal, 1971-1972.

cantly increased; however, a proportionately greater quantity of runoff was measured.

Chemical element content in runoff is shown in Table 11. The quantity of nutrients was larger for the ashed samples; however, results are difficult to compare with the solution values because of the different sampling periods and changes in lot management. The large quantity of monovalent cations indicates that the runoff from both types of samples could produce changes in soil if applied in large quantities to an area for an extended time. The levels of K, Na, and Mg are in a ratio of 13.1:1 to Ca in the solution samples and 4.9:1 for the digested samples. The difference in the method of analysis indicated that most of the Fe, Zn, Cu, and Mn are in a bound form and not immediately available.

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