85-139-A

ASAE Publication 8-85

Erosion and Soil Productivity

Proceedings of the
National Symposium on Erosion
and Soil Productivity

December 10-11, 1984
Hyatt Regency New Orleans
New Orleans, Louisiana

Published by
American Society of Agricultural Engineers
2950 Niles Road
St. Joseph, Michigan 49085-9659

Library of Congress Card Number (LCCN) 85-70630
International Standard Book Number (ISBN) 0-916150-69-0

AMOUNT AND NUTRIENT CONTENT OF PARTICLES PRODUCED BY SOIL AGGREGATE ABRASION

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From studies of wind erosion in wind tunnels and on farm fields, much practical knowledge about the physics of wind erosion has been amassed (Chepil and Woodruff 1963). During wind erosion, saltating particles abrade the surface aggregates. Typically, both the aggregates and the saltating particles (≈ 100 to 840 μm diameter) break down under impact and contribute to the suspension-size particles (< 100 μm diameter), which are transported beyond stable field boundaries. The fine suspension-size particles (< 50 μm in diameter) can be transported tens of kilometers by the wind. However, much is still unknown about the relative importance of the various factors which control the creation and emission of fine particles during wind erosion.

Because many variables, such as impacting particle velocity, are usually unknown in the field, a laboratory study of aggregate abrasion was designed where many of the variables could be controlled. One objective of the study was to determine the amount of suspension-size particles produced, as influenced by velocity, impact angle, diameter, and texture of the impacting saltation-size particles and the stability of the target aggregates. A second objective was to determine the nutrient content of the saltation-size and fine suspension-size particles created, compared to their parent aggregates to check for nutrient enrichment. Soil samples trapped in field saltation catchers also were checked for available phosphorus enrichment.

REVIEW OF LITERATURE

In the field, the factors that control soil aggregate production and degradation include cropping systems, microorganisms, earthworms, cultivation, and climate (Harris et al. 1966). Soil aggregates > 1.0 mm in diameter, which occur at a given location, show little variation in either chemical composition or texture (Tabatabai and Hanway 1968). However, at aggregate sizes below 1.0 mm in diameter, differences appear among aggregate size fractions when soil is fragmented in water using agitation or ultrasonic dispersion to reduce aggregate size (Chichester 1969, Cameron and Posner 1979).

Differences in texture between the parent soil and suspension-size particles created by wind erosion also have been reported. From observations of wind-eroded fields, Chepil (1957) found that silt was more readily depleted from eroding soil than were the sand or clay portions. He also found that wind erosion caused little textural change in loess soils but tended to remove the fine constituents from coarse-textured soils, leaving the sand behind.

Contribution from the U.S. Department of Agriculture, Agricultural Research Service, in cooperation with the Dept. of Agronomy and the Kansas Agricultural Experiment Station. Contribution 85-139-A.

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Gillette (1977) measured the vertical (suspension) flux of particles < 20 μm diameter caused by wind erosion and the total horizontal (saltation and creep) soil flux on several fields. He found that ratios of the vertical to horizontal flux had great scatter on sandy soils and there was little evidence of a trend with windspeed. For loamy soils there was a large increase in the flux ratio as windspeed increased. In general, he found that finer textured soils produced a higher ratio of vertical to horizontal flux than coarse-textured soils, except for a clay soil where the small aggregates were stable enough to resist impact breakage.

Nutrient enrichment of wind-eroded suspension or saltation-size particles has been little studied. However, in some preliminary work, Merva and Peterson (1983) reported that total phosphorus measured in wind-eroded material deposited on snow was very large compared to total phosphorus in waterborne sediment. They suggested further study of this phenomenon.

Although the creation and emission of fine particles are complicated processes, there is a need to determine how various factors control these processes so that creation and emission of fine particles can be calculated in simulation models on a field scale for a wide variety of soils. Earlier, Hagen (1984) reported how impact particle factors and target aggregate stability controlled total abrasive erosion from target aggregates. This report is a continuation of the earlier analysis, with emphasis on the production of fine suspension-size particles during abrasion.

EXPERIMENTAL PROCEDURES

A commercial sandblasting nozzle was used to abrade individual soil aggregates (4 to 8 cm diameter) with weighed amounts of abrader. The aggregates were placed inside a cyclone separator during abrasion and both the abrader and abraded soil were collected in various parts of an abrasion sampling apparatus (Fig. 1). The abrasion apparatus was designed to aerodynamically separate particles < 100 μm diameter and trap them in the largest cyclone, while finer particles were trapped in both cyclone separators, as well as on the impaction plates.

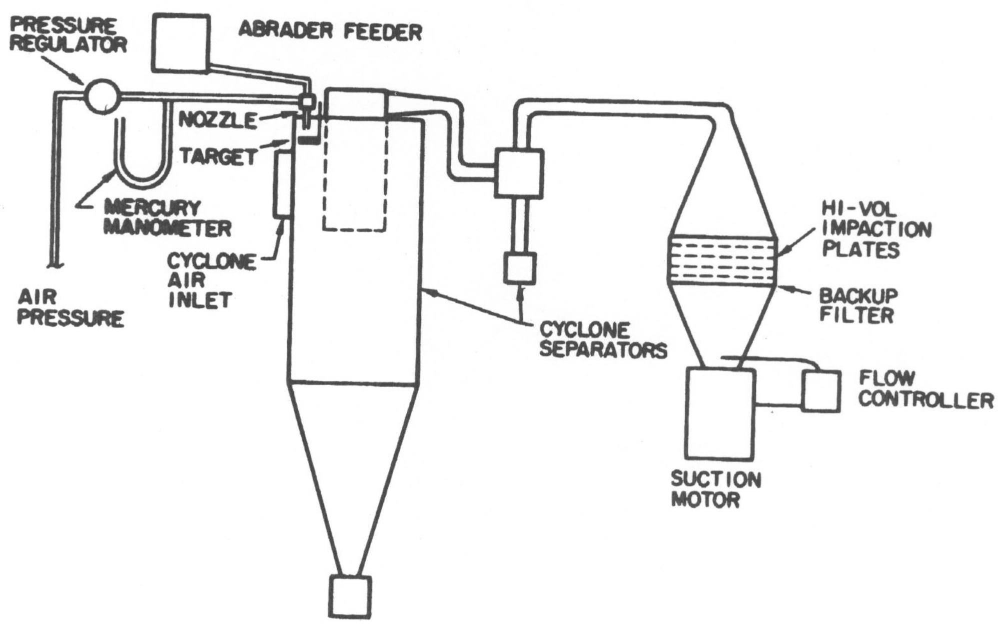

Fig. 1 Abrasion Apparatus Schematic

Because of the probability of creating new fine particles during sieving small amounts of fine particles (< 53 μm diameter) from the large amounts of sand abrader trapped in the large cyclone, 10 calibration tests with small amounts of soil abrader were performed to relate total production of fine particles to those trapped in the small cyclone and on the impaction plates. A regression equation with coefficient of determination (R^2) of 0.97 then was used in subsequent abrasion tests to predict total fine particle production, based on the subsamples collected in the small cyclone and on the impaction plates. During both calibration and abrasion tests, a steady flow of 9.44 L/s (20 ft^3/min) at STP was maintained in the abrasion apparatus by the flow controller. The sandblasting nozzle also was calibrated using procedures described elsewhere (Hagen 1984).

For the abrasion tests, soil samples of Haynie very fine sandy loam and Wymore silty clay loam were collected from the surface of tilled fields and air-dried. The soil samples then were rotary sieved to separate the fractions to be used as targets and abrader. In addition, local quartz river sand also was washed and sieved for use as an abrader. The three sieved size fractions used for abrader were 100 to 150, 290 to 420, and 590 to 840 μm in diameter. One side of the target aggregates was leveled with a knife for use as the impaction surface.

Four impact velocities (V_p) were used for each abrader size. The various V_p were obtained by varying the nozzle air pressure and ranged from 400 to 1200 cm/s for the smallest abrader particles to 300 to 900 cm/s for the largest. Two to 6 g of soil were abraded from target aggregates. Soil abrader was always the same texture as the target aggregate, while sand abrader was used on targets of all textures. Three abrader impact angles (α) of 15, 30, and 90 degrees were obtained by changing the angle of the nozzle relative to the impact surface.

After abrasion, each target aggregate was subjected to a drop-shatter test similar to that described by Farrell et al. (1967). The aggregates were dropped inside a tube onto a concrete floor from a height of 2 to 3 m, and the resultant particle size distribution was determined by sieving. Energy input to the aggregate was calculated from the drop height. New surface area created by the drop was calculated from the size distribution, assuming that the particles were spherical. The ratio of energy input to new surface area created was used as a measure of aggregate stability (S_a).

The amount of fine particles (WF) created during abrasion of aggregates was analyzed using multiple regression of the following primary variables:

$$WF = f(\alpha, d_p, V_p, S_a, AM, W) \tag{1}$$

where WF is the ratio of fine suspension-size particles (< 53 μm diameter) in g per kg of abrader, α is angle of abrader impact in degrees, d_p is average abrader diameter in μm, V_p is average particle impact velocity in cm/s, S_a is average stability of 4 aggregates in J/m^2, AM is abrader mass in g, and W is the ratio of total predicted abrasive erosion from the targets in g per kg of abrader. Regression equations for W were presented in an earlier report (Hagen 1984).

Secondary variables constructed from the primary variables and their interactions also were added to the data set. Each data observation of WF was based on collection of fine particles from four target aggregates. Because no single equation produced a satisfactory fit, separate regression equations for WF were calculated for three data sets: (a) 67 observations of sand abrader on both soil textures, (b) 53 observations of soil abrader on very fine sandy loam, and (c) 18 observations of soil abrader on silty clay loam aggregates. Most of the observations in the latter data set were made with α = 15 degrees.

From the two soils studied in the abrasion tests, composite samples of seven size fractions (treatments) of each texture were prepared for chemical and textural analysis. These fractions included suspension-size (< 53 μm diameter) trapped in small cyclone, three saltation sizes used as abrader, parent oil aggregates, and < 53 μm and 53 to 250 μm particles created by crushing and sieving parent aggregates. In addition, four similar size fractions (treatments), excluding the three saltation sizes, of a Keith silt loam soil also were prepared. Each soil fraction was analyzed for nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), available phosphorus (P), potassium (K), and organic matter (OM). Duncan's multiple range tests were used to test for differences in nutrient contents among the various size fractions.

Eroded saltation-size soil particles/aggregates collected in wind erosion (Bagnold) catchers (1977-78) located in Major Land Resource Areas (MLRA) 72 and 77 (Nebraska, Colorado, Kansas, Oklahoma, New Mexico, and Texas) were analyzed for available phosphorus. The erosion catchers were located on both cropland and rangeland sites according to soil wind erodibility groups (WEG) (Table 1). To make comparisons with the eroded material, residual (parent) soil samples to 5.1 cm depth obtained within 15 m of each catcher also were analyzed for available P. All the nutrient analyses were performed at the Kansas State University Soil Testing Laboratory.

Table 1. Soil Wind Erodibility Groups (WEG)

WEG	Predominant soil texture class of surface layer	Dry soil aggregates over 0.84 mm	Wind erodibility index (I)
		%	t/(ha·yr)
1	Very fine sand, fine sand, sand, or coarse sand.	1	695
		2	561
		3	493
		5	404
		7	359
2	Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic materials.	10	300
3	Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam.	25	193
4	Clay, silty clay, noncalcareous clay loam, or silty clay loam with more than 35 percent clay content.	25	193
4L	Calcareous loam and silt loam, or calcareous clay loam and silty clay loam.	25	193
5	Noncalcareous loam and silt loam with less than 20 percent clay content, or sandy clay loam, sandy clay, and hemic organic soil material.	40	126
6	Noncalcareous loam and silt loam with more than 20 percent clay content, or noncalcareous clay loam with less than 35 percent clay content.	45	108
7	Silt, noncalcareous silty clay loam with less than 35 percent clay content and fibric organic soil material.	50	85
8	Soils not suitable for cultivation due to coarse fragments or wetness, wind erosion not a problem.	--	--

RESULTS AND DISCUSSION

Suspension-Size Predictions

To find prediction equations for WF, a number of multiple linear regression models were considered. Using a stepwise regression procedure, the best six-variable model found to predict WF for sand abrader was

$$WF = 17.79 + 0.002293\ W^2 - 8.41 \times 10^{-6}\ W^3 - 0.05705\ d_p + 5.97 \times 10^{-5}\ d_p^{\ 2} - 0.04 \times 10^{-7}\ d_p\ V_p^{\ 2} + 4.9 \times 10^{-7}\ \alpha V_p^{\ 2}. \qquad (2)$$

The coefficient of multiple determination (R^2) for this model was 0.87. When using sand abrader, the only source of WF was the target aggregates, and the relative proportion of WF to total aggregate abrasive erosion (W) varied with test conditions (Fig. 2). As S_a increased, the relative proportion of WF increased at low velocities. This was probably because the slowest particles did not have enough kinetic energy to remove large fragments upon impact. However, W at an S_a of 8.0 J/m^2 was about 1/4 the value of W at 2.0 J/m^2 (Hagen 1984), so the absolute value of WF decreased as S_a increased using sand abrader.

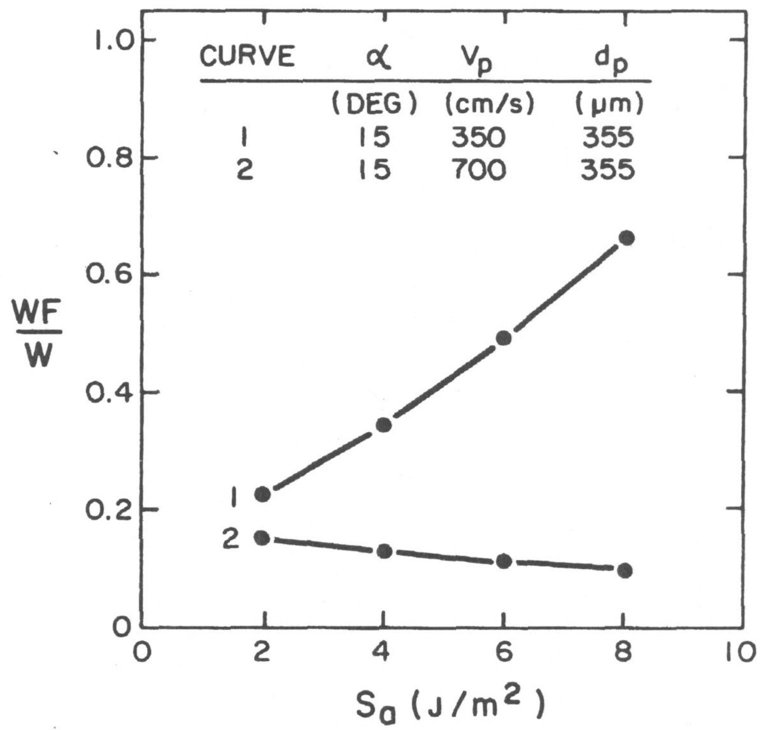

Fig. 2 Predicted Ratio of Suspension-Size (< 53 µm Diameter) to Total Erosion from the Target for Sand Abrader as a Function of Aggregate Stability and Abrader Velocity

For very fine sandy loam, the best seven-variable model found was

$$WF = 73.85 + 44.623\ S_a - 4.9476\ S_a^{\ 2} - 2.794\ \alpha + 0.03169\ \alpha^2 - 0.03653\ S_a\ d_p + 3.8 \times 10^{-7}\ \alpha V_p^{\ 2} - 0.04569\ AM. \qquad (3)$$

The R^2 for the preceding model was 0.79. The decrease in WF as Am increased suggests that the target surfaces became smoother as abrasion progressed.

For an AM of 200 g per target, WF of both very fine sandy loam and sand abrader increased with V_p but decreased with d_p as plots of Eq. (1) and (2) show (Fig. 3). Using soil abrader caused a three- to fifteenfold increase in WF over sand abrader for the conditions plotted. A portion of the increased WF may come from the target aggregates, because the soil abrader tends to fragment on impact. However, the majority of the WF came from the soil abrader. Average S_a for the very fine sandy loam target aggregates was 2.3 $\pm$ 1.33 J/m^2.

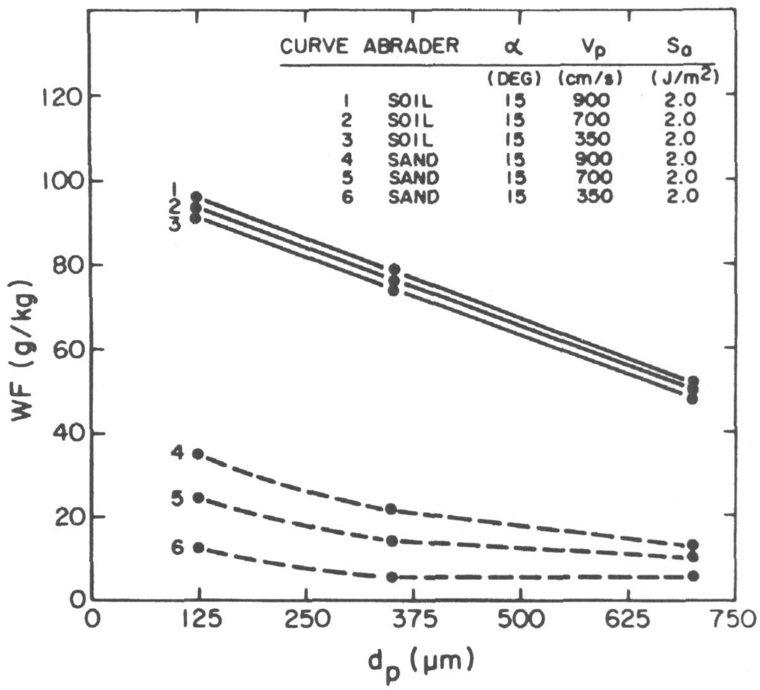

Fig. 3 Predicted Production of Fine Particles (< 53 μm Diameter) from Very Fine Sandy Loam Aggregates Per kg of Impacting Sand (Dashed Lines) and from both Aggregates and Very Fine Sandy Loam Abrader (Solid Lines) as a Function of Abrader Velocity and Diameter

For silty clay loam abrader, the best eight-variable model found was

$$WF = 238.31 - 0.6837\ W^2 + 0.010155\ W^3 + 2.9727\ S_a{}^2 + 0.6219\ V_p - 0.059534\ S_a\ V_p - 1.49671\ \alpha\ S_a + 0.187702\ W^2\ \alpha - 0.3262\ AM. \quad (4)$$

The R^2 for the preceding model was 0.81. For typical tests with AM of 500 g per target, the WF of silty clay loam abrader followed trends similar to that of fine sandy loam abrader (Fig. 4). Under similar test conditions, the silty clay loam abrader produced higher WF than the very fine sandy loam abrader. In contrast, the sand abrader on silty clay loam produced lower WF than on the fine sandy loam targets. This effect was probably due to the stability of the silty clay loam targets, which averaged 6.6 $\pm$ 3.7 J/m^2. As V_p and d_p increased, both abrader and abraded material broke into larger fragments (Fig. 4).

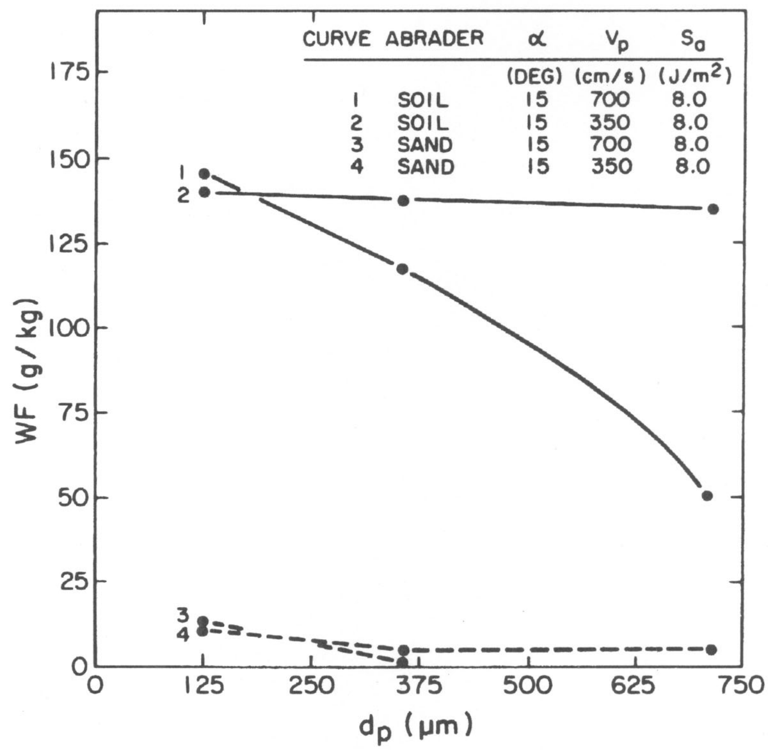

Fig. 4 Predicted Production of Fine Particles (< 53 μm Diameter) from Silty Clay Loam Aggregates Per kg of Impacting Sand Abrader (Dashed Lines) and from both Aggregates and Silty Clay Loam Abrader (Solid Lines) as a Function of Abrader Velocity and Diameter

For AM of 200 g per target, the effect of impact angle on very fine sandy loam targets is shown in Fig. 5. Increasing the angle of sand abrader increased WF slightly. However, WF for very fine sandy loam abrader decreased towards a minimum as α increased from 15 to 30 degrees but then increased sharply towards a maximum at 90 degrees. Evidently, normal impact is the most effective in breaking down the abrader and target to fine particles even though Hagen (1984) showed that total erosion from the targets was largest at 20- to 30-degree impact angles.

As field erosion proceeds, the initial saltation-size particles decrease in size and change in composition unless they were initially sand particles. Thus, the production of WF for the soil abrader in Eq. (2) and (3) should be viewed as maximums produced during the first few impacts. The production rate of new saltation-size particles by abrasion will determine if WF stays near the maximum during an erosion event. In contrast, the production of WF from sand abrader (Eq. 1) likely represents field minimums for impacts on stationary aggregates of a given stability. We have not studied WF production of saltation-size particles striking surface particles that move on impact but would speculate that WF production would be less than on stationary aggregate targets.

Mechanical analysis of the three soils showed that the surface of the silty clay loam soil was actually on the border between a silt loam and a silty clay loam and that its saltation-size particles became silt loam in texture after use as an abrader (Table 2). The mechanical analysis also showed that the suspension-size particles (< 53 μm) obtained by crushing and sieving parent soil aggregates produced a fraction enriched in silt primary particles.

Evidently, silt particles are easier to break down to suspension-size from the soil aggregates than are clay particles, which tend to remain in aggregates larger than suspension-size.

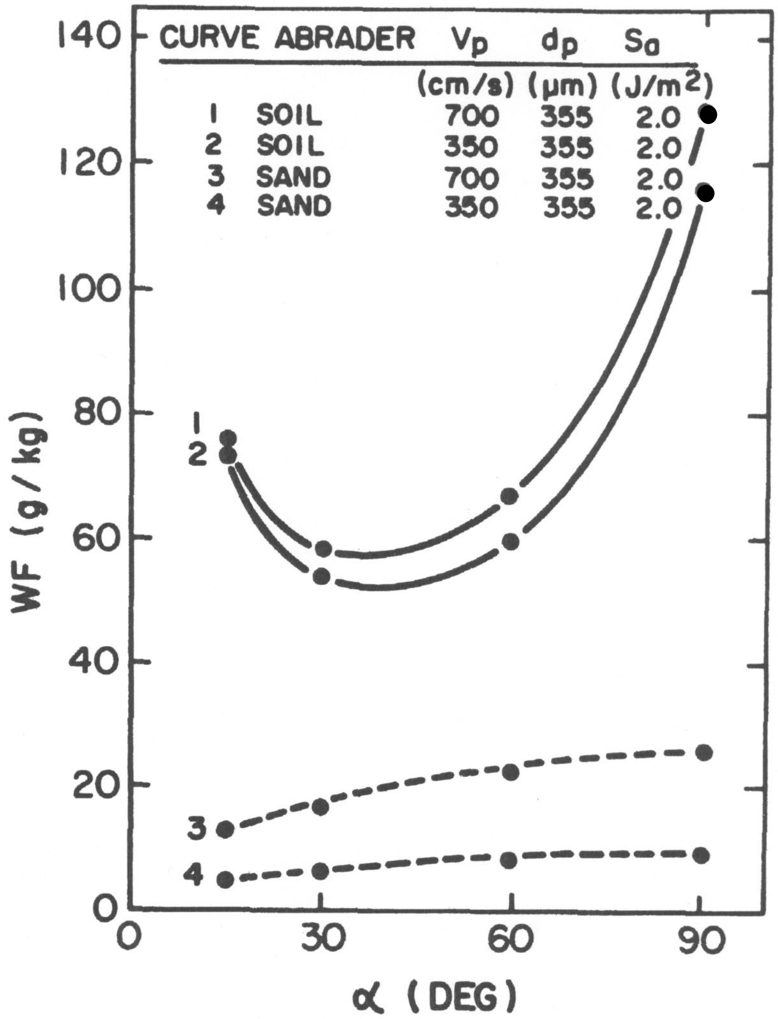

Fig. 5 Predicted Production of Suspension-Size Particles (< 53 µm Diameter) from Very Fine Sandy Loam Aggregates Per kg of Impacting Sand Abrader (Dashed Lines) and from both Aggregates and Very Fine Sandy Loam Abrader (Solid Lines) as a Function of Abrader Impact Angle and Velocity

Whether most coarse silt particles are suspended for long-range transport depends on the windspeeds during erosion events. Gillette et al. (1974) reported that trajectories of soil particles are significantly affected by settling when the ratio of particle sedimentation velocity (V_s) to wind friction velocity (u_*) is above 0.12 and less than 0.68. For a 40-µm-diameter particle, density 2.0 g/cm^3, settling velocity 10 cm/s, and u_* of 70 cm/s, the ratio is about 0.14. Thus, under strong erosive winds the silt fraction would be most likely to be abraded to suspension-size and carried long distances.

Table 2. Primary Particle Composition of Various Size Fractions

Treatment	Primary particle	Texture of parent soil: Very fine sandy loam	Silt loam	Silty clay loam
		(%)		
Eroded soil (μm)				
< 53	sand	0.07	0.01	0.01
	silt	79.16	72.48	75.36
	clay	20.77	27.51	24.63
100 - 150	sand	79.11		4.79
	silt	16.01		73.69
	clay	4.88		21.52
290 - 420	sand	76.36		5.18
	silt	18.87		74.49
	clay	4.77		20.33
590 - 840	sand	46.29		9.79
	silt	41.89		71.29
	clay	11.82		18.92
Parent soil (μm)				
< 53	sand	0.70	0.82	0.16
	silt	89.09	82.12	82.11
	clay	10.21	17.06	17.73
53 - 250	sand	77.86	32.05	15.78
	silt	16.67	49.38	63.88
	clay	5.47	18.57	20.95
Large aggregates	sand	55.78	15.40	5.11
	silt	37.16	65.77	71.17
	clay	7.06	18.84	23.72

For 40 μm diameter particles with u_* of 25 cm/s, the ratio V_S/u_* equals 0.4. Thus, under low erosive winds, particles in the coarse-silt range are subject to considerable aerodynamic separation from the suspended soil. In this study, abrasion followed by selective aerodynamic separation, as typified by the first treatment in Table 2, simulates the effect of low to moderate erosive windspeeds. The first treatment produced a suspension-size mixture enriched in both silt and clay primary particles compared to the parent soil. After abrasion, the two smallest saltation-size fractions of very fine sandy loam were higher in sand but lower in silt than the parent soil.

Nutrient Content

Nutrient concentrations of composite samples were similar for all size fraction treatments except the first one (Table 3). The nutrient content of the < 53 μm diameter soil in the first treatment was significantly greater than the whole parent soil in all cases at the 0.05 level except for NH_4-N, which was significant at the 0.10 level.

One can define enrichment ratios (ER) as the ratio of nutrients in the eroded soil to that in the parent soil. For treatment one, adding NO_3-N and NH_4-N gives an approximate ER for available N of 3.11. The ER for available P is 2.25, for K 1.67, and for OM 1.91. As one moves further from the wind erosion source area, the size distribution of particles tends to become finer than the size distribution in the immediate eroding area (Gillette, 1977). This downwind sorting will likely cause the ERs of suspended particles also to increase with distance from the source.

Table 3. Nutrient and Organic Matter Content of Various Soil Size Fractions

Treatment	No.[a]	NO_3-N	NH_4-N	P	K	OM
		(µg/g)				%
Eroded soil (µm)						
< 53	3	39.8 a[b]	32.8 c	95.2 e	816.7 g	4.77 i
100 - 150	2	23.5 ab	5.0 d	34.0 f	350.0 h	2.55 ij
290 - 420	2	18.1 b	4.6 d	31.3 f	337.5 h	2.10 j
590 - 840	2	27.7 ab	9.2 cd	39.0 f	395.0 h	2.90 ij
Parent soil (µm)						
< 53	3	16.0 b	9.2 cd	51.5 f	446.7 h	2.37 j
53 - 250	3	17.4 b	9.0 cd	43.5 f	408.4 h	2.67 ij
Large aggregates	3	15.4 b	8.0 cd	42.3 f	490.0 h	2.50 j

[a]Number of soil textures (observations) in each mean

[b]Treatment means followed by the same letter are not different at the 0.05 level using Duncan's multiple range test

Using the t-test to compare differences between P in windblown (eroded) and residual soils indicated significantly more P in windblown cropland samples for three of eight WEGs (Table 4). Results from similar tests on rangeland showed more P in three of seven WEGs. Data from cropland soils were more variable than those from rangeland soils, and 28 percent of P measurements on parent samples were larger than those from windblown samples. That compares to 13 percent for rangeland samples. Apparently, in some cases not enough observations were available to detect differences, e.g., WEG 5 soil on rangeland contained 5.1 times more P in windblown than residual samples but the means were not significantly different at the 95 percent level (only two observations were available).

Pooling all the cropland data without regard to WEG showed significantly larger amounts of P in windblown samples than residual samples, and the enrichment ratio was 1.43. The corresponding value for rangeland was 2.61. The larger ER on rangeland compared to cropland was probably due to a higher concentration of P in the surface because the surface layer was not mixed by tillage, and perhaps the erodible aggregates also contained more fine material on rangeland than on cropland.

These data show that the saltation-size particles moved by wind are often enriched in P relative to residual (parent) soils. The suspendible fraction that leaves the local area likely undergoes further enrichment, as suggested in Table 3.

SUMMARY AND CONCLUSIONS

During wind erosion, saltation particles abrade the surface aggregates. Typically, both the aggregates and saltating particles (≈ 100 to 840 µm diameter) break down and contribute to the suspension-size particles (< 100 µm diameter) which are transported beyond field borders. The fine suspension-size particles (< 53 µm diameter) can be transported tens of kilometers by the wind, but little is known about how various physical variables govern the creation of these fine particles and the final composition of the fine particles. A laboratory study of aggregate abrasion was designed in which many of the variables could be controlled.

Table 4. Available Phosphorus in Windblown and Residual Soil (0 - 5.1 cm) by Wind Erodibility Group (WEG). Windblown Soil Collected in Point Samplers in MLRA 72 and 77 (Colorado, Kansas, New Mexico, Nebraska, Oklahoma, and Texas)

WEG	Number of observations	Available phosphorus: Windblown (W)	Available phosphorus: Residual (R)	Enrichment ratio (W/R)
		(kg/ha) cropland		
1	20	33*[a]	21	1.57
2	20	66**[b]	34	1.94
3	14	60ns[c]	43	1.40
4	6	93	99ns	0.94
4L	10	67ns	29	2.31
5	2	44	46ns	0.96
6	34	83*	64	1.30
7	0			
8	2	60ns	33	1.82
Total	108	Av. 66**	46	1.43
		(kg/ha) rangeland		
1	12	42**	21	2.00
2	11	47**	21	2.24
3	6	64*	22	2.91
4	0			
4L	3	61ns	21	2.90
5	2	67ns	13	5.15
6	3	157ns	48	3.27
7	0			
8	2	75ns	23	3.26
Total	39	Av. 60**	23	2.61

[a]* - Significant at 95% level

[b]** - Significant at 99% level

[c]ns - Nonsignificant (< 95%)

One objective of the study was to determine the amount of fine particles (WF) produced per unit mass of abrader as influenced by velocity (V_p), impact angle (α), diameter (d_p), and texture of impacting saltation-size particles and the stability (S_a) of the target aggregates. A second objective was to compare the nutrient content of the saltation-size and fine suspension-size particles created to that of their parent aggregates to check for nutrient enrichment. Soil samples trapped in field saltation catchers also were checked for available P enrichment.

Individual aggregates (4 to 8 cm diameter) were placed inside a cyclone separator and a calibrated sandblasting device was used to abrade them with weighed amounts of abrader. Soil of the same textures as the aggregate and sand were used as the two abraders. Three regression equations were developed relating WF to V_p, α, d_p, S_a, AM, and W for sand, very fine sandy loam, and silty clay loam abraders. AM is abrader mass and W is predicted total abrasive erosion from the target aggregates.

The production of WF was influenced most by abrader texture. On very fine sandy loam targets (S_a = 2.0 J/m^2), using soil abrader increased WF 3 to 15 times compared to sand abrader, while on silty clay loam targets (S_a = 8.0 J/m^2), WF was always tenfold or more greater for soil than for sand abrader. Typical predicted values of WF were 5, 75, 4, and 138 g/kg for sand and soil abraders on very fine sandy loam and silt loam targets, respectively, with

d_p = 350 μm, V_p = 350 cm/s, and α = 15 degrees. Clearly, soil abrader was a larger source of WF than the target aggregates.

In general, WF decreased as d_p increased, while WF increased as α increased from 15 to 90 degrees. On very fine sandy loam, WF increased with V_p, but on silty clay loam at large d_p, the particles evidently broke into large fragments so WF decreased as V_p increased. While WF production from both soil abraders was initially large, the available WF in the very fine sandy loam abrader would be exhausted with fewer impacts than in silty clay loam.

The total erosion from the target aggregates decreased as S_a increased, but the proportion of the total that was WF arose at low V_p and remained nearly constant at high V_p. For sand abrader, WF ranged from 15 to 65 percent of the total soil eroded from the targets in typical test conditions.

Composite samples of the parent aggregates, saltation-size, and suspension-size particles for each soil texture used in the abrasion studies were analyzed for available nitrogen (N), available phosphorus (P), potassium (K), and organic matter (OM). If we define enrichment ratio (ER) as ratio of nutrients in particles to those in parent aggregates, then average ERs of particles < 53 μm in diameter derived from the laboratory abrasion studies were 3.11, 2.25, 1.67, and 1.91 for N, P, K, and OM, respectively.

Slightly abraded saltation-size particles in the laboratory tests usually had ERs > 1.0, but they were not statistically different than the large aggregates of their parent soils. However, soil particles trapped in a large number of field erosion catchers often had significantly more P than parent soils, and average ERs were 1.4 and 2.6 for available P on cropland and rangeland sites, respectively. The larger ER on rangeland compared to cropland probably was due to higher concentrations of P near the untilled rangeland surface. The enrichment data show that the saltation-size particles aerodynamically separated by the wind are often enriched in P and, as suspendible particles are created from them, they undergo further enrichment.

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