COMPARISON OF DIFFERENT METHODS OF MEASURING TURBIDITY FOR ESTIMATION OF TOTAL SUSPENDED SEDIMENTS

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Abstract. Turbidity in streams has long been thought of as an important indicator of stream health. The standard methods for measuring turbidity in streams today are nephelometric methods (NTU). However there are a variety of relationships and correlations between nephelometric units and total suspended sediments (Tss). Colorimetric methods (FAU) of measuring turbidity may reduce the number of instruments needed while stream sampling and may also have a more reliable relationship with total suspended sediments than nephelometric units in Southern Piedmont streams. We sampled stream base flow (n = 224) and storm flow (n = 145) and runoff (n = 141) from grazing lands within two Southern Piedmont watersheds and determined relationships of Tss with NTU and FAU. Using linear regression to predict Tss from either NTU or FAU, we found r^2 of 0.89 and 0.80 for base flow, 0.94 and 0.92 for storm flow and 0.93 and 0.94 for runoff, respectively. However, when turbidity units were < 25 NTU or 25 FAU, relationships with Tss were much weaker.

INTRODUCTION

Turbidity in streams has long been thought of as an important indicator of stream health. Childers and Gosselink, (1990) examined historical data for turbidity in conjunction with total suspended sediment, total N and total P to determine watershed health in the Tensas Basin, Louisiana. The standard methods for measuring turbidity in streams today are nephelometric methods (NTU, nephelometric turbidity unit). There are a variety of relationships between nephelometric units and total suspended sediments (Tss). Turbidity in water is caused by suspended and colloidal matter which can be either organic or inorganic in origin and is a measure of the optical clarity of a sample. More precisely turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample (Clesceri et al., 1998). Nephelometric turbidimeters detect scattered light at a 90 degree angle from the source light while most other turbidimeters measure light attenuation. In the past, inconsistencies in calibration methods and reporting units has made it difficult to compare turbidity data reported in the literature (Gippel, 1989). The international Organization of Standardization (1984) recommends the term FAU (formazine attenuation units) when using a standard turbidimeter that has been calibrated relative to the formazin standard. Colorimetric methods of measuring turbidity (a standard turbidimeter) standardized by the formazine reference standard may help universalize turbidity information.

The variety of relationships between turbidity and total suspended sediments have been attributed to several factors. Water in motion (base flow, storm flow and runoff in this case) contain both mineral and organic substances in the dissolved and suspended form. All of these substances influence turbidity. In addition, properties such as water color particle size distribution and particle mineralogy can vary with discharge (Gippel, 1989; Childers and Gosselink, 1990). The ratio of mineral to organic substances in water will vary with discharge rate or type and this variation could have a significant influence on the total suspended sediment and turbidity relationship. Additionally, sediments from variable sources may also have variable mineralogy which could also result in variable sediment-turbidity relationships. However, Lammerts van Bueren (1984) as well as Finlayson (1985) did report a linear relationships between turbidimeters and suspended sediment concentration with r^2 ranging between 0.6 to 0.97

When sampling turbidity under field conditions nephelometric instruments may require intense care when handling and in transportation. Colorimetric methods (FAU) of measuring turbidity (a standard turbidimeter) may help in the standardization of turbdity measurements, reduce the number of instruments needed while stream sampling, and may also have a more reliable relationship with total suspended sediments than nephelometric units in Southern Piedmont streams.

OBJECTIVE

The objective of this work was to determine the effectiveness of a nephelometer and a turbidimeter for determining total suspended sediments in base flow, storm flow, and runoff in two Southern Piedmont watersheds. The turbidometer and nephelometers are typical of those which would be used by either volunteers or technicians in either case, those who would be monitoring water quality to determine watershed health.

METHODS

Watershed Description

Rose and Greenbrier Creeks are two fourth-order watersheds in Oconee and Greene Counties, Georgia, and were selected for this study because they are typical Southern Piedmont watersheds where the presence of agriculture is prominent and urbanization is incumbent. The uplands range from gently sloping to steep and soils tend to be highly eroded, weathered soils deplete of native nutrients. Stream corridors are nearly level lowlands which are subject to frequent flooding or are deeply incised channels. The Southern Piedmont climate is temperate, humid and rainfall is on average 1250 mm per year. There are on average 20 runoff events/year, 74% occur in October through March (Tyson-Pierson, 2000).

Description of Sampling System

Seventeen stream sampling sites were located on the Rose Creek and 18 stream sampling sites on the Greenbrier Creek (Fig. 1). Sites were chosen to be disperse across the watershed but also to adequately analyze diverse land management practices on a particular tributary. Base flow and storm flow sampling were undertaken with different constraints at the same locations. Base flow sampling began in December 1998 and grab samples were collected seasonally. Prior to each sampling, bottles were conditioned in-stream with "three bottle fills". Storm flow samples from streams were collected from rising flow samplers. Collection bottles were placed on rising flow samplers installed 2.5 cm below bankfull, just above baseflow and midway between bankfull and base flow. Storm flow sampling was done after each rainfall event which resulted in runoff.

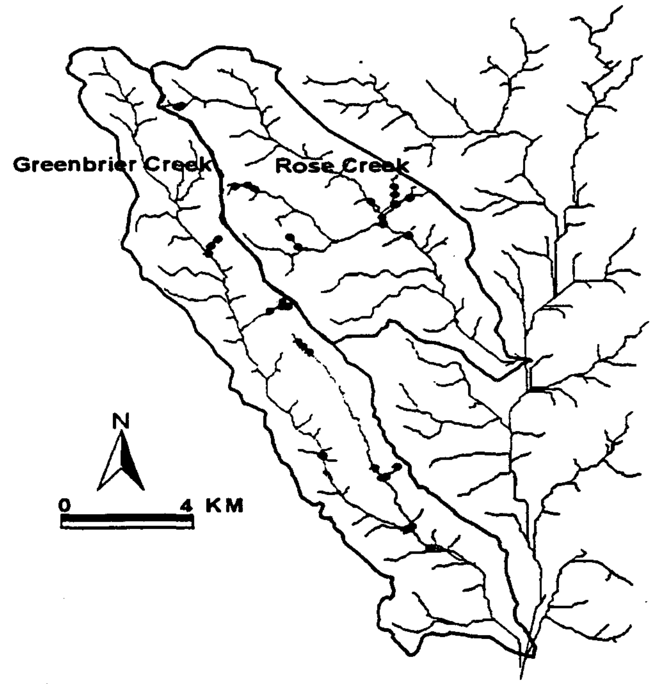

Figure 1. Distribution of stream collection sites on the Greenbrier and Rose Creeks. Stream sample sites are depicted by circles.

In addition to stream sampling, small in-field runoff collectors (SIRC, Franklin et al., 1999) were placed at the edge of stream-side fields (May 1998) to collect runoff. Runoff collectors and stream collectors were inspected and cleaned if necessary at least twice monthly. The morning following a rainfall event, sites were inspected for runoff and if runoff was present, sampling would begin. Runoff samples were taken from SIRC collection tanks and collection tanks were cleaned and rinsed with deionized water. All samples were placed in dark, iced coolers upon exiting each field and sent to analytical lab upon completion of sampling. It should be pointed out that from May 1998 to April 2000 (time watersheds have been under analysis for runoff and storm flow) we have had at most 10 runoff events.

Laboratory Analysis

Total suspended sediment (Tss), nephelometric turbidity (NTU), and colorimetric turbidity (FAU) were determined for each sample (base flow, n = 224; storm flow, n = 145; and runoff, n = 141). All samples were analyzed at room temperature and agitated preceeding each subsampling to ensure homogeneity. Total suspended sediment was analyzed gravimetrically (Clesceri et al., 1998) by filtering sample through

0.45µm, cellulose nitrate membrane filter and dried at 105°C for 24 h. The Hach Model 2100P Portable Turbidimeter was used to measure NTU. Manual Calibration was done quarterly using fresh formazin standards (20 NTU, 100 NTU, and 800 NTU; according to manufacturers recommendation). Manufacturer's Gelex standards were analyzed before each use to check calibration. No calibrations were needed before the next quarter's calibration. The Hach model DR/890 Colorimeter was used to measure FAU using the Absorptimetric Method. Fresh 200-FAU Formazin solution was prepared before each use to check calibration (all checks were within manufacturer's limits). Determination of relationships between total suspended sediment and NTU as well as total suspended sediment and FAU were executed with simple linear regression. Data from the Greenbrier and Rose Creeks were combined to predict Tss from either NTU or FAU. However, data was analyzed and presented on an annual basis (years 1999 and 2000), as well as for both years combined.

Table 1. Total suspended sediment (Tss) ranges and averages for base flow and storm flow in the Rose and Greenbrier Creeks, Georgia, for combined years 1999 and 2000. Turbidity measures, both nephelometric and colorimetric are also identified.

		Base flow	Storm flow	Runoff
Tss (mg/l-1)	Range	0 to 750	0 to 46,160	0 to 2,360
	Average	21	1,426	83
Nephel-ometer (NTU)	Range	0 to 574	0 to 13,050	0 to 3,180
	Average	24	874	103
Turbidi ometer (FAU)	Range	0 to 853	0 to 22,825	0 to 4,395
	Average	24	622	96

RESULTS AND DISCUSSION

Total suspended sediment and turbidity analysis were done on base flow and storm flow waters for two typical Southern Piedmont streams as well as for runoff from stream-side fields (predominantly grazing lands). Considering the whole set of base flow data sampled (years 1999 and 2000) from the Rose and Greenbrier Creeks, estimations of Tss from NTU and FAU using simple linear regressions yielded r^2 values of 0.89 and 0.80, respectively (Table 1). When we considered all storm flow data we obtained the tightest relationships between Tss and the turbidity measures NTU and FAU with r^2 of 0.94 and 0.92, respectively. R-square values of the same magnitude were also obtained for runoff data *in toto,* 0.93 and 0.94, in the same order. However, when turbidity measures below 25 for either NTU or FAU were isolated and tested for predictability of TSS (using simple linear regression), r^2 of 0.68 and 0.48 for base flow, 0.17 and 0.08 for storm flow and 0.01 and 0.02 for runoff were obtained, respectively.

In almost all cases storm flow had the highest r^2 values and base flow had the lowest r^2 values. As could be expected turbidity and Tss were lowest in base flow waters (Table 2) and highest in storm flow waters. Runoff from predominantly grazing lands was found to have mid-range Tss and turbidity measures.

It is clear from these results that neither turbidimeter did an adequate job of predicting Tss in these two watersheds for storm flow or for runoff when measures fell below 25 turbidity units. These results also indicate that the nephelometric method of measuring turbidity (NTU) better predicted Tss for base flow turbidity units below 25.

CONCLUSIONS

These results indicate that there is little effective difference found for nephelometric and colorimetric measures of turbidity when predicting TSS for levels of turbidity above 25 NTU or FAU with simple linear regression. However, when samples are not highly turbid (< 25 turbidity units) the nephelometric measure of turbidity better predicted total suspended sediments in base flow, in storm flow,and in runoff (< 100 turbidity units) from grazing lands within two Southern Piedmont watersheds. Additionally, these numbers also suggest that something other than sediments may be the cause of turbidity in these streams below 25 NTU and below 100 turbidity units in runoff where dissolved organic compunds likely account for a portion of the turbid nature of these waters in motion.

Table 2. R-squares for simple linear regressions for the estimation of total suspended sediment (Tss) from either nephelometric turbidity measures (NTU) or colorimetric turbidity measures (FAU). Midway turbidity units was 250 for base flow, 1000 for storm flow, and 500 for runoff. All data were collected from the Rose and Greenbrier Creeks in Oconee and Greene Counties, Georgia for years 1999 and 2000.

	-----R^2 values for $Tss = a + b$FAU ------					
Source	Year 1999	Year 2000	Both Years	Both Years < Midway FAU	Both Years FAU < 100	Both Years FAU < 25
Base flow	0.88	0.79	0.80	.66	0.54	0.48
Storm flow	0.96	0.95	0.92	0.70	0.51	0.08
Runoff	0.90	0.95	0.94	0.79	0.37	0.02
	-----R^2 values for $Tss = a + b$NTU ------					
Source	Year 1999	Year 2000	Both Years	Both Years < Midway NTU	Both Years NTU <100	Both Years NTU < 25
Base flow	0.94	0.78	0.89	0.72	0.59	0.68
Storm flow	0.96	0.97	0.94	0.69	0.57	0.17
Runoff	0.92	0.93	0.93	0.86	0.42	0.01

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LITERATURE CITED

Childers, D.L. and J.G. Gosselink,1990. Assessment of cumulative impacts to water quality in a forested wetland landscape . *J. Environ. Qual.* 19, 3:455-464.

Clesceri, L. S , A.E. Greenburg, and A.D. Eaton, 1998. *Standard methods for the examination of water and wastewater (20th edition)*. Am. Public Health Ass., Washington, D.C. 2-8p.

Finlayson, B.L., 1985. Field calibration of a recording turbidity meter. *Catena* 12:141-147.

Franklin, D., M. Cabrera, J. Steiner, D. Endale, and W. Miller, 1999. Evaluation of a small, in-field runoff collector. p. 275-278. *In* K. Hatcher (ed.) *Proceedings of the 1999 Georgia Water Resources Conference*, March 30-31, 1999, The University of Georgia, Athens, GA.

Gippel, C.J., 1989. The use of turbidimeters in suspended sediment research. *Hydrobiologia.* 176/177:465-480.

International Organisation for Standardisation, 1984. *Water quality - determination of turbidity (1st, edition). ISO 7027, 7p.*

Lammerts van Buren, D., 1984. The use of turbidity measurements for monitoring suspeded solids concentrations. In R.J. Loughran (ed.), *Drainage Basin Erosion and Sedimentation.* Conference on erosion, transportation and seimentation in Australian drainage basins, Univ. Of Newcastle, Newcastle, NSW: 169-174

Tyson-Pierson, S.K. 2000. *Surface water quality in grasslands fertilized with broiler litter.* Dissertation, Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA.