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ON THE CALIBRATION OF TRANSMISSOMETERS

by

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ABSTRACT

The effect of sediment type on the calibration of transmissometers has been investigated using two different sediment samples from Lake St. Clair. It was found that finer sediment caused more rapid light extinction as a function of concentration than the coarser sediment. The importance of calibrating transmissometers with the sediment encountered in use is highlighted. Two meter types used at NWRI (Sea Tech and Martek) were found to respond in similar fashion to the same suspended sediment. Two different methods of determining sediment concentration used at NWRI were found to be equivalent.

MANAGEMENT PERSPECTIVE

Establishing the pathways of toxics by the documentation of the movement of suspended sediment is important in such projects as that on the Upper Great Lake Connecting Channels. A useful tool in studying suspended sediment is the transmissometer which is used to determine time histories of suspended sediment, which can then be used with current data to estimate sediment transport. This report addresses the problem of properly calibrating transmissometers, and determines the calibration to be used for two meters deployed in Lake St. Clair in 1985.

SOMMAIRE

On a étudié l'incidence des différents types de sédiments sur l'étalonnage des transmissomètres en comparant deux échantillons tirés du lac Sainte-Claire. On a découvert que l'atténuation de la lumière en fonction de la concentration des particules était plus rapide pour les sédiments plus fins que pour les sédiments plus grossiers. L'étude fait valoir l'importance d'étalonner le transmissomètre en fonction des sédiments qui se trouvent sur place. L'INRE utilise deux types de transmissomètres (Sea Tek et Market) qui réagissent à peu près de la même manière aux sédiments en suspension de même type. Par ailleurs, les deux méthodes distinctes qu'utilise l'INRE pour déterminer la concentration des sédiments se sont avérées équivalentes.

PERSPECTIVE-GESTION

Il est important pour des projets tels que l'Upper Great Lakes Connecting Channels Study (étude sur les voies d'eau qui relient les Grands Lacs d'amont) de connaître le cheminement des substances toxiques en documentant le déplacement des sédiments en suspension. Le transmissomètre est un outil des plus utiles pour obtenir des données chronologiques sur les sédiments en suspension, lesquelles peuvent être comparées avec les données courantes pour ensuite estimer l'importance du phénomène de transport. La présente étude porte sur les problèmes de l'étalonnage approprié des transmissomètres et précise l'étalonnage s'appliquant aux deux transmissomètres qui ont été déployés dans le lac Sainte-Claire en 1985.

1.0 INTRODUCTION

During 1985, two transmissometers were deployed in Lake St. Clair to gain insight into the time history of suspended sediment during the growth and decay of wind waves. The transmissometers were located on towers which also had wave sensors on them, so that the concentration of suspended sediment could be correlated with the local wave field. This experiment was conducted in conjunction with a larger field study, the aim of which was to examine the dissipation effects of shallow water on the growth of wind generated waves.

The output of a transmissometer is simply a measure of the extinction of light along a prescribed path. The amount of extinction is dependent on a number of factors: medium (for example, air or water); characteristics of the light source; length of the light path; concentration of sediment; sediment particle size; optical characteristics of the sediment. Because of all these factors, the only simple way to calibrate a transmissometer is to conduct a series of measurements with known amounts of sediment in the water. Furthermore, the sediment must have the same characteristics as the sediment encountered in the field. The latter point is rather difficult to address because one cannot be certain as to the characteristics of the sediment in the field.

A series of experiments were conducted in an attempt to establish the calibrations of the two transmissometers. The two meters (one Sea Tech 25 cm pathlength, serial number 196, one Sea Tech 10 cm pathlength, serial number 163) were calibrated using a sample of bottom sediment (Sample A) collected near their location in Lake St. Clair. After the initial calibrations were established it was found that these calibrations resulted in measured concentrations much larger than those found using a Martek meter (T.J. Simons, personal communication). The Martek meter had been calibrated against total suspended sediment (seston) samples collected at the time and place of the Martek measurements in the field.

A series of comparative calibrations were then carried out to shed light on this difference. The 25 cm pathlength Sea Tech meter was calibrated at the same time as a Martek transmissometer (model 167/XMS-25, CCIW #2, 25 cm pathlength), used routinely in the field by the Technical Operations Division, again with bottom sediment (Sample B). This Martek meter was the same model as that in the previous paragraph. The calibration of these two instruments was repeated, using a sample (Sample C) collected from a sediment trap (M.N. Charlton, personnel communication) in Lake St. Clair in 1986.

2.0 METHOD

The meters were mounted side by side about 40 cm above the bottom of a rectangular tank approximately 80 by 120 cm in plan. The tank was filled with water to about 60 cm depth. The water was vigorously agitated with an impeller. The light paths of the meters were horizontal. A hose of about 1 cm inside diameter was mounted near the meters, at the same elevation. It was used to extract samples of the sediment-water mixture for determination of the sediment concentration. Typically, the outputs from the meters were sampled at 20 samples per second for 75 seconds and average values calculated, using a microcomputer. During this time interval, a sediment-water sample was syphoned through the tube. Care was taken to ensure that the tube was adequately purged between samples. The sediment-water samples were then analyzed to determine the sediment concentration. During the calibrations using the sediment identified as Sample B, sediment-water samples were also analyzed for concentration with the method routinely used by the Aquatic Ecology Division (AED), Charlton and Lean (1986). The purpose was to establish if the two methods were equivalent.

The tests always started with clear tap water. A sediment sample was subdivided into two. One subsample was used for size analysis, and the other for these tests. The subsample was well mixed and added to the water in the tank, a small amount at a time. The outputs of the meters were allowed to reach steady state after the addition of each sediment sample, then they were sampled by computer, and a sample of the sediment-water mixture taken as described. The procedure was repeated until the entire output range of the meters was covered.

3.0 CALIBRATIONS

The calibrations of the two Sea Tech transmissometers using bottom sediment from Lake St. Clair (Sample A) are shown graphically in figures 1 and 2. The equation for the 25 cm pathlength meter (S/N: 196) is:

$$V = 4.29\exp(-0.0368C); \qquad (1)$$

where V is the output voltage in volts, and C is the sediment concentration in mg/l. The equation for the 10 cm pathlength meter (S/N:163) is:

$$V = 4.65\exp(-0.0152C). \qquad (2)$$

The meters have similar light sources and electronics, and as a result, the 10 cm pathlength meter is able to detect much higher concentrations because of its shorter pathlength.

The calibrations of the 25 cm pathlength Sea Tech and the Martek meters, using bottom sediment (Sample B) are shown in figures 3 and 4. The equation for the Sea Tech (25 cm) meter is

$$V = 4.42\exp(-0.0342C). \qquad (3)$$

The equation for the Martek meter is:

$$V = 4.56\exp(-0.0378C), \quad (4)$$

where the output was amplified by a factor of 5 to give it the same full scale output as the Sea Tech meter.

Equations 1 and 3 are similar although determined from two separate sediment samples, giving some assurance as to repeatability of the calibration procedure. Equations 3 and 4 are similar, indicating that the two types of meters respond in like manner when used under conditions as close to identical as possible.

The concentrations were also found for the Sample B sediment using the standard AED method. The equation using this AED method for the Sea Tech meter is:

$$V = 4.30\exp(-0.0362C). \quad (5)$$

There is some scatter between the results of the two methods, as indicated in figure 5, which probably accounts for the slight differences between equation 3 and equation 5.

The calibrations of the Sea Tech (25 cm) and the Martek meters using sediment trap samples collected from Lake St. Clair (Sample C) are shown in figures 6 and 7. The equation for the Sea Tech (25 cm) meter is:

$$V = 4.81\exp(-0.130C) \quad (6)$$

and for the Martek meter, it is:

$$V = 5.19\exp(-0.160C). \quad (7)$$

As in the previous comparison between the two meter types, the calibrations are similar overall. On the other hand the difference between these calibrations and the previous ones (equations 3 and 4) is remarkable.

4.0 SEDIMENT SIZE ANALYSIS

The three sediment samples (A,B, and C) used in the calibration tests were analyzed for size distribution using a combination of seive and sedigraph techniques (Duncan and Lahaie, 1979). The results are shown in Table 1. Sample A contained 25% sand, 58% silt and 17% clay size material. Sample B contained 16% sand, 61% silt and 23% clay size material. These two samples were separate subsamples of a larger sample of bottom sediment. As their analysis indicates, the size distributions are similar: the largest component being silt. The differences in the distributions are probably sufficient to account for the slightly different calibrations obtained for the 25 cm Sea Tech transmissometer (Equations 1 and 3).

Sample C, obtained from a sediment trap in Lake St. Clair and representing suspended sediment, had a considerably different makeup. It contained 1% sand, 46% silt and 53% clay size material. This totally different distribution resulted in quite different calibrations for both the Sea Tech and Martec transmissometers (Equations 1 and 3 versus equation 6, and equation 4 versus equation 7). For both meters the exponent is about four times larger for the suspended sediment (finer material). A much higher concentration of the larger material (bottom sediment) is required to get the same amount of light extention.

5.0 CONCLUSIONS

The two Sea Tech transmissometers were successfully calibrated against a sample of bottom sediment taken from Lake St. Clair. The 10 cm pathlength meter was able to resolve concentrations about twice as large as the 25 cm one.

Comparative tests indicated that, under identical conditions, the responses of the 25 cm pathlength Sea Tech and the Martek transmissometers were similar. The Sea Tech meter was able to resolve sightly larger concentrations than was the Martek meter. The type of sediment had a strong bearing on the output of both meters. For a given concentration, finer grained suspended sediment resulted in more light extinction than the coarser bottom sediment.

The methods of determining the sediment concentration used in the Hydraulics Division and in the Aquatic Ecology Division are equivalent. The fact that there was some scatter between the results of the two methods indicates that the methods are very sensitive to technique, so that constant care must be taken to ensure high quality results.

The calibration of a transmissometer must be done with the material that is to be encountered in its application. Furthermore if there is a considerable range of sizes of material in the application, it is reasonable to assume that not all of the range will be suspended under moderate energy conditions. As the energy level increases, a larger fraction of the total size range will be suspended. One is forced, therefore, to the conclusion that a range of calibration curves must be employed, depending on the agitation level. For example, in Lake St. Clair, under most wave conditions, the calibration using the sediment trap sediment (Sample C) might be appropriate. Only under very severe wave conditions, would the calibrations using bottom sediment (Sample A or B) likely be more appropriate.

ACKNOWLEDGEMENTS

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REFERENCES

Charlton, M.N. and Lean, D.R.S. 1986 Organic sedimentation and Resuspension in Lake Erie. J. Great Lakes Res. In press.

Duncan, G.A., and Lahaie, G.G. 1979. Size analysis procedure used in the Sedimentology Laboratory, NWRI. Unpubl. Manual, National Water Research Institute, Burlington, Ontario.

TABLE 1

Size Distribution of Samples
(percent; except median size: mm)

Size Fraction	Sample A	Sample B	Sample C
Sand	25.0	16.2	1.2
Silt	57.6	60.9	45.7
Clay	17.4	22.9	53.1
Median Size	0.0278	0.0181	0.00345

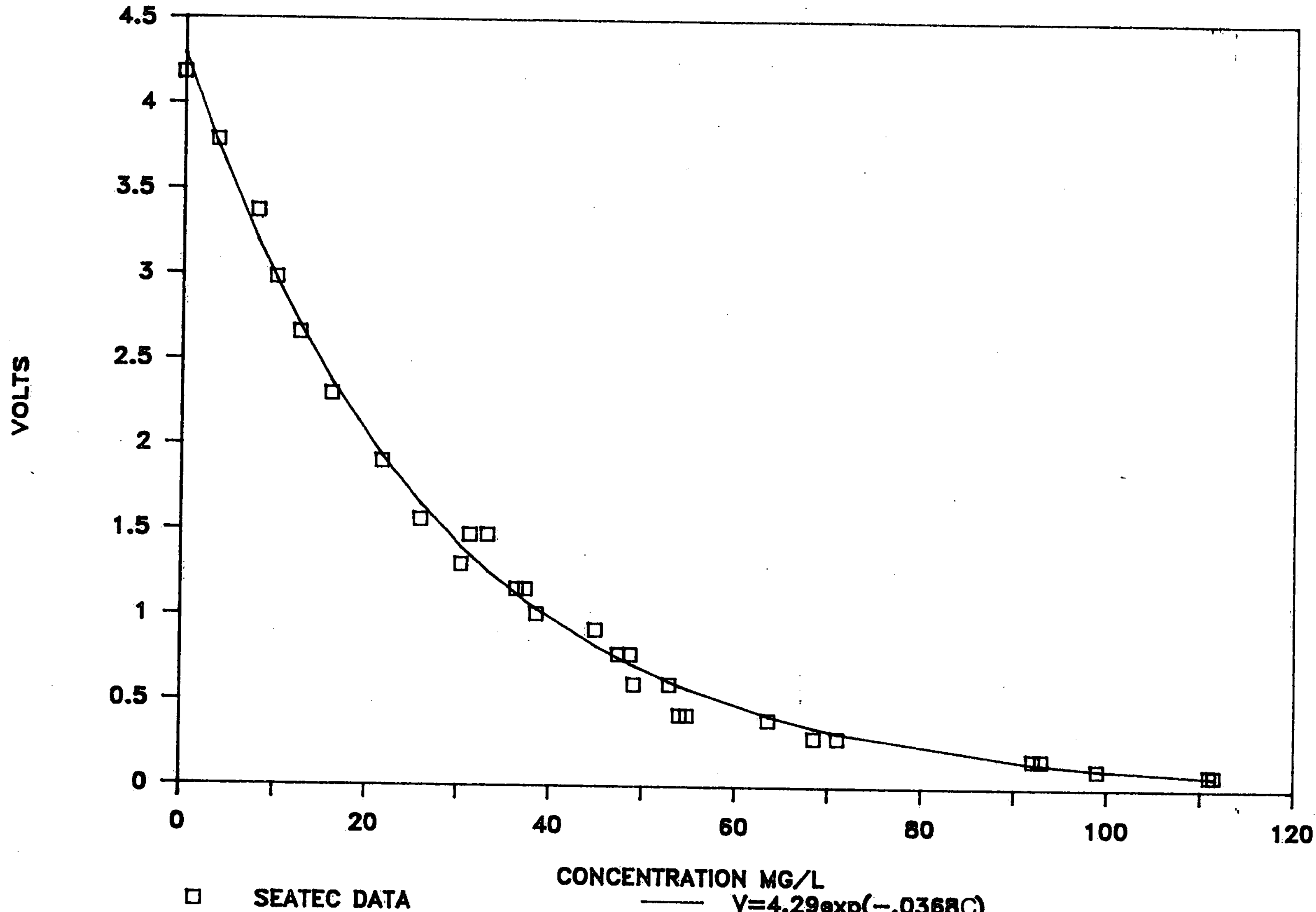

Figure 1. Calibration of the 25 cm pathlength Seatec transmissometer using Sample A.

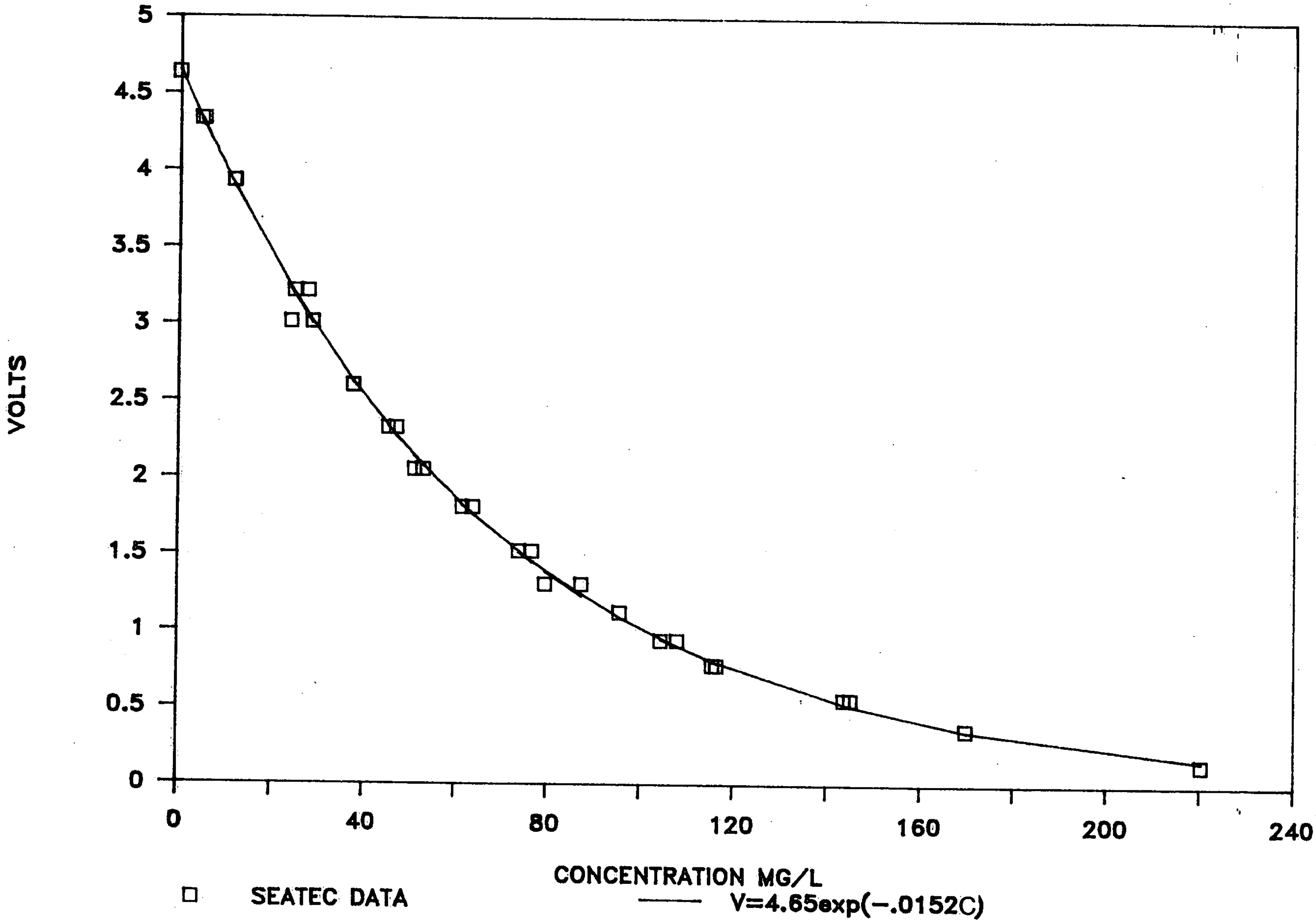

Figure 2. Calibration of the 10 cm pathlength Seatec transmissometer using Sample A.

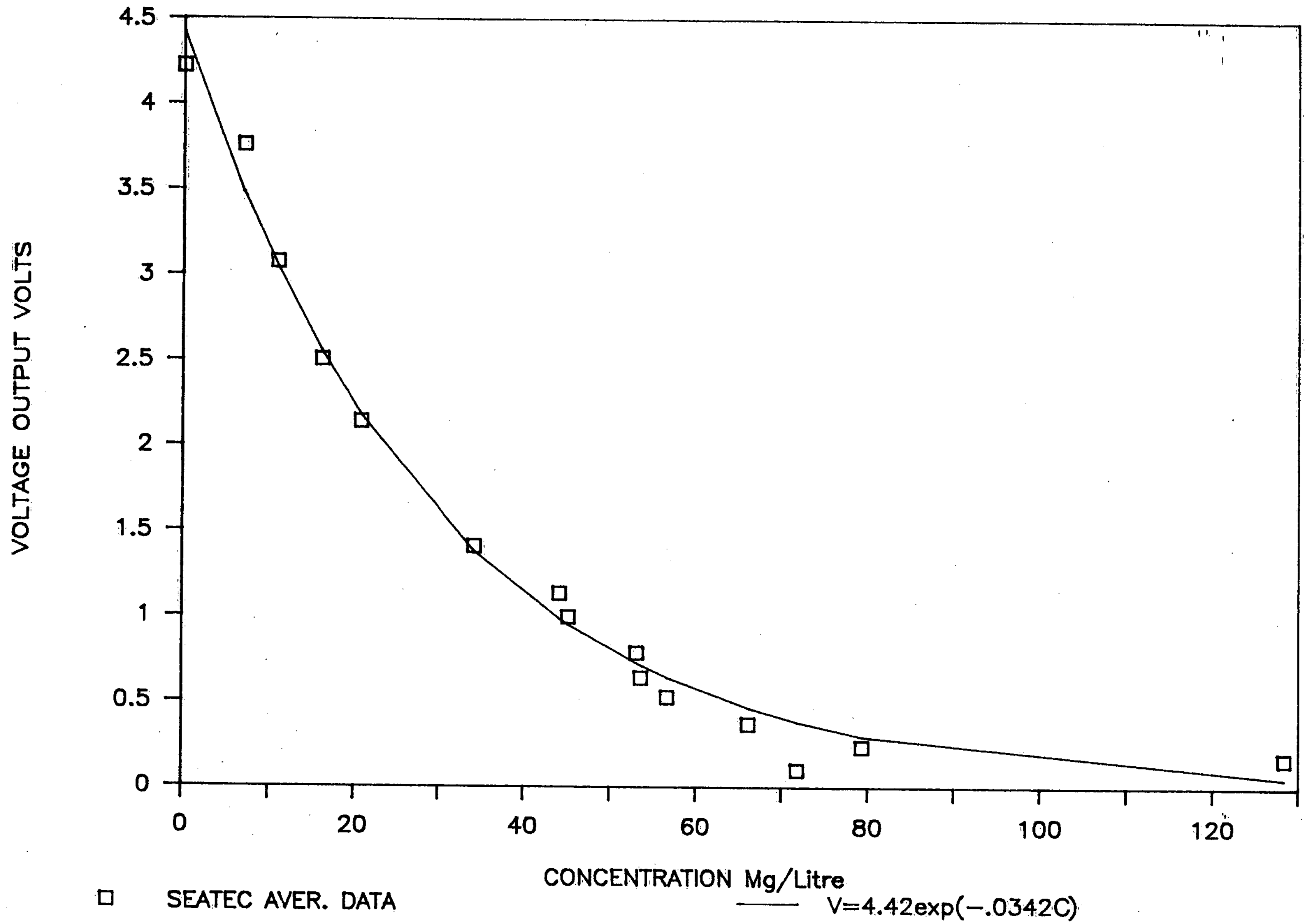

Figure 3. Calibration of the 25 cm pathlength Seatec Transmissometer using Sample B.

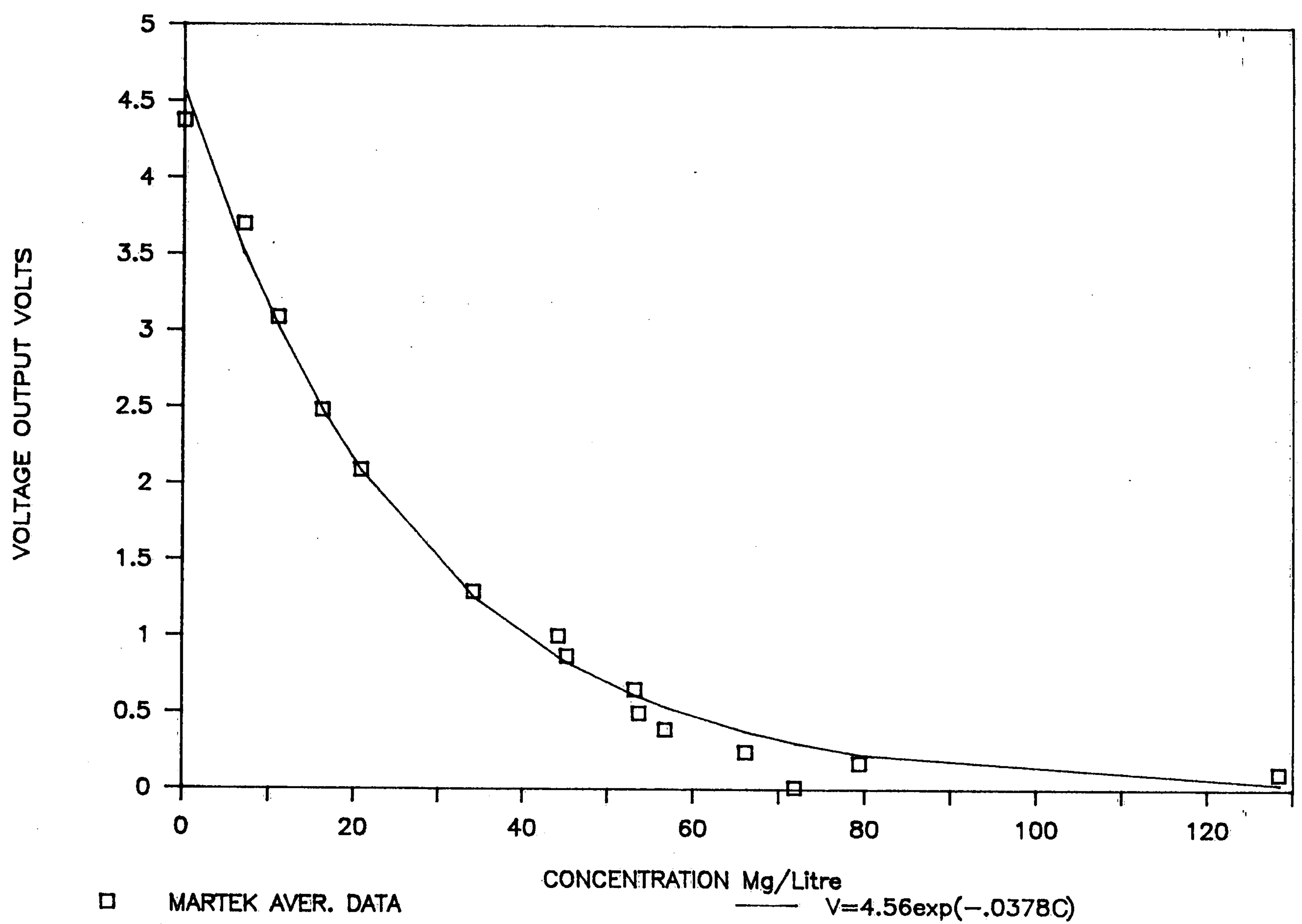

Figure 4. Calibration of the Martek transmissometer using Sample B.

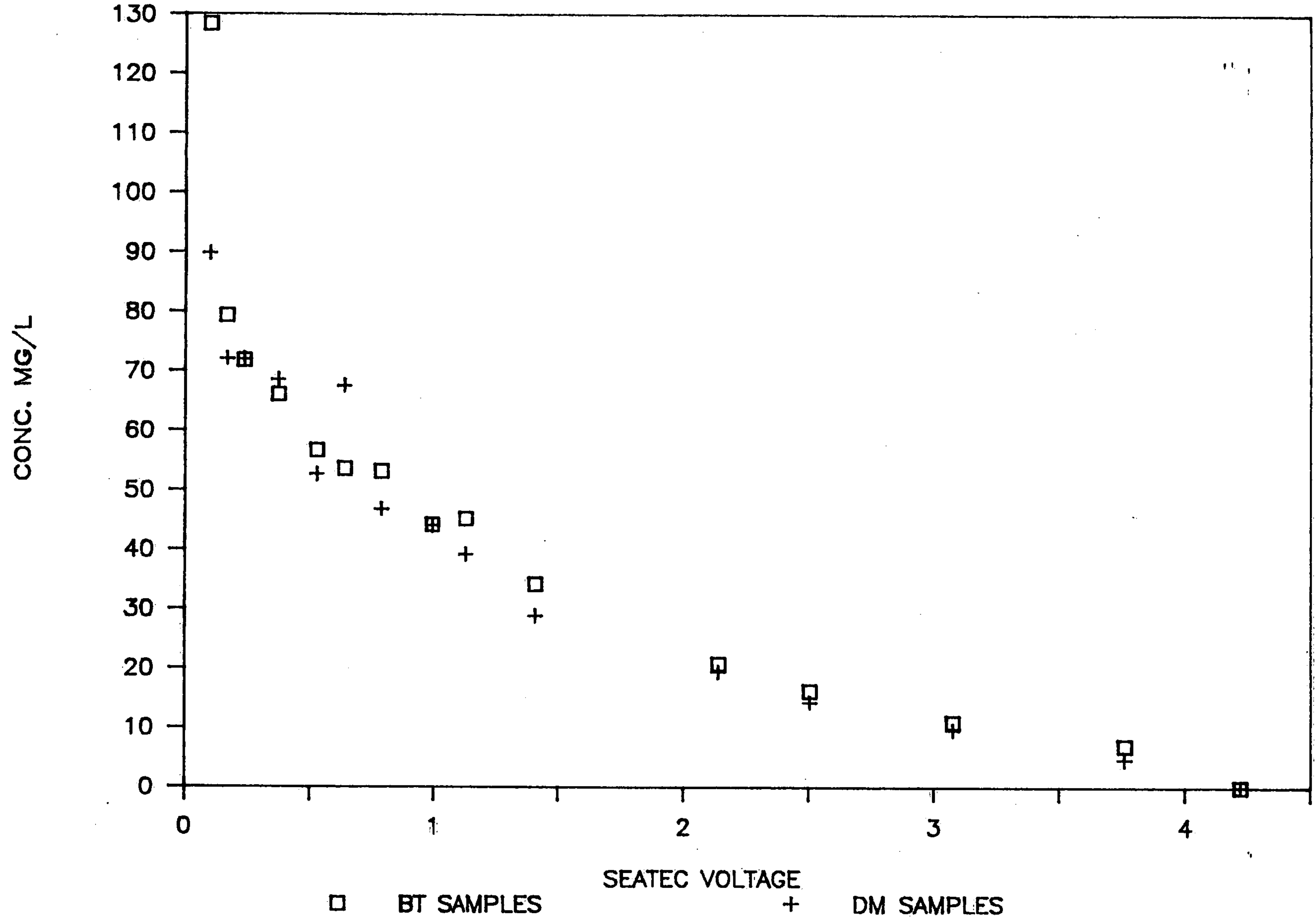

Figure 5. Sediment concentrations of Sample B measured by techniques used in the Hydraulics Division (BT) and the Aquatic Ecology Division (DM), plotted as functions of the voltage output of the 25 cm pathlength Seatec transmissometer.

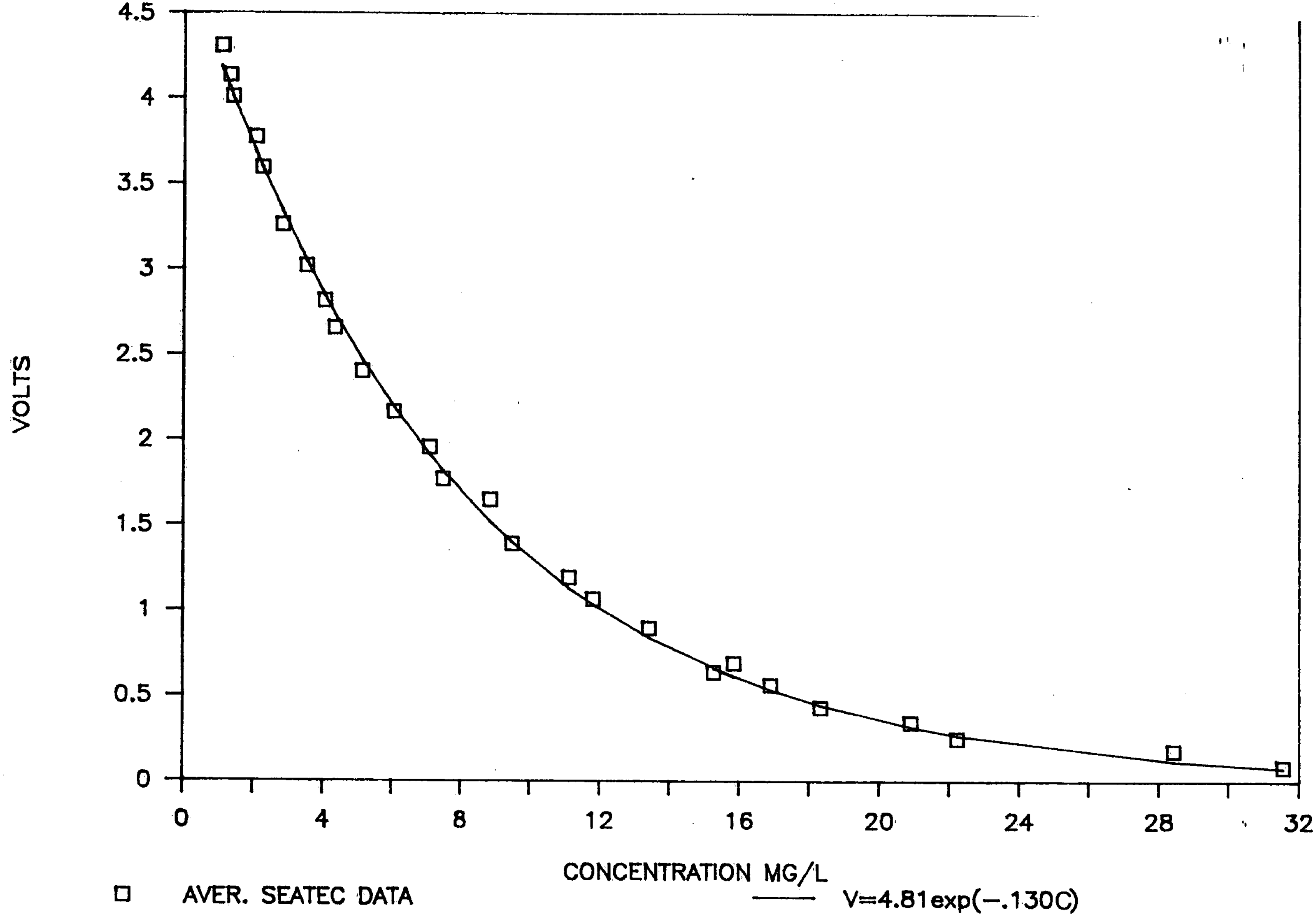

Figure 6. Calibration of the 25 cm pathlength Seatec transmissometer using Sample C.

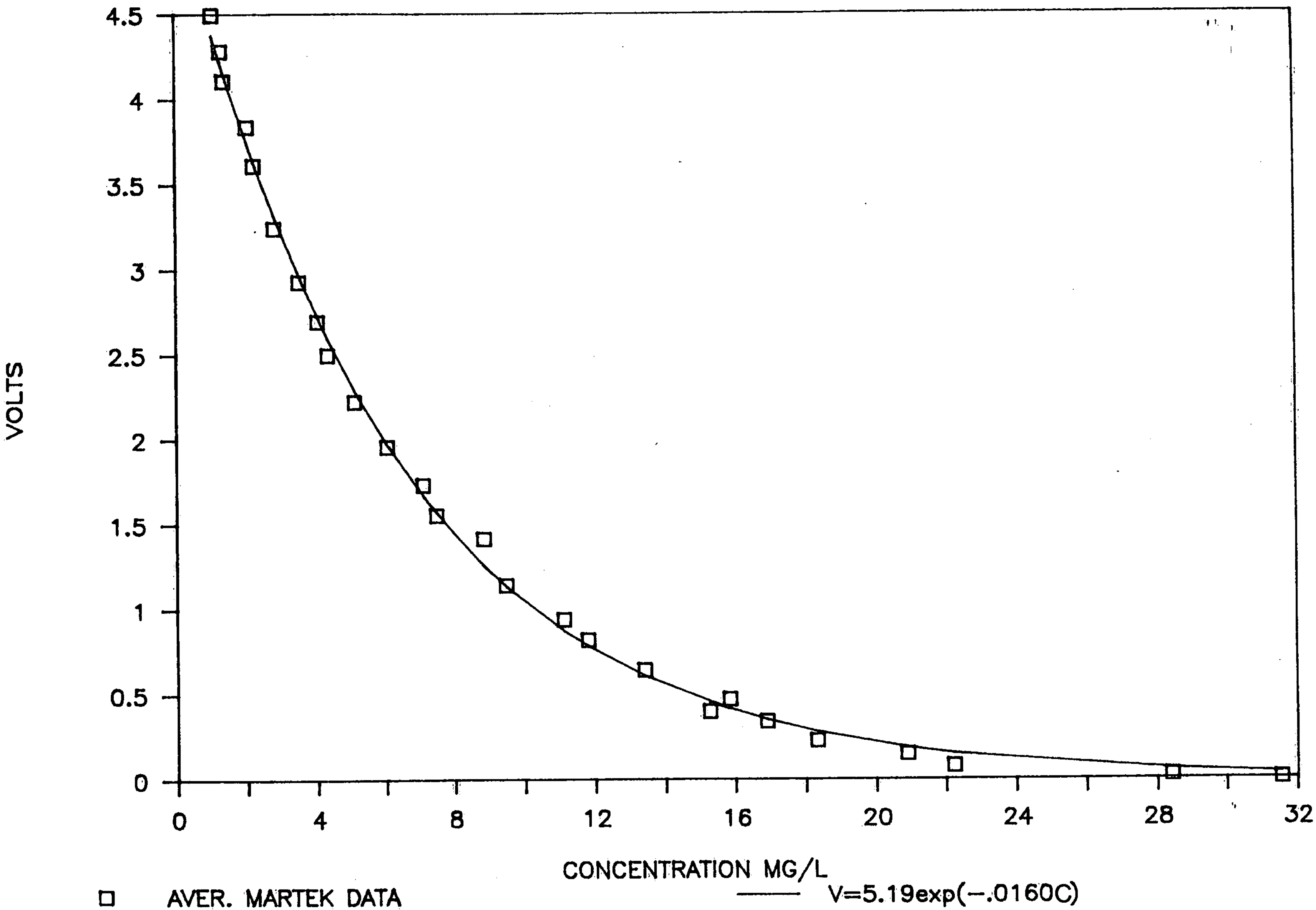

Figure 7. Calibration of the Martek transmissometer using Sample C.