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SEASONAL CHANGES IN PARTICLE
SIZE DISTRIBUTION, COMPOSITION,
AND STRONTIUM EXCHANGE CAPACITY
OF PARTICULATE MATTER SUSPENDED
IN THE COLUMBIA RIVER

January 1972

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SEASONAL CHANGES IN PARTICLE SIZE DISTRIBUTION,
COMPOSITION, AND STRONTIUM EXCHANGE CAPACITY
OF PARTICULATE MATTER SUSPENDED IN THE COLUMBIA RIVER

By

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SUMMARY

A centrifugation method was employed to fractionate, according to equivalent spherical diameter, particulate matter suspended in the Columbia River during November, February, April, June and August. The isolated size fractions were characterized as to particle size distribution, carbon content, predominant primary and secondary minerals and strontium exchange capacity. The results were related to watershed characteristics and seasonal changes in river conditions.

Relative to other seasons, the concentration of suspended matter increased markedly (over 100 fold) during the spring freshet. This increase was accompanied by a change in particle size distribution with the clay size fraction ($<2.0 \mu$) accounting for approximately 63% of total solids compared to a range of 14 to 30% for other periods of the year. Of the total suspended sediment load in the spring 24% and 8% occurred in the <0.5 and $<0.2 \mu$ fractions, respectively.

Primary minerals inherited from parent rocks (quartz, feldspar and amphibole) and the layer silicate mineral species (mica-illite, chlorite and montmorillonite) were generally present in particulate matter isolated throughout the year. Whereas seasonal changes in the primary mineral composition were not pronounced, the relative concentrations of the layer silicate minerals commonly present in soils increased during spring and summer corresponding to the periods of spring runoff and the return of irrigation water to the river. Mineral composition also differed between size fractions. Montmorillonite, a layer silicate mineral of comparatively high ion exchange capacity increased in relative abundance with decreased particle size.

The Sr exchange capacity of materials isolated in the spring increased with decreased particle size ranging from 11.5 to 93.9 me./100g for the $>2.0 \mu$ and $<0.2 \mu$ fractions, respectively, likely reflecting relative differences in mineral type as well as increased reactive surface area. Increases in suspended particulate concentration due to spring runoff and the return of irrigation waters results in a large capacity for cation sorption and transport during the spring and summer months. In fact, the Sr exchange capacity of particulate matter in equivalent volumes of river water amounted to 6 to 26 times higher in the spring than during other periods of the year.

Seasonal Changes in Particle Size Distribution,
Chemical Composition, and Strontium
Exchange Capacity of Particulate Matter
Suspended in the Columbia River¹

INTRODUCTION

Mineral and organic detritus suspended in natural waters exert a direct influence on ion concentrations in solution (Garder and Skullberg, 1964; O'Conner and Renn, 1964). The extent of this influence may be expected to be a function of water and particulate properties. Particulate characteristics likely to be of primary significance in influencing ion exchange reactions include (1) particle size and configuration as reflected in particle surface area available for reaction and (2) particle composition as this influences the nature and density of surface charge (Farrar, et. al.; 1967; Ormsby et. al., 1962).

Surface area increases directly with decreased particle size, however minerals in the same size range but of different configuration may differ in exposed surface area. For example, minerals in the clay size range ($<2.0 \mu$) differ greatly in specific surface area, ranging from 10-30 m^2/g for nonexpanding clays to approximately 800 m^2/g for expanding clays which exhibit internal as well as external surface area (Mortland and Kemper, 1965). The type and number of surface functional groups contributing to ionic bonding in turn reflect the properties of a broad range of mineral and organic materials in various stages of weathering and decomposition (Wiklander, 1964; Malcolm and Kennedy, 1970; Toth and Ott, 1970).

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Present knowledge of the extent of suspended particle subdivision, particularly in size fractions of diameter less than 0.45μ , the chemical and mineralogical properties of these materials and the degree to which these factors vary with season and watershed is not sufficient to allow precise definition of the influence of suspended particulate matter on the chemical behavior and transport of pollutants in river systems. The potential importance of the development of this knowledge for purposes of river management and pollution control cannot be over-emphasized. It has been estimated, for example, that virtually all of the phosphate and a major portion of the pesticides in streams are carried by suspended sediment (Williams, 1968). Similar situations may exist in the case of other pollutants depending on their chemical properties.

To assist in the evaluation of the influence of suspended particle concentration, size and composition on the behavior of radionuclides and other pollutants in the Columbia River adjacent to the Hanford nuclear reactors operated by the Atomic Energy Commission at Richland, Washington, a centrifugation technique was utilized to fractionate, according to equivalent spherical diameter suspended particulate matter isolated from the river throughout the year. Emphasis was placed on isolation of quantities of material in the micron and submicron size ranges sufficient for further studies of isolated fractions but without harsh chemical pre-treatment which might alter the properties of the individual components. The isolated size fractions were further characterized as to carbon content, predominant primary and secondary minerals and Sr exchange capacity and the results related to watershed characteristics and seasonal changes in river conditions.

MATERIALS AND METHODS

Isolation and size fractionation of suspended particulate matter

Suspended particulate materials were isolated from samples (200 liters) of Columbia River water taken off-shore during November, February, April, June and August approximately 5 miles upstream from the U. S. Atomic Energy Commission Hanford reactors near Richland, Washington.

Particulate materials greater than $53\ \mu$ in diameter were removed from subsamples of river water by siphoning the water through a $53\ \mu$ stainless steel sieve. Particulates in the sieve effluent water were concentrated by continuous flow centrifugation in a Sharples Laboratory Super Centrifuge (Model T-1) equipped with a No. 1-H standard clarifier rotor lined with cellulose acetate membrane and operated at maximum speed (23,000 rpm) which exerted a force of 13,200 g. Under these conditions, the flow rate through the centrifuge was 60 ml/min, and the turbidity of the supernatant solution as measured on a Hach Model 1860 Laboratory Turbidimeter was reduced to a level approximating that of distilled water. Assuming a particle specific gravity of 1.52 or greater (Jackson, 1956), centrifugation under these conditions will sediment medium-fine clay with a limiting particle diameter of 0.07 micron.

Particulate matter isolated from the raw river water by centrifugation and resuspended in neutral NaCl (1.5M), was fractionated according to approximate spherical diameter by centrifugation techniques which have been previously described (Wildung, et al., 1971b). Centrifugation parameters, i.e. centrifugation speeds and time intervals, were designed to meet the requirements of Stoke's law for viscous flow about a falling spherical body and centrifugation time intervals were calculated using the Svedberg and Nichol's integrated form of Stoke's law (Jackson, 1956).

A Lourdes Model A-2 Beta-Fuge, an automatic refrigerated centrifuge equipped with a No. 1100 Density Gradient Rotor and centrifugation bottles (250 ml) of the polypropylene type, was employed in the separation of particles suspended in the concentrated solution.

The dilute size fraction suspensions were concentrated for further characterization by addition of sufficient solid CaCl_2 to result in a 0.1M solution to flocculate the suspensions followed by centrifugation until the supernatant turbidity approximated distilled water. After dilution to volume, the concentrated suspensions were stored at 4C.

The concentration of solids in the size-fractionated suspensions was determined by filtration, under vacuum pressures up to 70 cm Hg, of a known volume of suspension through a dry (60C) pre-weighed filter disc of appropriate pore size, and gravimetric determination of the dry (60C) retained solids or by evaporation of known volumes of the size fraction suspensions to dryness (60C) in pre-weighed glass ampules which were evacuated and flame sealed before gravimetric measurement of the residues (Kittrick and Hope, 1970). The recovery of particulate matter in the size fractions ranged from 91.6 to 96.6% (mean 95.3%) of material initially concentrated by ultracentrifugation. Particle size distribution was calculated as a percentage of the oven dry (60C) weight of recovered material.

Carbon content

The C content of the isolated, size-fractionated particulate matter was determined using microcombustion techniques (Wildung, et al., 1970). Samples containing 0.005 to 0.025 g of C were heated in a stream of O_2

at 1000 C over a CuO wire containing several Pt screens. Evolved CO₂ was trapped in granular Ascarite (NaOH-treated asbestos) after retention of evolved H₂O on Anhydrite (Mg(ClO₄)₂) and of volatile halides and S on Ag. The C and ash contents were measured gravimetrically.

Mineralogical composition

The predominant mineral species present in isolated size fractions of particulate matter suspended in the Columbia River were determined by x-ray diffraction techniques (Whittig, 1965). To effect differentiation of the layer silicate mineral species present, particulate matter was chemically pretreated prior to x-ray exposure.

An aliquot (2 ml) of the previously size-fractionated particulate suspension was mixed with a solution (5 ml) of either MgCl₂ (saturated) or KCl (3M); dispersed by shaking and centrifuged to flocculate the particulate matter. The Mg or K saturated flocculates were redispersed in an aqueous solution (4 ml) of glycerol (10%) and in distilled H₂O, respectively. The redispersed samples were mounted on glass slides (2.6 x 4.6 cm) by transferring an aliquot (2 ml) of the suspension (15-25 mg suspended solids/ml) and drying at room temperature.

The dry slides were exposed to x-rays derived from Cu K α radiation (Ni filtered) in a Norelco diffractometer with a current of 15 ma at 40 K_V a detector scan rate of 2°/min and chart speed of 150 cm/hr. The K saturated material was heated (500C) in a muffle furnace (1 hr) and reanalyzed by x-ray diffraction techniques.

Montmorillonite, vermiculite, chlorite or a mixture of these species exhibited diffraction spacings of approximately 14 Å on mg saturation. Glyceration allowed positive identification of montmorillonite which expanded to a diffraction spacing of approximately 18 Å. Saturation with

K resulted in the collapse of vermiculite to approximately $10 \text{ \AA}$ accomplishing separation from chlorite which contains interlayer Al, Mg or Fe and does not collapse. Heating the K saturated sample to 500°C destroys kaolin minerals which exhibit a first order diffraction maximum at approximately $7 \text{ \AA}$ and are masked in the other treatments by a second order chlorite maximum at approximately the same d spacing. The presence of kaolin is therefore confirmed by a decrease in diffraction intensity after heating.

Strontium exchange capacity

In order to determine the capacity of the small quantities of suspended particulate matter to sorb Sr, a Sr saturation technique was employed. Particulate matter (0.010 to 0.050 g), collected in a pyrex sealing tube over a fritted glass disc and acid-washed asbestos and covered with a layer (0.1 cm depth) of quartz sand, was initially saturated with Sr by elution, under vacuum, with a solution (500 ml) containing 0.8 N SrOAc and 0.2 N SrCl_2 previously adjusted to pH 7.0 with SrOH_2 . In order to isotopically exchange Sr^{85} , a γ emitter, for the nonradioactive Sr, the initial saturation was followed by elution of the sediment with the original solution (500 ml) diluted to 0.05 N Sr (distilled H_2O) and amended with Sr^{85} (20,000 dpm/ml). Saturation and isotopic exchange were taken as complete when Sr concentrations and γ activities, respectively, were constant in column effluents. After draining, the column was eluted under vacuum with distilled H_2O (2 ml) to reduce the concentration of Sr contained in interstitial pores to levels insignificant with respect to Sr sorbed by the solid phase. A second tube containing a column of sand and asbestos of geometry similar

to the sample tube but without particulate matter served as a blank.

The column containing the particulate matter saturated with radiolabeled Sr was inserted into a well-type NaI crystal scintillation detector and the γ activity (0.46 to 0.56 mev) was measured using a multichannel pulse-height analyzer.

The Sr exchange capacity expressed in me./100 g of particulate matter was taken as the difference between the Sr content of the tube containing the particulate material, and the blank tube. The measured Sr sorption by the blank tube amounted to less than 5% of the tube containing isolated particulate materials.

RESULTS AND DISCUSSION

The relative size distribution and chemical properties of suspended particulate matter in the Columbia River and the seasonal changes in these characteristics provided a unique background of information which should prove useful in the development of mathematical models for the prediction of pollutant behavior over a broad range of river conditions.

Particle concentration and size distribution

The concentration of total suspended matter of diameter less than 53μ exhibited considerable seasonal variation (Table 1) ranging from a low of $310 \mu\text{g/l}$ of river water in November to a high of $34,680 \mu\text{g/l}$ of water in April. During the year under study, the Columbia River spring freshet occurred over the period April to June and the high suspended sediment load therefore likely originated from surface runoff and geologic erosion due to higher water elevations in the Columbia River and its tributaries. Irrigation of the Columbia Basin was initiated in April and

a portion of the suspended particulate matter present in April, June and August entered the river as irrigation return flow. The irrigation season normally terminates in October.

The increase in particulate concentration which occurred in April was accompanied by marked changes in particle size distribution (Table 2). Whereas the particulate matter in the 53 to $2.0\ \mu$ or silt size fraction constituted the major portion (70 to 86%) of the total suspended particulate matter in November, February, June and August, this fraction amounted to 37% of the total solids contained in river water samples in April with the clay fraction ($<2.0\ \mu$) accounting for the major portion of total solids present at this time. Furthermore, of the total suspended particle load, 24% occurred in the $<0.5\ \mu$ size fraction and 8% was in the $<0.2\ \mu$ fraction. Due to the high suspended sediment load in April, the April water concentration of particles $<0.5\ \mu$ in diameter greatly exceeded the total ($<53\ \mu$ in diameter) of particulate concentrations in waters sampled at other time intervals throughout the year.

For practical purposes, materials passing a $0.45\ \mu$ filter have often been classified as "soluble", however as colloidal particles these materials may be expected to exhibit large surface areas and, if of terrestrial origin, high charge densities relative to particles larger in diameter. The high concentration of materials of large surface area in the river during the spring may be expected to exert a strong influence on the behavior and on the rate and mechanism of transport of pollutants and subsequently may have significant influence on river chemistry throughout the year. For these reasons, a program of intensive characterization of particulate matter isolated from the river during the spring was undertaken.

Carbon content

The concentration of C in intact (nonfractionated) suspended matter isolated during the year ranged from a low of 1.5% in April to a high of 14.4% in November on a total weight basis and from 19.4% in April to 42.0% in February on an ash-free basis (Table 3). The C content calculated on either bases was highest during November, February and August. The ash-free C content during these months most closely approximated that of living tissue and therefore it is likely that the suspended particulate matter, present in low concentrations compared to April and June (Table 1), contained higher concentrations of phytoplankton cells relative to mineral matter. Microscopic measurements, with the aid of an ocular micrometer, of the number of phytoplankton cells in a known quantity of particulate matter deposited on a 0.45μ filter provided presumptive evidence to verify this hypothesis. The proportion of identifiable cells per unit weight of particulate matter in the November and February samples amounted to 6 and 30 times higher, respectively, than phytoplankton cells from water sampled in the spring.

The C content of material in the suspended size fractions isolated during the spring ranged from 2.0 to 3.4% on a total weight basis and from 8.8 to 12.6% C on an ash-free basis (Table 4). Highest total C contents were in the 53-2.0 and $<0.2\mu$ fractions amounting to 2.7 and 3.4% C, respectively. The significantly higher C content of the $<0.2\mu$ fraction may have resulted from the presence of organo-clay complexes known to be present in soil systems and in which C is relatively stable to microbial degradation. As might be expected, the ash-free C content was highest (12.6%) in the 53-2.0 μ fraction representing a relatively higher proportion of phytoplankton cells in the coarser fraction. However, the C content of this fraction was considerably lower than would be predicted if the fraction

consisted exclusively of organic matter in the form of fresh phytoplankton tissues. Thus, a portion of the isolated material consisted of organic detritus of lower organic C content than living tissue.

Mineralogical composition

Methods of x-ray diffraction analysis generally provide qualitative measures only of mineral species present in a mineral mixture, however the relative abundance of the mineral species may be defined approximately by comparison of the relative height of diffraction maxima if relative crystallinity and response are known. The probable concentration range of individual minerals may be expressed as a percentage of total minerals present. These techniques indicated the presence, in intact river-suspended particulate matter sampled throughout the year, of significant quantities of the minerals quartz, feldspar, amphibole, mica-illite, chlorite and montmorillonite (Table 5). Primary minerals inherited from parent rocks and including quartz (SiO_2) feldspar (MAlSi_2O_8) and amphibole ($\text{M}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$) were generally prevalent at the 5-25% level in particulate matter isolated throughout the year. Of the major 2:1 layer silicate mineral species (unit cell formula, $\text{XSi}_8\text{M}_6\text{O}_{20}(\text{OH})_4 \cdot n$ where x represents interlayer charge, M represents cation positions, and n is the number of interlayer solvating molecules per unit cell; Jackson, 1964) known to be present in the silt and clay fractions of soils, mica-illite, chlorite and montmorillonite were present in all samples with mica-illite and chlorite present in relatively larger quantities (5 to >25%) than montmorillonite (2 to 10%).

On a seasonal basis, changes in primary mineral composition were not pronounced, however, the concentration of layer silicate minerals differed significantly during the year. Compared to the river water in February which should not receive significant input of particulate matter from local land surface runoff, increases occurred in mica-illite in April and June, chlorite in June and montmorillonite in April, June and August possibly reflecting increases in the quantity of particulate matter from local soils and sediments due to spring runoff and the return of Columbia Basin irrigation water into the river.

The relative concentrations of minerals in size fractions of suspended particulate matter isolated from river water taken in April are outlined in Table 6. Of the primary minerals, quartz and feldspar were generally more abundant in the larger ($>0.5\mu$) size fractions than the smaller ($<0.5\mu$) size fractions. Amphibole was abundant in all size fractions. The layer silicate minerals mica-illite and chlorite decreased in abundance with decreased particle size whereas montmorillonite concentrations increased. The tendency for colloidal mineral species to concentrate in specific size fractions is a function of their stability as well as their rate of formation (Jackson and Sherman, 1953). Thus, the most stable minerals, e.g. the montmorillonite series, tend to persist in greater quantities in the finer clay fractions where chemical weathering processes are accelerated due to relatively high exposed surface areas. The presence of the less stable primary minerals quartz and feldspar in the small size fraction (Table 6) suggests that the principal weathering mechanism in these systems is mechanical disintegration as opposed to chemical dissolution. Furthermore, the mica-illite and chlorite likely originated from granitic and metamorphic rocks characteristic of the upper

Columbia River drainage (north-central Washington and southern Canada) as compared to the lower basin (south-central Washington) where the river samples were taken and which is characterized by basaltic parent materials.

The changes in mineral composition may be significant in influencing solid phase cation exchange capacities.

Cation exchange capacity

The ability of intact, nonfractionated particulate matter, isolated from water sampled during the year, to sorb Sr from solution at pH 7.0 ranged from 13.5 me. of Sr/100 g of particulate matter in November to 43.5 me./100 g in February (Table 7). Thus, with the exception of the November sample, the Sr exchange capacity was of the order obtained for surface soils of similar particle size distribution in the region (Wildung, et al., 1971a).

In contrast to terrestrial soils (Helling, et al., 1964) no relationship between the cation exchange capacity and C content (Table 3) of the particulate matter was evident. In the absence of a direct correlation between C content and cation exchange capacity and suitable techniques for the removal of C without alteration of the mineral substrate, it is difficult to assess the influence of the particulate C complex on the magnitude of the Sr exchange capacity.

The capacity of particulate matter to sorb Sr under experimental conditions may be extrapolated to river water (Table 7) by multiplication of the measured Sr exchange capacity by the concentration of particulate matter in the water sample (Table 1). It should be noted, however, that

in order to obtain data useful for comparison with standard methods, to eliminate variables due to changes in solution composition, and to measure the exchange capacity, concentration of Sr in the saturating solution was designed to exceed by orders of magnitude the concentration of Sr likely to be present in the aquatic environment.

The large quantity of suspended matter in the river in April resulted in a marked increase (Table 7) in the capacity for solid phase sorption of Sr relative to other periods during the year. The potential for solution scavenging of cations entering the river is therefore highest at this time. Prediction of the chemical behavior and transport of cationic pollutants during this period and after materials have flocculated downstream must therefore be based in part upon a detailed knowledge of the behavior of associated particulate matter.

The influence of particle size on cation behavior in solution is emphasized in Table 8 which shows the Sr exchange capacity of particle size fractions isolated from river water sampled in April. The Sr exchange capacity increased with decreased particle size and was markedly higher (37.1 to 93.9 me./100 g) in the $<2.0\mu$ fraction compared to the $>2.0\mu$ fraction (11.5 me./100 g) reflecting an increase in the total negative charge per unit weight in the smaller size fractions. The increase in charge may result from relative differences in mineral type as well as increased reactive surface area. The layer silicate minerals mica-illite and chlorite which exhibit (Grim, 1953) low cation exchange capacity values (10-40 me./100 g)

relative to montmorillonite (100-150 me./100 g) were generally more abundant in the larger ($>0.5\mu$) size fractions, whereas the opposite situation prevailed in size fractions smaller in diameter ($<0.5\mu$).

As in the case of the nonfractionated material, no relationship between the C content and the Sr exchange capacity (Table 8) of the size fractions was apparent. However, if the higher ash-free C content of the 53 to 2.0μ size fraction results from the presence of phytoplankton cells as indicated by microscopic examination, the lower Sr exchange capacity of this fraction may reflect the lower charge density of these materials in less advanced stages of decomposition.

The calculated size fraction contributions to the Sr exchange capacity of the unfractionated material are outlined in Table 8. Over 85% of the total particulate Sr exchange capacity measured in the spring, was attributable to the $<2.0\mu$ or clay size fraction, whereas 43.8% of the Sr exchange capacity was attributed to particles $<0.5\mu$ in diameter. The validity of the methods used to fractionate and measure the Sr exchange capacity of suspended particulate matter was illustrated by the relatively close agreement (within 5.6%) between the calculated total size separate contribution to Sr capacity (33.3 me./100 g, Table 8) and measured intact particulate Sr exchange capacity (31.5 me./100 g, Table 7).

It is evident that effective models for the prediction of the chemical behavior and transport of Sr, and other potential cationic pollutants, in river systems and the subsequent use of models for river management and pollution control must be predicated on an understanding of suspended particulate properties and behavior as influenced by seasonal changes and watershed characteristics.

Particular research emphasis should be accorded the particulate matter originating from terrestrial sources and suspended during the spring freshet, or the return of irrigation waste waters. This material, containing higher concentrations of colloidal particles of large surface area and minerals of high charge density and usually present in comparatively high concentrations during runoff periods, may account for a large fraction of pollutant transport during the year.

REFERENCES

- Farrar, D. M. and J. D. Coleman. 1967. Correlation of surface area with other properties of nineteen British clay soils. *J. Soil Sci.* 18:118-124.
- Garder, K. and O. Skulberg. 1964. Sorption phenomena of radionuclides to clay particles in river water. *Int. J. Wat. Poll.* 8:229-241.
- Grim, R. 1953. *Clay mineralogy*. McGraw-Hill Book Co., Inc., New York, N. Y.
- Helling, C. S., G. Chesters and R. B. Corey. 1964. Contribution of organic matter and clay to soil cation-exchange capacity as affected by the pH of the saturating solution. *Soil Sci. Soc. Amer. Proc.* 28:517-520.
- Jackson, M. L. 1956. *Soil chemical analysis*. Department of Soils, University of Wisconsin, Madison, Wis. 991 p.
- Jackson, M. L. 1964. Chemical composition of Soils. In F. E. Bear (ed.), *Chemistry of the soil*. Reinhold Publishing Company, New York, N. Y. 515 p.
- Jackson, M. L. and G. D. Sherman. 1953. Chemical weathering of minerals in soils. *Advances in Agron.* 5:219-318.
- Kittrick, J. A. and E. W. Hope. 1970. Preventing water resorption in weight loss determinations. *Soil Sci. Soc. Amer. Proc.* 34:536-538.
- Malcolm, R. L. and V. C. Kennedy. 1970. Variation of cation exchange capacity and rate with particle size in stream sediment. *J. Water Poll. Control Fed.* 42:R153-R160.

- Mortland, M. M. and W. D. Kemper. 1965. Specific surface. In C. A. Black (ed.), Methods of soil analysis. Part 1. Amer. Soc. of Agron., Inc., Madison, Wis. 770 p.
- O'Connor, J. T. and C. E. Renn. 1964. Soluble-adsorbed zinc equilibrium in natural waters. J. Amer. Water Works Assoc. 56:1055-1061.
- Ormsby, W. C., J. M. Shartsis and K. H. Woodside. 1962. Exchange behavior of kaolins of varying degrees of crystallinity. J. Amer. Ceramic Soc. 45:361-366.
- Toth, S. J. and A. N. Ott. 1970. Characterization of bottom sediments: Cation exchange capacity and exchangeable cation status. Environ. Sci. Tech. 4:935-939.
- Whittig, L. D. 1965. X-ray diffraction techniques for mineral identification and mineralogical composition. In C. A. Black (ed.), Methods of soil analysis. Part 1. Amer. Soc. of Agron., Inc., Madison, Wis. 770 p.
- Wildung, R. E., G. Chesters and D. E. Behmer. 1970. Alkaline nitrobenzene oxidation of plant lignins and soil humic colloids. Plant and Soil 32:221-237.
- _____, B. F. Hajek and K. R. Price. 1971a. Chemical properties of the arid soil organic fraction. Northwest Sci. 45:73-79.
- _____, R. C. Routson and R. L. Schmidt. 1971b. Isolation and size fractionation of microparticulate matter suspended in the Columbia River. Northwest Sci. (accepted for publication, November, 1971).

Wiklander, L. 1964. Cation and anion exchange phenomena. In F. E. Bear (ed.), Chemistry of the soil. Reinhold Publishing Company, New York, N. Y.

Williams, H. R. 1968. Water quality management. An address before the Federal Water Quality Association, May 22, 1968, Washington, D. C.

Table 1. Seasonal changes in the concentration of particulate matter ($<53\mu$) in river water.

Time of sampling	Concentration* of suspended particulate matter
	$\mu\text{g/l}$
November	310
February	2002
April	34680
June	5788
August	3726

*Based on oven dry (60C) weight.

Table 2. Seasonal changes in the size distribution of particulate matter isolated from river water.

Equivalent spherical diameter μ	Particle size distribution*				
	November	February	April	June	August
	-----%-----				
53 to 2.0	70	85	37	78	86
2.0 to 0.5	14	8	39	16	7
0.5 to 0.2	9	5	16	4	5
<.2	7	2	8	2	2

*Based on oven dry (60C) weight and expressed as a percentage of total recovered particulate matter (<53 μ)

Table 3. Seasonal changes in the carbon content of particulate matter (<53 μ) isolated from river water.

Time of sampling	Ash	Contents* of	
		C	
		Total sample	Ash-Free sample
		-----%	
November	65.7	14.4	42.0
February	80.4	7.8	39.7
April	92.1	1.5	19.4
June	86.8	2.8	20.8
August	75.0	7.7	30.9

* Based on oven dry (60C) weight

Table 4. Distribution of carbon in particle size fractions isolated from river water*

Equivalent spherical diameter	Contents ^t of		
	Ash	Total sample	Ash-free sample
μ		%	
53 to 2.0	79.1	2.7	12.6
2.0 to 0.5	81.1	2.0	8.8
0.5 to 0.2	77.9	2.2	10.1
<0.2	63.5	3.4	9.2

*April sampling

^tBased on oven dry weight

Table 5. Seasonal changes in the relative abundance of minerals in particulate matter (<53 μ) isolated from river water.

Time of sampling	Relative abundance* of					
	Quartz	Feldspar	Amphibole	Mica-illite	Chlorite	Montmorillonite
November	2	2	2	3	2	1
February	2	2	2	2	2	1
April	2	1	2	3	2	2
June	2	2	2	3	3	2
August	2	2	2	2	2	2

* Relative mineral abundance designated as: 1, trace (2-10%); 2, intermediate (5-25%); 3, abundant (>25%)

Table 6. Relative abundance of minerals in size fractions of suspended particulate matter isolated from river water*.

Equivalent spherical diameter	Relative abundance+ of				
	Quartz	Feldspar	Amphibole	Mica- illite	Chlorite
53 to 2.0	2	3	3	3	3
2.0 to 0.5	2	3	3	3	3
0.5 to 0.2	2	1	3	2	2
<0.2	1	2	3	2	2

* April

+ Relative mineral abundance designated as: 1, trace (2-10%); 2, intermediate (5-25%); 3, abundant (>25%)

Table 7. Seasonal changes in the strontium exchange capacity of intact (nonfractionated) particulate matter isolated from river water.

Time of sampling	Strontium exchange capacity*	
	Absolute	Based on river water particulate concentration
	me./100g	me./liter (x 10 ⁻⁴)
November	13.5	4.2
February	43.5	8.8
April	31.5	109.0
June	29.6	17.1
August	36.3	13.5

*Based on oven dry (60C) weight

Table 8. Strontium exchange capacity at pH 7.0 of particle size fractions isolated from river water*.

Equivalent spherical diameter	Strontium exchange capacity ⁺	
	Absolute	Relative size fraction contribution to total [‡]
μ	me./100g	%
53 to 2.0	11.5	12.7
2.0 to 0.5	37.1	43.5
0.5 to 0.2	44.4	21.3
> 0.2	93.9	22.5

* April sampling

⁺ Based on oven dry (60C) weight

[‡] Absolute strontium exchange capacity multiplied by the fraction of total particulate yield (Table 2) and expressed as a percentage of the resulting total (33.3 me./100 g).

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