NITROGEN, PHOSPHORUS AND OTHER CHEMICALS IN SEDIMENTS FROM RESERVOIRS IN NORTH MISSISSIPPI[1/]

by

J. Roger McHenry, Jerry C. Ritchie, and Angela C. Gill[2/]

INTRODUCTION

Much interest and concern has developed in recent years concerning the pollution of the environment due to man's activities. This concern has included a controversy over the role that agricultural chemicals play in the pollution of natural waters. Water quality is affected by the characteristics of both the dissolved and suspended materials in the water (4)[3/]. Sediment produced from soil erosion has been called the major pollutant of surface waters in terms of absolute mass (1). Chemical pollutants from agricultural, commercial, industrial, and domestic sources are associated with the sediments from soil erosion. The role that agricultural fertilizers play in the pollution of natural waters concerns both the agriculturist and the general public (3). The capacity of lake or reservoir sediments to adsorb or exchange various elements or compounds from all input sources influences the concentration of these chemicals in the overlying waters (8).

Sediment samples were collected in 1969-72 from a number of reservoirs and lakes, and surface soil samples were collected from the contributing watersheds. The results of chemical analyses on samples collected in north Mississippi are presented and discussed in this report. The purpose of this study is to relate the chemical loading of these sediments with their origin and to the stresses placed on the system by man's activities.

MATERIALS AND METHODS

Sediment and soil samples were collected in 1969, 1970, and 1971 from five reservoirs and watersheds in northern Mississippi. The reservoirs selected for this report are briefly characterized in Table 1. The methods of sampling (5) and analyses (2) have been reported. The watersheds range in size from half a square mile to 1,545 square miles. Four of the

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2/ Research Chemist, Botanist, and Chemist, Oxford, Mississippi.

3/ Numbers in parentheses refer to reference citations.

watersheds are in the Tallahatchie River basin above Sardis Dam; the fifth is in Tallahatchie County on a tributary of the Yazoo River. All watersheds are in the hill country of north Mississippi. The soils on the hilltops and upper slopes are developed from loessial deposits; the soils on the lower slopes and eroded areas are derived from Coastal Plains deposits. The Askalmore reservoir is only a few miles from the bluff line separating the Delta from the hill country, and hence the loessial mantle is thicker than in the Tallahatchie River basin above Sardis. At one time, all the watersheds had cultivated areas. Presently, land above Powerline reservoir is not cultivated - the present cultivated acreage in the Puss Cuss, East Cypress, and Askalmore watersheds is limited and is decreasing. Acreages of improved pastures and pine plantations are increasing.

Sardis Reservoir was built as a flood control structure. The smaller dams were designed for both flood and sediment control. All have drop-inlet structures for control of the water level in the conservation or permanent pool. An emergency spillway controls the level of the flood pool which is several times the volume and area of the conservation pool. In the small reservoirs sediment samples were taken under water within the conservation pool. In Sardis Reservoir, some of the samples were taken under water, others were taken in the flood pool area after the water level had dropped below the elevations of the sampling sites.

The sediment profiles were completely sampled in East Cypress, Powerline and Puss Cuss; the Sardis profile was sampled only to 12 inches. This depth of sediment in this profile in Sardis Reservoir has been shown to have accumulated since the early 1950's - comparable in age to the sediments in the other reservoirs (6).

EXPERIMENTAL RESULTS

Sediments, collected from the five north Mississippi reservoirs, were enriched in clay (Table 2) but contained less organic material than the sampled surface soils from the contributing watershed. The enrichment of these sediments with clay reflects both the trap efficiency of the reservoirs for sediments and the selective segregation of eroded particles that occurs in the transport and deposition processes. The larger-sized particles move slower in transport than do the finer-sized particles and hence are deposited first in the slackwater above the reservoir or in the upper end of the conservation pool (delta area). The lack of enrichment of these sediments in organic material (nitrogen, carbon, oxidizable matter) reflects the relative low organic content of the soils in the hill area of north Mississippi and the large contribution to sediments from gully and other nonsheet erosion processes. These sources provide a clay enrichment due to selective transport but do not supply organic matter. For example, to obtain the enrichment of clay observed (16 to 24%) per unit weight of sediment from East Cypress, one and one-half units of material containing 16% clay would need to be eroded and delivered to the reservoir. In order to account for the approximate 50% reduction in organic matter, that accompanies the clay enrichment, the additional one-half unit of soil material should contain little or no organic matter. Subsoils in this area would satisfy this requirement as might materials from streambank erosion (older valley depositions).

The data given in Table 2 are mean values obtained for either the entire sediment profiles or for all 0- to 2-inch soil samples. Within the sediment profiles sampled, the measured parameters vary markedly (Table 3). The pattern of deposition illustrated by these data shows an increase of finer particles and of organic materials as one proceeds from the deeper to shallower - older to younger - sediments. This is undoubtedly the result of changes in land use within the contributing watershed and the effect of improved conservation practices which have been widely implemented in recent years.

Presently the public is acutely aware of environmental pollution and the words "phosphates" and "nitrates" are household words. In characterizing the sediments in these north Mississippi reservoirs, measurements of phosphorus (readily available) and of potassium (total) were made (Table 4) as well as previously indicated measurements of nitrogen. Data on the cation exchange capacity (CEC) also are included to permit an assessment of the relative potential nutrient adsorption values. In general, the greater the amount of colloidal material present, as clay or organic matter, the greater the adsorptive, or ionic exchange, capacity of the system. Sediments with greater amounts of clay, organic matter, or both will adsorb and release greater amounts of plant nutrients, i.e., N, P, K.

All sediments show a marked increase in inorganic phosphorus over that in the soils of the watershed. In two reservoirs, Sardis and Askalmore, organic phosphorus is also increased in the sediments. In the other three reservoirs, the decrease in content of organic phosphorus in the sediments is small compared with that of the watershed soils. The total potassium content also is found to increase in the sediments compared with that in the soils of the contributing area. In all examples, except Puss Cuss, CEC is increased in sediments, a direct reflection of the increased clay content.

The increase in phosphorus, particularly the inorganic form, in sediments of these north Mississippi watersheds indicates, perhaps, the recently increasing use of phosphates by man. This increase--73% in the Powerline sediments, 40% in East Cypress sediments, 91% in Puss Cuss sediments, 75% in Askalmore surface sediments, and 92% in Sardis sediments--may be due to the increased agricultural usage of phosphates. All watersheds, except Powerline, have cultivated land, and all watersheds have programs of pasture improvement. The relative distribution of phosphorus in the sampled sediments is illustrated in Table 5. These profiles are the same as those presented in Table 3. The content of inorganic phosphorus in the sediment profile increased from bottom to top, i.e., from older to newer deposits. The values for cation exchange capacities and clay percentages (Table 3) showed very similar trends. A close relationship between the clay content and CEC was expected. The correlation of inorganic P with CEC was highly significant (99%) for all sets of sediments. The statistical significance of the correlation of inorganic P and CEC was less positive for soils from the same sets of data.

The organic phosphorus content, in general, increased from the bottom to the top of the sediment profile. The actual amounts of organic P present were low, except perhaps in the Sardis Reservoir profile, and the organic P was variable in the East Cypress, Powerline, and Sardis profiles. The small reservoirs, whose waters drain into Sardis, contain significantly less organic and inorganic phosphorus in their sediments than does Sardis reservoir. The watersheds behind these reservoirs also contain lower percentages of cultivated land than exists in the Sardis watershed. Further, cultivated areas in general are known to contribute more runoff than noncultivated areas. All these facts point toward the conclusion that phosphorus is accumulating in reservoir sediments at a faster rate now than in past years. Also, sewage effluents from several cities (Oxford, New Albany, Pontotoc, Ripley) drain into Sardis reservoir. No settlement of any size is within the drainage area of the three smaller watersheds.

The content of potassium in the sediment profiles did not follow a general pattern. In Puss Cuss, an increase was observed in the K content of the more recent sediments; conversely, the K content of the illustrative Sardis profile was less than in the recent sediment. The results for Powerline were similar.

In the same context, the nitrogen content of the illustrated sediment profiles (Table 3) markedly increased in recent sediments. The increases were quite striking in the upper inches of these profiles, indicating a recent increased input of N to the system.

The number of farms, their acreages, and the tonnages of fertilizer used were obtained from data published in the Census of Agriculture (7). The average acreage per farm has increased steadily since 1950, while the total harvested acreage has decreased steadily (Table 6). The fertilizer usage has tended to increase on a harvested acre basis as shown below:

County	1969	1964	1959	1954
	COMMERCIAL FERTILIZERS, tons per harvested acre			
Lafayette	0.21	0.20	0.16	0.17
Tippah	0.19	0.24	0.17	0.18
Union	0.15	0.20	0.15	0.14

No data on the average plant nutrient content of the fertilizer was available. In the period 1949 to 1969, the practice of using 6-8-8 fertilizer changed to using 9-12-12 or even more concentrated mixes. The data presented are for harvested acres. The actual number of acres planted and fertilized would be larger. The tons of commercial fertilizer applied per planted acre would be slightly smaller than those calculated for harvested acres. The trend in fertilizer usage would not be affected. The three counties for which data are shown, all lie largely within the Sardis drainage area. Input from these areas would be highly representative of the total input to Sardis. The data do substantiate statements concerning increased fertilizer usage per acre. The total fertilizer tonnage in the area does show a decrease as shown here:

County	1969	1964	1959	1954
	COMMERCIAL FERTILIZERS, tons used			
Lafayette	6713	6806	6275	9540
Tippah	6021	10024	8104	10505
Union	7342	9737	8545	9775

These data are actual tonnages reported. Even allowing for a shift in plant nutrient content noted, no increase in fertilizer nutrients used within the drainage basin is apparent. To be sure, there is an increase in fertilizer used per harvested acre, but the reduction in harvested acres is large. The increased phosphorus content measured in the recent sediments of sampled reservoirs in north Mississippi (Table 5) was not due, it appears, to an increase in agricultural fertilizer use. Likewise, the increase of nitrogen in recent sediments (Table 3) did not appear to be the result of any extensive change in agricultural fertilizer use. The possibility of correlating the recent increases of P and N in sediments in Sardis Reservoir with increased urban and commercial waste discharges remains to be considered. That information is beyond the scope of this study. The sampled sediment profiles in the small upland reservoirs did show an increase in inorganic phosphorus (Table 5), but the increase was small compared with that for the profile from Sardis Reservoir. Inputs to these small reservoirs were strictly from agricultural areas. The same was true for nitrogen (Table 3). The input of total K, not known to be associated particularly with urban, commercial, or agriculture runoff or wastes, did remain relatively stable for both the small reservoirs and for Sardis.

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Table 1.--Characteristics of selected reservoirs and watersheds in north Mississippi.

Name	Location	Date of Construction	Watershed Area	Design Capacity
			mi^2	ac. ft.
Powerline (R-9-3)*	Lafayette Co., Miss.	1953	0.48	31
Puss Cuss (LT-14A-1)	Lafayette Co., Miss.	1962	65.6	1,853
East Cypress (LT-14A-6)	Lafayette Co., Miss.	1962	3.65	914
Askalmore (Y-17A-2)	Tallahatchie Co., Miss.	1959	5.99	1,928
Sardis	Panola, Lafayette, Marshall, Benton, Union, Pontotoc, Tippah Co., Miss.	1939	1545	1,569,900

* Soil Conservation Service identification numbers.

Table 2.--Relative particle-size distribution and organic matter concentration in sediments in selected north Mississippi reservoirs and in the surface soils of the contributing watershed.

Reservoir	Number of Samples	Sand > 50 μ %	Clay <2μ %	Nitrogen %	Carbon %	Oxidizable Organic Matter %
				(mean values)		
Powerline						
Soils 0-2"	17	34.83	13.49	0.083	1.38	2.75
Sediments	54	11.67	36.37	0.075	0.31	0.81
Puss Cuss						
Soils 0-2"	12	36.01	13.40	0.088	2.12	3.83
Sediments	11	21.65	15.02	0.039	0.35	0.46
East Cypress						
Soils 0-2"	23	34.58	15.99	0.095	1.60	2.89
Sediments	18	13.81	23.79	0.077	1.08	1.95
Sardis						
Soils 0-2"	15	23.77	17.97	0.095	1.37	2.43
Sediments	121	22.91	22.45	0.076	0.74	1.33
Askalmore						
Soils 0-2"	9	1.63	16.68	0.081	1.46	2.58
Sediments	5	1.81	28.58	0.067	0.52	0.90

Table 3.--Variation in particle-size distribution and organic matter content in profiles of sediments from north Mississippi Reservoirs.

Reservoir	Depth inches	Clay <2μ %	Sand > 50μ %	N %	C %	Oxidizable Organic Matter %
East Cypress	0-4	36.48	28.29	0.166	2.89	6.50
(71-S-1)*	4-8	21.25	29.00	0.113	1.55	3.67
	8-12	24.31	21.31	0.044	0.64	1.26
	12-16	25.30	20.76	0.047	0.54	1.05
	16-20	24.47	1.59	0.043	0.59	1.54
Powerline	0-4	68.32	0.12	0.062	0.44	0.16
(70-S-59)	4-8	50.25	0.14	0.061	0.25	0.25
	8-12	37.21	0.49	0.018	0.19	0.13
	12-16	37.48	0.70	0.024	0.23	0.70
	16-20	39.64	0.59	0.039	0.24	0.44
	20-24	22.69	24.68	0.074	0.25	0.10
Puss Cuss	0-6	18.30	4.23	0.083	0.72	1.07
(69-S-1)	6-12	15.20	23.40	0.046	0.51	0.76
	12-18	12.24	37.32	0.033	0.21	----
	18+	15.75	24.45	0.023	0.12	0.56
Sardis	0-1	73.63	2.38	0.275	2.99	5.40
(69-S-77)	1-2	55.78	2.09	0.226	2.27	4.60
	2-3	50.05	2.69	0.210	2.18	3.90
	3-4	45.97	4.46	0.140	1.49	2.15
	4-5	42.71	2.92	0.140	1.40	2.02
	5-6	51.83	0.95	0.150	1.65	2.54
	6-7	57.38	0.70	0.162	1.67	2.32
	7-8	55.09	0.62	0.159	1.63	3.06
	8-9	50.12	0.76	0.170	1.61	3.19
	9-10	45.09	0.93	0.164	1.57	2.90
	10-11	37.28	1.29	0.127	1.24	2.37
	11-12	33.61	2.28	0.118	1.29	2.32

*USDA Sedimentation Laboratory identification number.

(These are individual profiles and the average of the individual profile is not that reported for the reservoir as a whole.)

Table 4.--Phosphorus, potassium and nitrogen contents of sediments from selected north Mississippi reservoirs and of surface soils from contributing watersheds.

Reservoir	CEC meq/100 g	Organic P ppm	Inorganic P ppm	Total N %	Total K %
			(mean values)		
Powerline					
Soils 0-2"	5.67	57	113	0.083	0.97
Sediments	13.37	13	196	0.075	1.33
Puss Cuss					
Soils 0-2"	9.55	44	69	0.088	0.77
Sediments	7.22	35	132	0.039	1.24
East Cypress					
Soils 0-2"	12.09	59	129	0.095	0.97
Sediments	14.33	43	181	0.077	1.40
Sardis					
Soils 0-2"	11.98	54	172	0.095	1.30
Sediments	13.26	68	330	0.076	1.21
Askalmore					
Soils 0-2"	14.30	70	237	0.081	1.64
Sediments	18.61	117	416	0.067	1.87

Table 5.--Variation in phosphorus, potassium and cation exchange capacities in profiles of sediments from selected north Mississippi reservoirs.

Reservoir	Depth	CEC	Organic P	Inorganic P	Total K
	inches	meq/100 g	ppm	ppm	%
East Cypress	0-4	24.03	78	265	1.36
(71-S-1)	4-8	15.99	11	166	1.39
	8-12	14.34	3	174	1.34
	12-16	15.22	31	137	1.41
	16-20	14.46	34	134	1.36
Powerline	0-4	28.71	16	316	1.46
(70-S-59)	4-8	21.64	2	262	1.56
	8-12	12.51	8	170	1.52
	12-16	16.96	6	188	1.50
	16-20	17.40	16	225	1.61
	20-24	9.90	24	170	1.27
Puss Cuss	0-6	10.20	57	190	1.60
(69-S-1)	6-12	6.13	44	120	1.18
	12-18	5.02	22	110	1.17
	18+	4.83	15	95	1.00
Sardis	0-1	39.96	209	806	1.33
(69-S-77)	1-2	31.82	172	620	1.32
	2-3	30.43	107	548	1.39
	3-4	26.75	95	483	1.31
	4-5	24.40	76	454	1.29
	5-6	32.63	160	513	1.35
	6-7	28.23	107	660	1.36
	7-8	30.45	158	577	1.42
	8-9	26.08	93	535	1.41
	9-10	28.53	102	473	1.44
	10-11	20.88	45	343	1.48
	11-12	21.06	28	355	1.51

Table 6.--Changes in the number and size of farms and the acreages of harvested and pastured lands for three counties in Sardis watershed.

County	1969	1964	1959	1954	1949-50
Number of farms reported:					
Lafayette	948	1342	1682	2532	2925
Tippah	1403	1711	1937	2590	2980
Union	1334	1615	2034	3044	3564
Average size of reporting farms:					
Lafayette	235	172	151	117	106
Tippah	136	117	109	96	88
Union	128	109	90	74	65
Harvested acres of cropland:					
Lafayette	32000	33090	38680	56471	63876
Tippah	32514	41559	48916	58268	68570
Union	49506	48072	56345	67965	77310
Acres of pasture and grazing lands:					
Lafayette	35087	10564	14054	16705	11005
Tippah	21692	8703	8857	9214	10399
Union	25532	6105	12262	5621	19411
Total area of county - Acres					
Lafayette	387,840				
Tippah	296,960				
Union	270,080				