5380

Physical and Chemical Properties of Eroded Soil Aggregates

E. E. Alberts, R. C. Wendt, R. F. Piest
MEMBER
ASAE

This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 26, No. 2, pp. 465–471, 1983)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

ABSTRACT

RAINFALL simulation was used to evaluate the characteristics of aggregates eroded from erosion plots on two loess soils in southwestern Iowa. The mean aggregate diameters (D_{50}) for interrill erosion were 44 and 34 μm for soils with 26% clay and 1.9% carbon and 22% clay and 0.8% carbon in their matrix, respectively. The D_{50} size increased as rilling occurred, but the percentage of increase was quite different for the soils. The D_{50} size increased by 91% for the soil with higher clay, whereas it increased by only 15% for the other soil. The eroded aggregates >50 μm in diameter contained more clay and total nitrogen than did the aggregates <50 μm, when analyzed as a single fraction. The >50-μm aggregates were also enriched in clay and nitrogen when their contents were compared to those of the matrix soil. Enrichment was greater for interrill than for interrill plus rill erosion because of greater particle selectivity during the transport process. Equilibrium phosphorus concentration curves varied with aggregate size, suggesting that 250 to 50-μm aggregates are of greater importance in buffering soluble P levels and transporting labile P than larger aggregates.

INTRODUCTION

Analyses of the physical and chemical properties of sediment have received limited attention when compared to evaluating the effects of various agricultural management practices on sediment yield. However, the recent impetus in erosion and chemical transport modeling has created a need to better understand sediment properties and the factors that affect them (Onstad et al., 1979; Young, 1980).

Most of the sediment eroded from fertile, agricultural soils is composed of aggregated particles (Swanson et al., 1965b; Alberts et al., 1980; and Young, 1980). Recent modeling approaches based upon fundamental erosion mechanics have separated the sediment into several size fractions to improve predictive capability of sediment and chemical transport (Foster et al., 1980). The size distributions of aggregated particles in runoff as affected by soil type (Meyer, 1980), erosion process (Alberts et al., 1980), and soil surface condition (Alberts and Moldenhauer, 1981a) have been studied recently. The total nitrogen (N) and plant-available phosphorus (P) concentrations of several aggregate fractions have also been studied (Alberts and Moldenhauer, 1981a). Particle aggregation should influence soluble P levels in surface runoff, but the effect on sorption and desorption reactions has not been studied and is poorly understood (Sharpley et al., 1981).

Our study was conducted to gain additional understanding of the effects of soil type, erosion process, and initial condition of the soil surface on several physical and chemical properties of eroded aggregates. We also evaluated the effects of two sample sieving techniques, three sample storage methods, and six sample storage times on the size distribution of eroded aggregates.

MATERIALS AND METHODS

The rainfall-simulation study was conducted in July of 1980 on an experimental watershed located in southwestern Iowa, near Treynor. The watershed is located within the deep loess hills region of western Iowa and northwestern Missouri. The soils of this region are highly productive, but are extremely susceptible to field and gully erosion (Spomer et al., 1981). The watershed has been planted to corn using a till-plant system since 1972, after being in bromegrass for 15 yr.

Two soils were studied (see Table 1 for a description of soil properties). The Monona soil (fine-silty, mixed, mesic, *Typic Hapludolls*) is a deep, fertile soil located near the summit, while the Ida soil (fine-silty, mixed, calcareous, mesic, *Typic Udorthents*) is located on the back slope. The Monona and Ida soils were on 6 and 12% slopes, respectively.

Three adjacent plots on each soil were moldboard plowed 15 to 20-cm deep in May, 1980. No crop residue was present because the plots were used in a similar rainfall-simulation study the previous year (Piest et al., 1980). Plot dimensions were 3.0 by 10.7 m. The plots were cultivated, disked, and covered with plastic several days before rainfall was applied. In addition to these plots, which were long enough for rilling to initiate, much smaller plots (0.3 × 0.3 m) were established to study interrill erosion. The small plots were duplicated on each soil type. Plot preparation was the same as for the longer plots.

TABLE 1. SOIL PROPERTIES OF THE 0 TO 5-CM DEPTH.

Property	Soil series	
	Monona	Ida
Sand, %	2.0	2.0
Coarse silt (50-20 μm), %	36.0	39.0
Fine silt (20-2 μm), %	36.0	37.0
Clay, %	26.0	22.0
Dry sieving MWD*, μm	2100	1800
Wet sieving MWD, μm	910	460
Carbon, %	1.9	0.8
Total N, μg/g	1800	830
Organic, P, μg/g	410	100
Total P, μg/g	740	760

*Mean weight diameter.

Article was submitted for publication in April, 1982; reviewed and approved for publication by the Soil and Water Div. of ASAE in November, 1982.

Contribution from the Watershed Research Unit, USDA-ARS, Columbia, MO.

The authors are: E. E. ALBERTS and R. C. WENDT, Soil Scientists, and R. F. PIEST, Hydraulic Engineer (retired), Watershed Research Unit, USDA-ARS, Columbia, MO.

Rainfall was applied at a rate of 6.4 cm/h using a rotating-boom simulator (Swanson, 1965a). The initial 1-h run was followed 24 h later by a ½-h run. Rainfall was applied to both plot types at the same time. Discharge rates were determined by gravimetric sampling at frequent time intervals during the event.

Two samples for aggregate analysis were collected in 2-L containers from each plot during each runoff event. For the first event, samples were collected after 40 and 50 min of rainfall, whereas samples were collected after 10 and 20 min of rainfall during the second event. The samples were transported immediately to the laboratory and gently rotated to resuspend the sediment. The suspended sediment was passed through a nest of four sieves, with screen openings of 2000, 1000, 500, and 250 μm, which were supported above an empty 2-L container. The sieves were then immersed in a bucket of tapwater and attached to a wet-sieve machine (Yoder, 1936). The water level within the bucket was adjusted so that the screen of the top sieve was covered with water when the sieve nest was in the uppermost stroke position. After the sieve nest was oscillated for 0.5 min (about 15 oscillations), the sieve nest was removed from the bucket, the sieves separated, and the aggregates washed into drying cans. The <250-μm fraction in the 2-L container was combined with that in the bucket and passed through a sieve having screen openings of 50 μm. The size distribution of the remaining sediment was determined by obtaining timed withdrawals using a 25-mL pipette (Day, 1965). Four withdrawals were taken from each bucket, after stirring, to determine the amount of sediment in the 35-, 20-, 10-, and <2-μm size fractions. A particle density of 2.20 g/cc was assumed for the 35- and 20-μm size fractions, while the smaller fractions were assumed to have a density of 2.65 g/cc. After the final withdrawal, 5 mL of concentrated alum solution was added to each bucket to facilitate the rapid drying and weighing of the <50-μm fraction.

The effects of two sample sieving techniques, three sample storage methods, and six sample storage times on the size distribution of the >2000-, 2000 to 1000-, 1000 to 500-, 500 to 250-, 250 to 50-, and <50-μm size fractions were also studied. These evaluations were limited to the first runoff event for the Monona soil. Samples were collected in the 2-L containers after approximately 40 and 50 min of rainfall. Sampling technique was evaluated by comparing the size distribution of aggregates separated in the field to those separated in the laboratory by procedures already described. Samples were collected in the field by inserting a stacked nest of sieves directly into the runoff. The sieves, which were the same as those used in the laboratory, were enclosed in a plastic bag and inserted into the runoff until about 1 L of suspension had been collected. The sediment on each screen was washed immediately into drying cans. The samples were taken immediately after those obtained for laboratory separation.

The sample storage methods evaluated included: (a) storage at room temperature, (b) storage at 4 °C, and (c) the addition of 40 mg of $HgCl_2$/L immediately after collection and subsequent storage at room temperature. The last two treatments were used to reduce microbial activity within the sample.

The effect of 1, 3, 7, 21, 56, and 84 days of storage on the size distribution of the eroded aggregates was also determined using the laboratory sieving technique. Initially, we had planned to evaluate all six storage times for all three storage methods. However, only the samples stored at room temperature were separated after 1 and 3 days of storage. The influence of storage method on the size distribution of eroded aggregates was evaluated for the remaining four storage times, however.

After 84 days, the samples stored in the containers at room temperature and 4 °C were separated into 50 to 35-, 35 to 20-, 20 to 10-, 10 to 2-, and <2-μm size fractions using sieving and decantation procedures to obtain samples for additional analyses (Alberts et al., 1981b). The samples stored at room temperature and 4 °C were used to determine the primary particle size distribution and N concentrations of the various size fractions, respectively.

The percentage of sand, silt, and clay in each aggregate fraction was determined by sonifying 10 g of sample in 25 mL of distilled water for 6 min (Genrich and Bremner, 1972). Samples for a given fraction were generally composited over sample time (after 40 and 50 min of rainfall) to obtain the 10 g sample for analysis. The sand fraction was separated immediately after sonification. The withdrawal to determine the clay (<2 μm) fraction was performed using standard pipetting procedures.

The N concentration of each size fraction was determined by Kjeldahl digestion (Nelson and Sommers, 1972) and continuous flow, colorimetric procedures (Technicon Industrial Systems, 1978). Organic and total P were determined by extracting unignited and ignited samples, respectively, with 0.5 M H_2SO_4 (Walker and Adams, 1958). Phosphorus concentrations in the extract were determined using the one-step method (Murphy and Riley, 1962).

Phosphorus sorption-desorption isotherms were determined for the 2000 to 1000-, 1000 to 500-, 500 to 250-, and 250 to 50-μm size fractions by equilibrating each for 2 h with P solutions containing 0, 0.25, 0.50, and 0.75 μg P/mL and 0.001 M $CaCl_2$ at a solution-to-soil ratio of 100 to 1. Equilibrations were performed at 25 °C in 50-mL Oak Ridge-type polycarbonate centrifuge tubes. Special precautions were taken to minimize aggregate breakdown. Prior to wetting, 0.4-g air-dry samples in tubes were placed in a dessicator containing free water and continuously evacuated at 66 cm of mercury (Kemper and Koch, 1966). After evacuating at least 10 min, the samples were wetted by adding 5 mL of deaired 0.001 M $CaCl_2$ at the same vacuum. Samples were then removed from the dessicator and adjusted to final volume with the appropriate P and Ca containing solutions. During equilibration, samples were mixed by rotating the sample tubes on their longitudinal axis at about 5 rpm. After 2 h equilibration, the samples were centrifuged for 10 min at 10,000 rpm and the supernatant passed through a 0.45 μm filter. The dissolved P concentration in the filtrate was determined by the method of Murphy and Riley (1962). In addition, 10-g samples of each size fraction were sonified for 6 min in 25 mL of 0.001 M $CaCl_2$ to disrupt the aggregates. The final volume of each sample was then brought to 250 mL with 0.001 M $CaCl_2$ so that a 10-mL aliquot of the suspensions would deliver about 0.4 g of sediment. Sorption-desorption isotherms for 0.4-g dispersed samples were then determined in the same manner as

TABLE 2. WATER AND SEDIMENT DISCHARGE RATES AT EQUILIBRIUM FLOW.

Initial soil conditon	Soil Series			
	Monona		Ida	
	Water	Sediment	Water	Sediment
	mm/h	kg/m^2·h	mm/h	kg/m^2·h
	Interrill erosion			
Dry	56.6	1.62	58.7	3.84
Wet	56.3	1.54	74.9	3.98
	Interrill plus rill erosion			
Dry	34.5	1.45	39.6	4.06
Wet	46.5	2.33	47.6	5.73

those for aggregated samples.

Kemper and Chepil's (1965) procedures were used to characterize the dry and wet aggregate size distributions of the matrix soils. The carbon content of the matrix soils was determined by the Mebius method (1960).

RESULTS AND DISCUSSION

Water and Sediment Discharges

Discharge rates at or near equilibrium flow are shown in Table 2. Differences in soil type and initial condition of the surface prior to rainfall had relatively little effect on water discharges from the interrill plots. Surface sealing appeared to be greater for the Ida than Monona soil during the second runoff event, which would be expected because of the almost twofold difference in wet aggregate stability of the soils (Table 1). Slope differences partially confounded the evaluation of soil type on water discharges. However, Lattanzi et al. (1974) found that water losses from interrill plots were affected negligibly by slope steepness.

Sediment discharge rates were affected significantly ($p \leq 0.01$) by soil type. Slope steepness has not greatly affected sediment discharges from interrill areas (Lattanzi et al., 1974; Meyer et al., 1975b). Lattanzi et al. (1974) measured sediment discharges from a silt-loam soil which had very similar properties to the Monona soil. Sediment discharges from their soil were 0.20 kg/M^2·h·degree of slope, when measured on a 6% slope, and 0.16 kg/m^2·h·degree of slope, when measured on a 12% slope. Based on their relationship, the estimated sediment discharge rate for the Monona soil (12% slope) during the first runoff event would be 2.6 kg/m^2·h, well below the measured value for the Ida soil. The K values from Wischmeier's et al. nomograph (1971) are 0.31 for the Monona and 0.42 for the Ida soils. It appears that the relative difference in interrill erosion between these two soils after adjusting for slope is expressed well by the relative difference in the K values from the nomograph.

The effect of soil condition on water discharges from the rill plus interrill plots was highly significant ($p \leq 0.01$). We observed that considerable rilling occurred on the soils during the second runoff event. Rill development improves water delivery because runoff velocity is much greater within rills than from interrill areas.

Sediment discharges from the interrill plus rill erosion plots were affected significantly ($p \leq 0.01$) by the initial soil condition (Table 2). Sediment discharges increased proportionately more than water discharges during the second runoff event because of the rapid increase in rilling that we observed on the plots. Differences in sediment discharges caused by differences in soil type

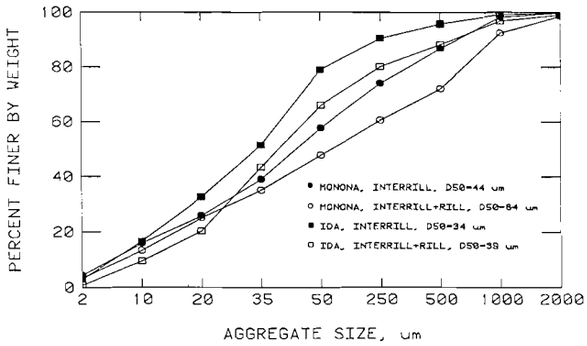

Fig. 1—Effect of soil and erosion process on the aggregate size distribution of the sediment.

were about the same as for the interrill erosion plots. However, the adjustment of sediment discharges from the Monona soil for slope steepness using well-known relationships (Wischmeier and Smith, 1978) resulted in higher sediment discharges than actually measured on the Ida soil when averaged over both runoff events. Differences in K values between the Monona and Ida soils will be discussed in more detail in a future paper.

Aggregate Size Distribution

The effects of soil type and erosion process on the aggregate size distribution of the sediment were highly significant ($p \leq 0.01$) for many of the size fractions (Fig. 1). For soil type, the 2000 to 1000-, 1000 to 500-, 500 to 250-, 50 to 35-, 35 to 20-, and <20-μm size fractions were affected significantly. Others have found differences in the eroded aggregate size distribution of soils (Meyer et al., 1980). The effect of erosion process was significant for the >2000-, 2000 to 1000-, 1000 to 500-, 10 to 2-, and <2-μm size fractions. The percentages of sediment in the >2000-, 2000 to 1000-, and 1000 to 500-μm fractions for the Monona soil and the >2000-, 2000 to 1000-, 1000 to 500-, 500 to 250-, and 250 to 50-μm fractions for the Ida soil were lower for interrill erosion than for interrill plus rill erosion. These findings are in agreement with those reported by Alberts et al. (1980). Particle selectivity occurs because interrill flow does not have sufficient energy to transport many of the sand-sized aggregates. Rill flow is seldom transport limiting; thus, very large aggregates can be transported (Meyer et al., 1975a). Because of this selectivity, interrill erosion has a larger percentage of primary clay particles (<2 μm) than interrill plus rill erosion. A change in the aggregate-size distribution of the sediment can affect the nutrient loads being transported (Alberts and Moldenhauer, 1981a).

The type of erosion process affected the mean aggregate diameters more for the Monona than for the Ida soil (Fig. 1). The D_{50} sizes for interrill sediment agree well with those found by Meyer et al. (1980) for ten Mississippi soils. The D_{50} size for interrill plus rill erosion for the Monona soil was almost twice that for interrill erosion. We found the D_{50} size will increase as rilling occurs, but the proportion of increase will depend on the size and stability of aggregates in the matrix soil.

The condition of the soil surface prior to a runoff event had only a slight effect on the size distribution of the sediment (Fig. 2). We thought previously that the rougher surface present after tillage would reduce runoff velocity enough to cause many of the larger aggregates to deposit within the plots. For the Ida soil, there was

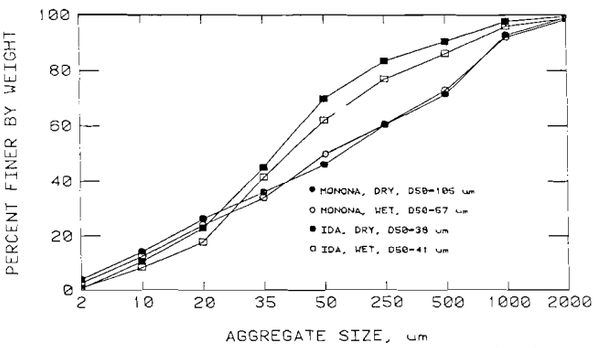

Fig. 2—Effect of initial soil condition on the aggregate size distribution of the sediment from the interrill plus rill erosion plots.

evidence of this occurring. The proportion of the total sediment in all the large-size fractions >50 μm was lower for the first runoff event that occurred soon after tillage than for the second runoff event. For the Monona soil, only the >2000- and 2000 to 1000-μm fractions had a lower proportion of sediment in them for the first runoff event.

Aggregate Sampling, Handling, and Storage

Field sieving by inserting a sieve nest directly into the runoff apparently trapped aggregates that were smaller than the nominal size of the screen openings (Fig. 3a). Significant differences were found for >2000- and 1000 to 500-μm ($p \leq 0.10$) and the 2000 to 1000-μm ($p \leq 0.01$) aggregates. As the sieve nests were inserted into the runoff, aggregates of the correct diameter were trapped immediately onto the screen. Smaller aggregates were trapped unintentionally, however, as more openings closed with additional sampling. Thus, the proportion of aggregates >50 μm was higher for field than for laboratory sieving. Laboratory sieving, where the sieves were oscillated in a bucket of tapwater while additional separation occurred, allowed ample time for the smaller aggregates to wash through to the correct screen size.

Sample handling had no effect on the aggregate-size distribution of the sediment (Fig. 3b), implying that microbial activity within the aggregates was extremely low. The effect of storage temperature on chemical parameters was not studied. Values were averaged over data collected from three plots, two sampling times, and four sample storage times.

The effect of 1 to 84 days of sample storage on the aggregate-size distribution of the sediment was generally quite small (Fig. 3c). There was evidence that some of the 250 to 50-μm aggregates broke down after 1 day of storage. No additional breakdown within this fraction occurred, however. After 84 days of storage, the aggregate-size distribution was very similar to that measured within several hours of sample collection.

The evaluation of sample sieving technique, sample handling, and sample storage on the aggregate-size distribution of the sediment from a fertile Cornbelt soil provides information which will be useful to others studying aggregate transport. Our findings indicate that the size distribution of the sediment is not affected by differences in sample handling and storage time. Sieving technique did affect the D_{50} size considerably, however.

Primary Particle Composition of Eroded Aggregates

In Fig. 1, we showed that less than 5% of the sediment

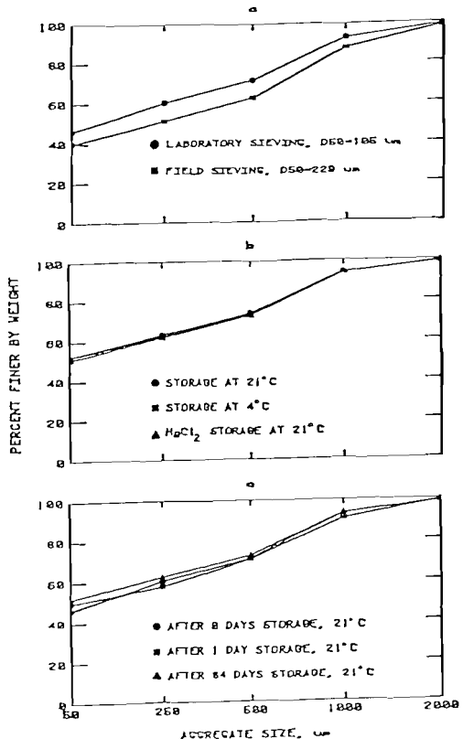

Fig. 3—Effect of (a) sample sieving technique, (b) sample handling technique, and (c) sample storage on the aggregate size distribution of the sediment.

was transported as primary clay particles for soils with clay contents of over 20% in their matrix. Table 3 shows that much of the eroded clay is transported within the larger aggregates >50 μm in diameter. These aggregates are also enriched in clay, when their clay contents are compared to those of the matrix soils. Clay enrichment has generally been attributed to an increase in the selectivity of the erosion process for the finer fractions of the soil (Massey and Jackson, 1952; Frere, 1976). However, clay enrichment occurs for even large eroded aggregates. This finding agrees with other published results (Alberts and Moldenhauer, 1981a; Meyer et al., 1980; and Young, 1980). The amount of clay enrichment for all the aggregates >50 μm was about 15%, which agrees quite well with that found by Alberts and Moldenhauer (1981a). For the aggregates <50 μm, clay contents were equal to or less than the clay contents of the matrix soils. Obviously, enrichment does not occur because of a decrease in the mean particle diameter of the sediment.

The influence of the erosion process on the primary particle composition of the aggregates was slight (Table 3). For interrill erosion on the Ida soil, the clay content of the aggregates >50 μm was about 7% greater than the clay content of the same-sized aggregates from the interrill plus rill erosion plots. The clay content of large aggregates eroded from rills is generally lower than that measured from interrill areas (Alberts et al.;, 1980). Thus, our data suggests that the proportion of rill erosion was greater for the Ida than for the Monona soil.

Total N Concentrations of Eroded Aggregates

Much of the total N was transported by the larger aggregates >50 μm (Table 4), which would be expected because organic N is primarily associated with the clay

TABLE 3. PRIMARY PARTICLE COMPOSITION OF ERODED SOIL AGGREGATES.

Primary particle	Primary particle composition of aggregates in size fractions, μm							
	2000-1000	1000-500	500-250	250-50	50-35	35-20	20-10	10-2
	% of total wt.							
				Monona soil — interrill erosion				
Sand	—*	2	2	12		0		
Silt	—	71	67	56		74 for < 50-μm fraction		
Clay	—	27	31	32		26		
				Monona soil — interrill plus rill erosion				
Sand	3	2	3	10	0	0	0	0
Silt	68	67	65	59	79	87	75	51
Clay	29	31	32	31	21	13	25	49
				Ida soil — interrill erosion				
Sand	—	2	3	12		0		
Silt	—	73	70	62		81 for < 50-μm fraction		
Clay	—	25	27	26		19		
				Ida soil — interrill plus rill erosion				
Sand	—	3	2	13		0		
Silt	—	73	73	63		81 for < 50-μm fraction		
Clay	—	24	25	24		19		

*Insufficient sample for analysis

fraction of the soil (Frere, 1976). Any conservation practice that induces deposition of the larger aggregates will significantly reduce the total N load being transported. The aggregates >50 μm were also enriched in total N when compared to the total N concentration of the matrix soil. For the Monona soil, the aggregates >50 μm were enriched in total N by about 10%, while the 250 to 50-μm aggregates were enriched by about 25%. Alberts and Moldenhauer (1981a) also found similar enrichment levels for a fertile agricultural soil in Indiana. The particles >50 μm, when analyzed as a single fraction, had a lower total N concentration than the matrix soil. When the particles <50 μm were separated into five fractions, the 35 to 20-μm fraction had the lowest total N concentration of any size fraction. This finding agrees with that of Alberts et al. (1981b). The total N concentration of the clay fraction was about 270% greater than the total N concentration of the large aggregates >50 μm.

Total N enrichment of the >50-μm aggregates was considerably higher for the Ida than for the Monona soil. The 2000 to 1000-μm fraction was enriched in total N by about 200% for the Ida soil. However, this size fraction contained little sediment (Fig. 1). The 1000 to 500- and 500 to 250-μm fractions were enriched by about 70%, while the 250 to 50-μm fraction was enriched by about 216%. The <50-μm fraction was not enriched in total N, which agreed with the findings for the Monona soil.

Total N concentrations were affected by the type of erosion process and the condition of the surface much more for the Ida than for the Monona soil. For the Ida soil, N concentrations of the aggregates >50 μm transported from the interrill erosion plots contained about 32% more N than did those aggregates transported from the interrill plus rill erosion plots. Particle selectivity during the erosion process is associated with the interrill component (Foster and Meyer, 1975). Generally, selectivity is associated primarily with a change in the particle-size distribution. However, selectivity can also occur within a given size fraction. Selectivity decreased, however, when rilling occurred on the Ida soil.

Total N concentrations of the >50-μm aggregates transported from the plots during the first runoff event after tillage were about 17% higher than those of the aggregates transported from the second runoff event. Selectivity during the erosion process is also dependent upon the condition of the soil surface. Tillage loosened large aggregates which created micro-depressions on the surface. Particle sorting occurred as runoff ponded temporarily behind the aggregates and in other micro-depressions. This ponding continued until most of the large aggregates had been broken down and the micro-depressions filled. The condition of the soil surface prior

TABLE 4. TOTAL NITROGEN CONCENTRATIONS OF ERODED SOIL AGGREGATES.

Initial soil condition	Total N concentrations of aggregates in size fractions, μm								
	2000-1000	1000-500	500-250	250-50	50-35	35-20	20-10	10-2	<2
	μg N/g sediment								
				Monona soil — interrill erosion					
Dry	2210	1910	1960	2240		1760	for < 50-μm fraction		
Wet	2020	1830	1980	2260		1550			
				Monona soil — interrill plus rill erosion					
Dry	2020	1910	2030	2130	1350	900	1720	3520	5360
Wet	1890	1830	1960	2420		1640	for < 50-μm fraction		
				Ida soil — interrill erosion					
Dry	2450	1620	1680	2080		640	for < 50-μm fraction		
Wet	1920	1540	1470	1790		620			
				Ida soil — interrill plus rill erosion					
Dry	1410	1260	1420	1760		640	for < 50-μm fraction		
Wet	1140	1100	1280	1550		610			

to the second runoff event was quite different. The soil had consolidated some and most of the large aggregates and micro-depressions had disappeared. This alteration in the condition of the soil surface improved sediment delivery because of the decrease in particle sorting during transport.

Particle sorting is generally associated with a change in the size distribution of the eroded aggregates, and these differences do exist (Fig. 1). However, we have shown that particle sorting can also occur within well-defined size fractions of the sediment. Most of this sorting probably occurs because of differences in aggregate density. Particles of a given size must range in composition from those that are coarser textured (more sand and coarse silt) to those that are finer textured (more fine silt and clay). Differences in the type and percentage of primary particles comprising the aggregates lead to differences in aggregate density. Aggregate densities have been measured for certain size fractions of the sediment (Long, 1964). However, no research has evaluated aggregate density as a function of transport capacity. This is an important research need. Aggregate density should be inversely related to the percentage of clay and fine silt comprising the aggregates. However, Young (1980) showed that the density of uneroded aggregates was inversely related to the silt content. It is an important research need to better understand the factors that affect the density of eroded aggregates.

Phosphate Sorption-Desorption Isotherms of Eroded Aggregates

Phosphate sorption-desorption isotherms for the 2000 to 1000-, 1000 to 500-, 500 to 250-, and 250 to 50-μm aggregates eroded from the Monona interrill plus rill plots were developed to compare the relationship between the intensity factor (soluble P concentration) and capacity factor (amount of P sorbed) for each fraction (Fig. 4a and b). Similar types of comparisons have been made for soils by Taylor and Kunishi (1971) and McDowell and McGregor (1980). Because the aggregates were transported in runoff and separated by wet sieving, variable amounts of P sorption or desorption may have occurred. Thus, observed equilibrium phosphorus concentrations or EPC's (the P concentration at which no sorption or desorption occurs) may not be directly comparable among size fractions or valid indications of expected P concentrations in runoff. However, the slopes of the isotherms, often termed the buffer capacity or buffer power, should give a relative indication of the availability of sites for sorption or desorption on the solid phase for the equilibrium time used (2 h). Although the primary particle composition of these aggregates are quite similar (Table 3), the buffer power generally increased with decreasing aggregate size. This finding suggests that smaller aggregates have a higher capacity to buffer soluble P levels because of a larger number of accessible sorption sites. The EPC's of the 2000 to 1000-, 1000 to 500-, and 250 to 50-μm aggregates were similar (Fig. 4a). Thus, estimates of sediment labile P obtained by extrapolating the sorption-desorption isotherm to zero soluble P should be comparable. These estimates are 7, 13, and 23 μg P/g sediment labile P for the 2000 to 1000-, 1000 to 500-, and 250 to 50-μm aggregates, respectively, and were made by

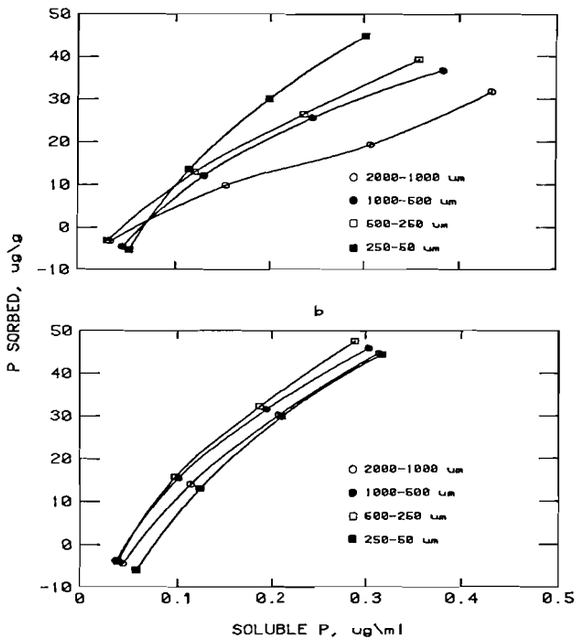

Fig. 4—Phosphate sorption-desorption isotherms for (a) natural aggregates and (b) mechanically dispersed aggregates from the Monona interrill plus rill erosion plots.

extrapolating the line defined by the lower two points on the curve (Kunishi and Taylor, 1977). This finding indicates that, at a common EPC, smaller aggregates will transport greater quantities of labile P per gram. Sediment labile P concentrations were not related to the external surface areas of the aggregates, however. Calculated external surface areas for the 2000 to 1000-, 1000 to 500-, 500 to 250-, and 250 to 50-μm aggregates were 15, 30, 60, and 151 cm^2/g, assuming spherical aggregates for the midpoint size within each fraction. This finding suggests that more sites are accessible per unit external surface area for the 2000 to 1000- and 1000 to 500-μm aggregates, which may partially relate to differences in the percentage and size of pores among the various aggregates. The relative importance of these differences in runoff will depend on the amount of material eroded in each of the above fractions as well as the sediment labile P concentrations and amounts eroded for other-sized aggregates and primary particles. Further research comparing amounts of sediment labile P over a wider range of particle sizes is needed.

Sorption-desorption isotherms for aggregates dispersed by sonification have a common shape indicating similar buffering powers (Fig. 4b). These curves are similar to that for the 250 to 50-μm aggregates (Fig. 4a), suggesting that the accessibility of sites is not restricted by aggregation for this size fraction. If the accessibility of P sorption sites is not restricted for the <50-μm aggregates, as this data suggests, then the sediment labile P concentration and buffer power of a given fraction should be related to its clay content, which can vary widely among the <50-μm fractions (Table 3). However, solutions equilibrated with sonified samples were observed to have a more intense yellow color than those for the aggregated samples. This observation indicates that sonification may have increased levels of dissolved organics, which could bias the shape of the

sorption-desorption curves by blocking sites for P sorption. Further research is needed to establish the suitability of sonification as a means of non-chemically disrupting aggregates.

SUMMARY

We studied some physical and chemical properties of aggregates eroded from two fertile agricultural soils in southwestern Iowa. We found that:

1. D_{50} aggregate sizes increased as rilling occurred, with the effect more pronounced for a better structured soil.
2. Clay and total N concentrations of the >50-μm aggregates were higher than those of the 50 to 10-μm aggregates.
3. Clay and total N enrichment occurred for all aggregates >50-μm, with the effect related to the amount of particle sorting that occurred during transport.
4. EPC curves varied with aggregate size and suggested that 250 to 50-μm aggregates transported in runoff were of greater relative importance in buffering soluble P levels and in transporting labile P than larger aggregates.
5. Field sieving by inserting a stacked nest of sieves directly in runoff trapped some particles smaller than the nominal screen size. Samples for aggregate analysis can be stored at room temperature for 84 days without affecting the aggregate size distribution.

References

1. Alberts, E. E., and W. C. Moldenhauer. 1981a. Nitrogen and phosphorus transported in eroded soil aggregates. Soil Sci. Soc. Am. J. 45:391-396.
2. Alberts, E. E., W. C. Moldenhauer, and G. R. Foster. 1980. Soil aggregates and primary particles transported in rill and interrill flow. Soil Sci. Soc. Am. J. 44:590-595.
3. Alberts, E. E., W. H. Neibling, and W. C. Moldenhauer. 1981b. Transport of sediment nitrogen and phosphorus through cornstalk residue strips. Soil Sci. Soc. Am. J. 45:1177-1184.
4. Day, Paul R. 1965. Particle fractionation and particle size analysis. In: C. A. Black (ed.) Methods of soil analysis. Part 1. Agronomy 9:545-566. Am. Soc. of Agron., Madison, WI.
5. Foster, G. R., L. J. Lane, J. D. Nowlin, J. M. Laflen, and R. A. Young. 1980. A model to estimate sediment from field-sized areas. p. 36-64. In: Walter G. Knisel (ed.): CREAMS, A field scale model for chemicals, runoff, and erosion from agricultural management systems. Vol. 1. USDA Rep. No. 26.
6. Foster, G. R., and L. D. Meyer. 1975. Mathematical simulation of upland erosion using fundamental erosion mechanics. Proc. Sediment Yield Workshop, USDA Sedimentation Lab., Oxford, MS ARS-S-40:190-207.
7. Frere, M. H. 1976. Nutrient aspects of pollution from cropland. Vol. II. U.S. EPA Rep. No. EPA 600/2-75-026b. USDA Rep. No. ARS-H-5-2.
8. Genrich, D. A., and J. M. Bremner. 1972. A reevaluation of the ultrasonic-vibration method of dispersing soils. Soil Sci. Soc. Am. Proc. 36:944-947.
9. Kemper, W. D., and W. S. Chepil. 1965. Size distribution of aggregates. In: C. A. Black (ed.) Methods of soil analysis. Part 1. Agronomy 9:499-509. Am. Soc. of Agron., Madison, WI.
10. Kemper, W. D., and E. J. Koch. 1966. Aggregate stability of soils from western United States and Canada. Tech. Bul. No. 1355, USDA. U.S. Government Printing Office, Washington, DC.
11. Kunishi, H. M. and A. W. Taylor. 1977. Predicting pollution potential of phosphorus at heavy application rates. p. 349-356. Proc. Intl. Seminar on Soil Environment and Fertility Management in Intensive Agriculture, Tokyo, Japan.
12. Lattanzi, A. R., L. D. Meyer, and M. F. Baumgardner. 1974. Influence of mulch rate and slope steepness on interrill erosion. Soil Sci. Soc. Am. Proc. 38:946-950.
13. Long, D. C. 1964. The size and density of eroded soil material. M.S. Thesis, Iowa State University, Ames, IA.
14. Massey, H. F., and M. L. Jackson. 1952. Selective erosion of soil fertility constituents. Soil Sci. Soc. Am. Proc. 16:353-356.
15. McDowell, L. L., and K. C. McGregor. 1980. Nitrogen and phosphorus losses in runoff from no-till soybeans. TRANSACTIONS of the ASAE 23(3):643-648.
16. Mebias, L. J. 1960. A rapid method for the determination of organic carbon in soil. Anal. Chim. Acta 22:120-124.
17. Meyer, L. D., G. R. Foster, and S. Nikolov. 1975a. Effect of flow rate and canopy on rill erosion. TRANSACTIONS of the ASAE 18(5):905-911.
18. Meyer, L. D., G. R. Foster, and M. J. M. Römkens. 1975b. Mathematical simulation of upland erosion using fundamental erosion mechanics. Proc. of Sediment Yield Workshop, USDA Sedimentation Laboratory, Oxford, MS ARS-S-40:177-189.
19. Meyer, L. D., W. C. Harmon, and L. L. McDowell. 1980. Sediment sizes eroded from crop row sideslopes. TRANSACTIONS of the ASAE 23(4):891-898.
20. Murphy, J., and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.
21. Nelson, D. W., and L. E. Sommers. 1972. A simple digestion procedure for estimation of total nitrogen in soils and sediment. J. Environ. Qual. 1:423-425.
22. Onstad, C. A., R. A. Young, M. A. Otterby, and R. F. Holt. 1979. Sediment yield modeling for 208 planning. p. 25-32. In: A. E. Peterson and J. B. Swan (ed.): Universal soil loss equation: past, present, and future. Soil Sci. Soc. Am., Madison, WI.
23. Piest, R. F., J. M. Laflen, and R. G. Spomer. 1980. Integrated erosion studies for improved sediment transport models. ASAE Paper No. 80-2029, ASAE, St. Joseph, MI 49085.
24. Sharpley, A. N., R. G. Menzel, S. J. Smith, E. D. Rhoades, and A. E. Olness. 1981. The sorption of soluble phosphorus by soil material during transport in runoff from cropped and grassed watersheds. J. Environ. Qual. 10:211-215.
25. Spomer, R. G., A. T. Hjelmfelt, and R. F. Piest. 1981. Conservation aspects of selected tillage systems on western Iowa cornfields. p. 216-225. In: Crop Production with Conservation in the 80's. Proceedings of the ASAE Conference, December 1980. ASAE, St. Joseph, MI 49085.
26. Swanson, N. P. 1965a. Rotating-boom rainfall simulator. TRANSACTIONS of the ASAE 8(1):71-72.
27. Swanson, N. P., A. R. Dedrick, and H. E. Weakly. 1965b. Soil particles and aggregates transported in runoff from simulated rainfall. TRANSACTIONS of the ASAE 8(3):437, 440.
28. Taylor, A. W., and H. M. Kunishi. 1971. Phosphate equilibrium on stream sediment and soil in a watershed draining an agricultural region. J. Agric. Food Chem. 19:827-831.
29. Technicon Industrial Systems. 1978. Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Industrial Method No. 329-74W/B. Tarrytown, NY.
30. Walker, T. W., and A. F. R. Adams. 1958. Studies on soil organic matter: 1. Influence of phosphorus content of parent materials on accumulations of carbon, nitrogen, sulphur, and organic phorphorus in grassland soils. Soil Sci. 85:307-318.
31. Wischmeier, W. H., C. B. Johnson, and B. V. Cross. 1971. A soil erodibility nomograph for farmland and construction sites. J. Soil Water Conserv. 26:189-195.
32. Wischmeier, W. H., and D. D. Smith. 1978. Predicting rainfall erosion losses—A guide to conservation planning. Agric. Handb. No. 537. USDA-SEA, Washington, DC.
33. Yoder, R. R. 1936. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. J. Am. Soc. Agron. 28:337-351.
34. Young, R. A. 1980. Characteristics of eroded sediment. TRANSACTIONS of the ASAE 23(5):1139-1146.