DOCUMENT RESUME

ED 221 402 SE 039 214

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TITLE	Turbidity. Operational Control Tests for Wastewater Treatment Facilities. Instructor's Manual [and] Student Workbook.
INSTITUTION	Linn-Benton Community Coll., Albany, Oreg.
SPONS AGENCY	Office of Water Program Operations (EPA), Cincinnati, Ohio. National Training and Operational Technology Center.
PUB DATE	Aug 81
GRANT	EPA-900953010
NOTE	34p.; Slide/tape program which accompanies this module is also available from Linn-Benton Community College.
AVAILABLE FROM	Linn-Benton Community College, 6500 S.W. Pacific Blvd., Albany, OR 97321 ($1. student workbook, $2. instructor's guide).
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Instructional Materials; *Laboratory Procedures; Postsecondary Education; Sludge; Solid Wastes; Teaching Guides; *Training Methods; *Waste Water; *Water Treatment
IDENTIFIERS	Turbidity

ABSTRACT

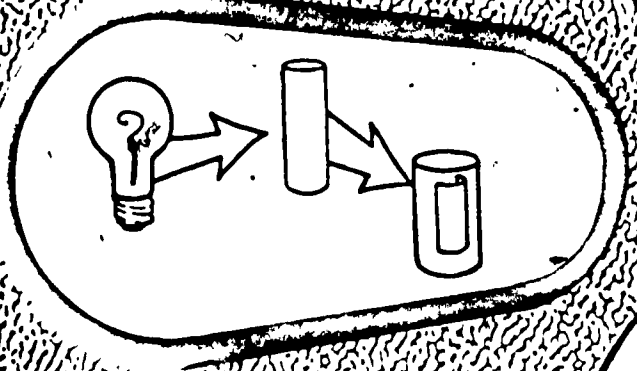
Designed for individuals who have completed National Pollutant Discharge Elimination System (NPDES) level 1 laboratory training skills, this module provides waste water treatment plant operators with the basic skills and information needed to: (1) standardize a nephelometric turbidimeter; (2) determine the turbidity of a sample; and (3) calculate turbidity for tests requiring sample dilution. The instructor's manual contains a statement of instructional goals, lists of instructor/student activities and instructional materials, narrative of the slide/tape program used with the module, overhead transparency masters, and student worksheet (with answers). The student workbook contains objectives, prerequisite skills needed before the module is started, list of Environmental Protection Agency (EPA) approved nephelometric turbidimeters, sample problem, laboratory procedures for the nephelometric method of measuring turbidity, and worksheet. (Author/JN)

Operational Control Tests

for Wastewater Treatment Facilities

Turbidity

Instructor's Manual



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TURBIDITY

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Developed Under:
EPA Grant #900953010
August, 1981

TURBIDITY

CONTENTS

INSTRUCTIONAL GOALS

Upon completion of this module the student should be able to standardize a nephelometric turbidimeter and successfully determine the turbidity of a sample. The student should also be able to calculate turbidity for tests requiring sample dilution.

INSTRUCTOR ACTIVITIES

The following sequence is recommended for best use of this material:

	Activity	Time
1.	Review Objectives with students.	3 minutes
2.	Have students read through the procedure.	10 minutes
3.	View and listen to the slide/tape program.	14 minutes
4.	Demonstrate the procedure.	15 minutes
5.	Assign the worksheet.	10 minutes
6.	Correct the worksheet.	5 minutes
7.	Have students perform the test.	20 minutes

OTHER ACTIVITIES

Items to emphasize during the demonstration should include:

1. Be sure instrument is warmed up properly.
2. Use a standard in the same range as the sample.
3. Stress the need for clean sample cell. No fingerprints, water spots, dust or scratches.
4. Remind students to let air bubbles escape.
5. Keep fingers off of sides of sample cell.
6. Be careful to read correct scale and be aware of scale selection knob position.

You should encourage students to read thoroughly the instruction manual for their particular brand of instrument. Discuss the problems of reading the scales. Describe "paralax"; eyes must be directly in front of needle. Most errors in this test result from misreading the scale. Sealed standards should be discarded after one year. Laboratory prepared standards are good for one week. Samples with turbidity greater than 40 NTU should be diluted.

STUDENT ACTIVITIES

1. Read objectives.
2. Read procedure.
3. Listen to and view slide/tape program.
4. Observe demonstration.
5. Complete worksheet.
6. Perform test.

INSTRUCTIONAL MATERIALS LIST

1. Instructor's Guide for Turbidity
2. Student Workbook for Turbidity
3. 35mm projector
4. Cassette tape player with automatic synchronization
5. Projector screen
6. Overhead projector
7. Equipment listed in lab procedure
8. Copies of instruction for various brands of instruments
9. Demonstration models for various brands of instruments (optional)

NARRATIVE

Slide #

1. This lesson covers the turbidity test. The theory of the test, the test procedure itself, and the calculations are all addressed.

2. The lesson was written by Dr. John W. Carnegie. Dr. Carnegie was also the project manager. Instructional design was done by Priscilla Hardin.

3. Potable water and treated wastewater both contain some suspended materials. Operators can judge treatment efficiency by measuring how much of the suspended material has been removed.

4. This suspended material causes a cloudy appearance which is referred to as turbidity. Technically, turbidity is an expression of the optical properties which cause light to be scattered and absorbed.

5. Very cloudy water scatters a larger amount of light and the turbidity value is high. Clear water scatters less light and the turbidity value is lower.

6. The nephelometric method of determining turbidity measures the light scattered at a 90^{o} angle to a beam of light.

7. Turbidity determined by the nephelometric method is expressed as NTU's or Nephelometric turbidity units. In the potable water treatment industry, turbidity is often expressed simply as TU's or turbidity units.

8. The nephelometer consists of a light source, a glass sample tube, a phototube or other light sensitive device and a meter to visually display the intensity of the scattered light.

9. Light enters the sample and is absorbed, scattered, and transmitted. A portion being scattered at 90^{o} is picked up by the light sensing device. The light sensing device measures the intensity of the scattered light and the instrument converts the light energy to an electric signal which is displayed by the meter.

10. The glass sample tube must be clean and unscratched so as not to interfere with the path of the light. The tube is placed in a compartment with a light-tight lid or cap so that outside light will not enter the sample and interfere in the results.

11. The intensity of the light scattered by the sample is displayed on the meter. The meter may have more than one scale, which allows use with a wide range of sample turbidities. High range scales allow measurement of turbidity as high as 1,000 NTU's. The lower scales are used to obtain greater accuracy on less turbid samples. The

range selector sets the instrument to read on the appropriate scale. Experience with different samples will help you determine which scale to use.

12. The instrument must be standardized each time a test is run and whenever switching from one scale range to another. Restandardization is accomplished by placing a standard of known turbidity in the instrument and setting the meter to read the correct value by adjusting the standardization knob.

13. Several nephelometric turbidimeters are available and meet EPA specifications. These include Hach Chemical Co., HF Instruments, Turner Designs, and LaMotte Chemical Co. Sample tubes are usually supplied with the instruments.

14. Running the turbidity test involves the preliminary steps of solution preparation and sample collection, the main procedure itself, followed by calculations and, of course, clean-up.

15. Let's first take a look at the two required solutions. A turbidity standard and turbidity-free water are the only solutions required. Turbidity-free water is used to prepare the standard and dilute the sample.

16. Turbidity standards solution made from a Formazin suspension are used to standardize the instrument. These standards may be purchased from chemical suppliers or they may be prepared in the laboratory from dry reagents. Refer to the lab manual for the details of preparation and shelf life.

17. To prepare turbidity-free water, pass some distilled water through a membrane filter. If filtration lowers the measured turbidity of the distilled water, use the filtered water. If not, the distilled water can be considered turbidity-free. The lab manual explains this process in detail.

18. Next, let's look at sample collection and preservation. When collecting samples for turbidity, avoid debris and rapidly settling coarse materials.

19. Samples should be run as soon as possible, but they may be stored up to 24 hours in the dark.

20. Now, we're ready to start the actual turbidity measurement procedure.

21. Each time a measurement is made, you must check the set up, standardize the instrument, then run the sample and record the turbidity value.

22. Be sure the instrument has sufficient time to warm up. Set up the instrument so that it is on a stable base. Vibration can lead to false results.

23. As with most electrical instruments, the turbidimeter must be standardized before each use. A separate standard must be used for each scale range of the instrument. Sealed standards for various ranges are available. Lab prepared standards can also be made in various ranges. Place the lab prepared standard in one of the sample tubes.

24. Wipe the tube or sealed standard carefully and place it in the instrument. Do not touch the sides of the tube with your fingers since this will leave finger prints and interfere with the light. Place the cap over the tube and close the lid.

25. Adjust the meter so that it reads the NTU value of the standard.

26. Now we can run the sample.

27. The sample tube must be clean, free of finger prints, water spots, scratches, and dust. Wash inside and out with warm, soapy water and a soft brush. Discard any tube that becomes scratched.

28. Mix the sample thoroughly by shaking at least 15 times in a one foot arc.

29. Rinse the tube several times with the sample and then fill it to the recommended level. Remember, do not touch the tube with your fingers where the light will pass through.

30. Allow any air bubbles to escape before testing since they will interfere with the light.

31. Wipe off the tube, put it in the instrument and place the cover over the tube. Select the appropriate scale. If you have no idea what range to use start with the high range and work down. Remember to standardize the instrument in the range that you use.

32. Some instruments do not read in high turbidity ranges. If the turbidity is greater than 40 NTU's dilute with turbidity-free water until it falls between 30-40 NTU's. Record the amount of sample and water used. These values are used later to calculate the turbidity of the undiluted sample.

33. Read turbidity directly off the meter and record as NTU's. Remember to read the correct scale. If the sample has been diluted a calculation will have to be made.

34. But first, practice reading this scale. Notice that the scale selector is set at 1. What do you read on the 1 scale? I would read 0.63. What would you read on the 10 scale? I read 63. How about the 0.2 scale? That's right, 0.13.

35. Here's another instrument. First check the range selector. It's set at 10. So what do you read? I get about 7.0.

36. Here's one more. What scale is it on? It's the "times 10" scale. What is the reading? Right! 1.2 X 10 or 12 NTU's.

37. After you have finished the test discard the sample and clean the sample tube. This keeps the tube clean for the next test.

38. If no dilutions were made the turbidity is read directly off the meter and no calculations are necessary. If the sample was diluted the turbidity must be calculated taking into account the amount of dilution. Refer to manual for explanation and a sample calculation.

39. The most direct application of turbidity measurement to wastewater operations is measurement of final effluent turbidity. This value can be used to monitor overall plant performance. Small changes in effluent quality even when the plant is running very well can be detected.

40. Another application is to differentiate the final clarifier problems from sludge quality problems. This is done by comparing clarifier effluent turbidity with the turbidity of the supernatant from a settled aeration basin sample.

41. A third application differentiates clarifier problems from overall treatment system imbalance. In this comparison, initial turbidity of clarifier effluent is compared to one-hour turbidity of the clarifier effluent. The one-hour value is free of any distortion caused by the secondary clarifier. Any variations between the initial and one-hour value would be caused by treatment processes other than the clarifier.

42. In summary, determining turbidity is a means of measuring the clarity of water. The nephelometric method measures light scattered at a 90° angle to a beam of light. A sample in a clean glass tube is placed in the instrument and the turbidity is read as NTU's directly on the instrument's meter.

APPENDIX A

Overheads #1 and #2

Use these two overheads to explain calculations for samples requiring dilutions.

NEPHLOMETRIC TURBIDITY UNIT (NTU)

$$NTU = \frac{A \times (B+C)}{C}$$

A = NTU of diluted sample

B = Vol of water

C = Vol of undiluted sample

Example Calculation

A = diluted sample read 40 NTU

B = 50 ml water added to sample

C = 10 ml undiluted sample

$$NTU = \frac{A \times (B+C)}{C}$$

$$= \frac{40 \times (50+10)}{10}$$

$$= 240 \text{ NTU}$$

TURBIDITY TEST

WORKSHEET

Directions: Place an "X" by the best answer. There is only one best answer for each question.

1. Turbidity is:

   a)_____ always equal to suspended solids content.

   b)__X__ an optical property which causes light to scatter.

   c)_____ an optical property which causes fluorescence.

   d)_____ measured routinely as mg/l.

   e)_____ only used in potable water treatment.

2. Turbidity is most commonly expressed as:

   a)_____ JTU's.

   b)_____ mg/l.

   c)_____ %.

   d)__X__ NTU's.

   e)_____ ppm.

3. The best description of the path that light follows through a nephelometric turbidimeter is:

   a)_____ light source, sensing device, sample, slit.

   b)_____ sample, light source, slit, sensing device.

   c)__X__ light source, sample, slit, sensing device.

   d)_____ light source, sensing device, slit, sample.

   e)_____ sensing device, slit, sample, light source.

4. Turbidity standards are made from:

a) X formazin.

b) _____ copper.

c) _____ phosphate.

d) _____ silica.

e) _____ chloride.

5. Turbidity standards may be obtained:

a) _____ by purchasing prepared, sealed standards.

b) _____ filtering double-distilled water.

c) _____ preparing fresh in the laboratory.

d) _____ a and b above.

e) X a and c above.

6. Turbidity-free water can be used:

a) _____ to dilute samples.

b) _____ to prepare standards in the laboratory.

c) _____ as a buffer to prevent etching of glass.

d) X a and b above.

e) _____ a and c above.

7. Which of the following is not a precaution regarding sample collection and preservation?

a) _____ avoid debris.

b) _____ avoid rapidly settling coarse material.

c) _____ get a representative sample.

d) _____ store 24 hours in dark.

e) X add HCl to hold longer than 24 hours.

8. Which of the following is not part of the turbidity test procedure?

a) ____ calibrate the instrument.

b) ____ allow air bubbles to escape from the sample cell.

c) ____ wipe sample cell carefully.

d) X dilute if greater than 80 NTU's.

e) ____ read proper scale.

9. What is the turbidity of a sample if 15 ml was diluted with 35 ml of turbidity-free water and the diluted sample read 12 NTU's?

$$NTU = \frac{A \times (B + C)}{C}$$

a) ____ 4 NTU's

b) X 40 NTU's

c) ____ 80 NTU's

d) ____ 43 NTU's

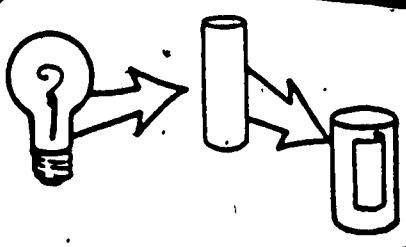
e) ____ none of the above

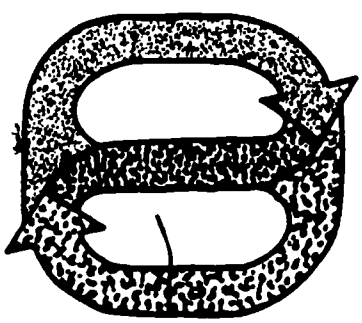
Operational Control Tests

for Wastewater Treatment Facilities

Turbidity

Student Workbook





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Developed Under:
EPA Grant #900953010
August, 1981

TURBIDITY

CONTENTS

INTRODUCTION

This module on turbidity is intended to give the operator the basic information necessary to make turbidity measurements using a nephleometric turbidimeter. After studying this module and reading the instructions manual you should be able to make a turbidity measurement with any of the approved instruments. The mention of turbidimeters by brand name should not be taken as an endorsement of that instrument.

This module is intended to be used by individuals who have completed NPDES Level 1 laboratory skills training.

OBJECTIVES

Upon completion of this module you should be able to:

1. Define turbidity.
2. Recall that turbidity is usually expressed as NTU's.
3. Describe the path that light travels through a nephelometric turbidimeter.
4. Recall that turbidity standards are made from Formazin.
5. List the two methods of obtaining a standard solution for turbidity.
6. Recall the uses of turbidity-free water.
7. Recall the precautions in sample collection and preservation.
8. Describe the test procedure.
9. Correctly and accurately read the scale of the turbidimeter.
10. Make calculations for diluted samples.
11. Perform the test procedure.

PRE-REQUISITE SKILLS

In addition to the skills listed in the introduction, you should be able to prepare turbidity-free water using a vacuum filtration apparatus and by able to make accurate dilutions.

RESOURCE LIST

EPA approved Nephelometric Turbidimeters include:

1. Bausch and Lomb
   820 Linden Ave
   Rochester, NY 14625
   Mini 20 Nephelometer

2. Hach Chemical Company
P.O. Box 907
Ames, Iowa 50010

Models 16800
1860A
2100A

3. HF Instruments
Fisher Scientific Co.
2225 Martin Ave
Santa Clara, CA 95050

Models DRT-1000
DRT-200
DRT-150
DRT-100
DRT-15

4. LaMotte Chemical Co.
Chesterton, Maryland 21620

Model BH-2

5. Monitek, Inc.
630 Price Ave
Redwood City, CA 94063

Model 21
21P

6. Turner Designs
2247 A Old Middlefield Way
Mountain View, CA 94043

Model 40-002
40-100

Standards:

Sealed prepared standards are available from most of the instrument suppliers.

The powdered formazin polymer can be obtained from:

AMW Standards International, Inc.
239 Polariz Ave. #C
Mountain View, CA 94043

SUPPLIMENTARY MATERIAL

If the turbidity of a sample is greater than 40 NTU's it should be diluted using turbidity-free water until the turbidity reads less than 40 NTU's.

To dilute a sample, carefully transfer with a pipette a portion of undiluted sample (10 ml) to a graduated cylinder. Then add measured amounts of turbidity-free water with a pipette until the turbidity reads less than 40 NTU's. Record both the volume of undiluted sample and of turbidity-free water used.

Calculations:

$$NTU = \frac{A \times (B + C)}{C}$$

Where A = NTU's of diluted sample
B = Volume of turbidity-free water used
C = Volume of undiluted sample

SAMPLE PROBLEM

If 10 ml of sample was diluted with 50 ml of turbidity-free water and the diluted sample read 40 NTU's, calculate the turbidity of the undiluted sample.

A = 40 NTU
B = 50 ml
C = 10 ml

$$NTU = \frac{A \times (B + C)}{C}$$

$$= \frac{40 \times (50 + 10)}{10}$$

$$= 240 \text{ NTU}$$

TURBIDITY
(NEPHELOMETRIC METHOD)

INTRODUCTION

Turbidity is an expression of the optical properties of water which cause light to be scattered and absorbed. It is used as a measure of the clarity of water. Turbidity can be caused by a variety of suspended materials, both organic and inorganic.

The nephelometric method of measuring turbidity measures the light scattered at a 90 degree angle to a beam of light. As the amount of scattered light increases, the turbidity value increases. Turbidity determined by the nephelometric method is expressed as Nephelometric Turbidity Units (NTU's). Attempts to correlate turbidity to suspended solids is not recommended because turbidity is affected by particle size, shape, and refractive index, as well as quantity of suspended material.

The procedure outlined below can be applied to several brands of nephelometric turbidimeters. Be sure to read carefully the manufacturer's operation manual for your particular instrument.

EQUIPMENT

Several nephelometric turbidimeters are available and approved by the Environmental Protection Agency. Manufacturers include Hach Chemical Co., HF Instruments, and Turner Designs.

Sample tubes are generally supplied with the instrument.

REAGENTS

Turbidity Standards may be purchased from several sources or prepared in the laboratory. One standard for each range used should be on hand. Maximum shelf life for purchased standards is one year. Formazin is used for the turbidity standard.

To prepare Formazin standard:

Hydrazine sulfate	$(NH_2)_2 \cdot H_2SO_4$
Hexamethylenetetramine	$(CH_2)_6N_4$

SOLUTION PREPARATION

1. Turbidity-free Water.

   Pass distilled water through a membrane filter with pore size no greater than 100 µm. If filtration lowers turbidity, discard first 200 ml and use filtered water. If filtration does not lower turbidity, use distilled water.

2. Formazin Stock Turbidity Suspension

Prepare Solution I - Dissolved exactly 51.000 g hydrazine sulfate in about 400 ml distilled water.

Prepare Solution II - Dissolved exactly 50.000 g hexamethylenetetramine in about 400 ml distilled water.

Mix Solution I and II - Pour both into a 1 liter volumetric flask and rinse beakers into flask. Dilute to 1 liter with distilled water. Allow to stand at 22-28° C for 48 hours.

The Formazin stock is rated as 4000 NTU's.

Prepare solutions and stock monthly.

3. Formazin Standard Turbidity Suspensions

Dilute stock turbidity suspension to desired range by first referring to the table below:

Turbidity Range NTU's	ml of Stock Suspension Diluted to 1.000 liter with "Turbidity-free" Water
1000	250
500	125
100	25
50	12.5
10	2.5
5	1.25
1	0.25

For example, if you are working in the 10 NTU range transfer exactly 2.5 ml of stock suspension to a 1.0 liter volumetric flask add dilute to the 1 liter mark with turbidity-free water. This dilution would be rated as 10 NTU's.

Dilute Formazin standards should be prepared weekly.

PROCEDURE

1. COLLECT SAMPLE.

   Samples should be run as soon as possible but may be stored up to 24 hours in the dark. Avoid debris and rapidly settling coarse material.

2. SET UP THE INSTRUMENT.

   Be sure to check the manufacturer's manual for warm-up time. Set up the instrument so that it is stable - vibration can lead to false results.

3. CALIBRATE THE INSTRUMENT.

   A separate standard must be used to calibrate each scale used. Carefully wipe off the tube containing the standard, place it in the instrument and adjust to the corresponding NTU reading.

4. CLEAN SAMPLE CELL.

   The sample cell must be free of fingerprints, water spots, scratches, and accumulated dust. Wash inside and out with warm soapy water and soft brush. Discard if scratched.

5. MIX THE SAMPLE.

   The sample should be thoroughly mixed by shaking 15 times through a one-foot arc.

6. POUR SAMPLE INTO CELL.

   Check the manufacturer's information for the amount of sample to place in the tube. Rinse tube twice with sample. Allow air bubbles to escape before testing.

7. WIPE SPILLED SAMPLE FROM OUTSIDE OF CELL.

   Do not touch tube with your fingers where the light passes through it.

8. PLACE CELL IN INSTRUMENT.

9. PLACE COVER OVER CELL.

10. ADJUST SCALE.

Once the proper range has been found, it may be desirable to check calibration with the standard for that range.

11. DILUTE SAMPLE IF NECESSARY.

If turbidity is greater than 40 NTU, dilute sample with turbidity-free water until it falls between 30-40 NTU. Record amount of sample and turbidity-free water used for the dilution.

12. READ AND RECORD DATA.

The reading is recorded as NTUs.

13. DISCARD SAMPLE AND CLEAN SAMPLE CELL.

CALCULATIONS

If no dilution was required read turbidity directly as NTU's.

If sample was diluted, calculate as follows:

$$NTU = \frac{A \times (B+C)}{C}$$

Where: A = NTU of diluted sample
B = Volume of turbidity-free water
C = Volume of undiluted sample

Example:

If 10 ml of sample was diluted with 50 ml of turbidity-free water and diluted sample read 30 NTU, then:

A = 30
B = 50
C = 10

$$NTU = \frac{A \times (B+C)}{C}$$

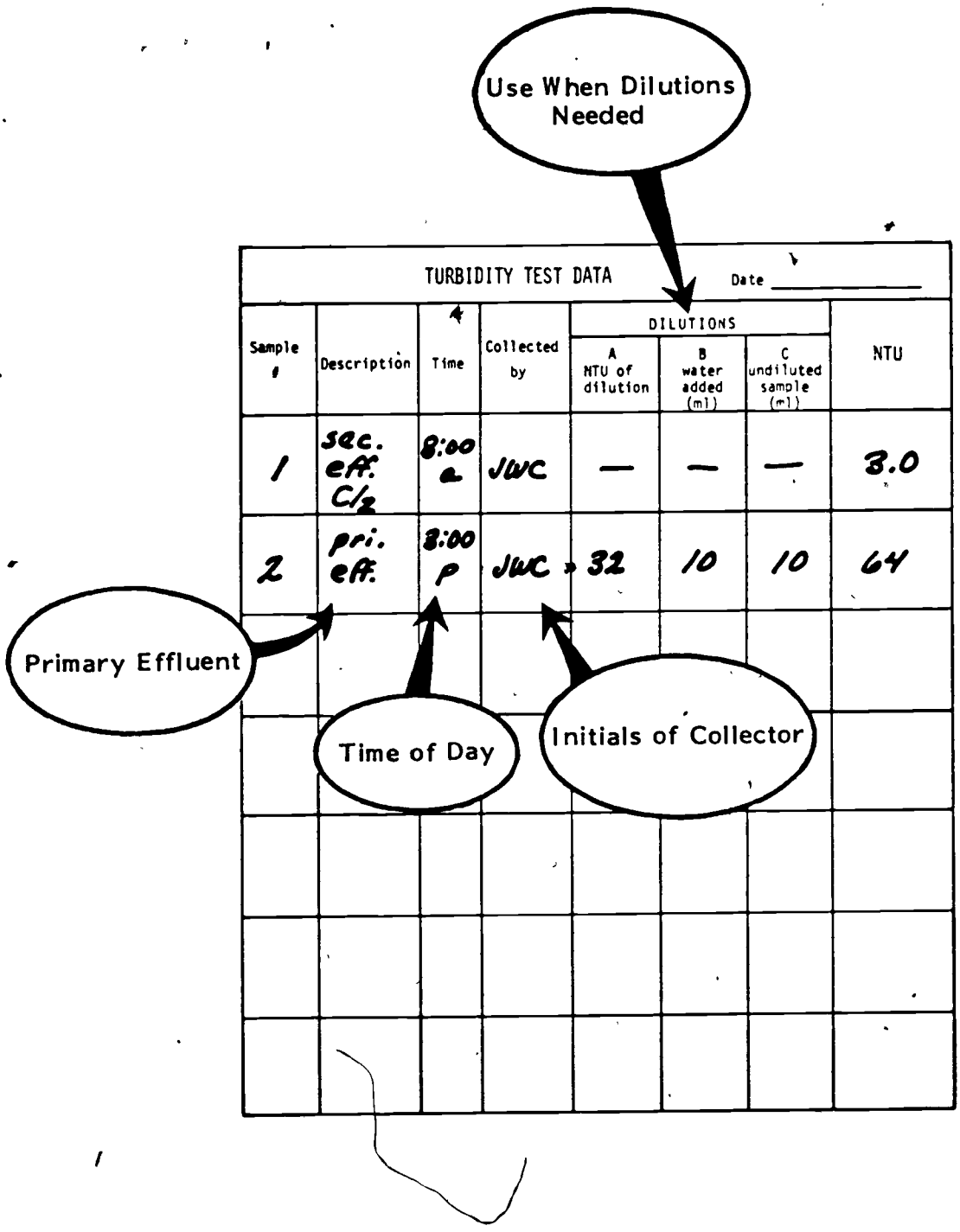
$$= \frac{30 \times (50+10)}{10} = 180 \text{ NTU}$$

TURBIDITY TEST DATA

Date _____

Sample #	Description	Time	Collected by	DILUTIONS			NTU
				A NTU of dilution	B water added (ml)	C undiluted sample (ml)	

SAMPLE DATA SHEET



PROCEDURE SUMMARY

PROCEDURE

1. Collect sample
2. Warm-up instrument
3. Calibrate instrument
4. Clean sample cell
5. Mix sample
6. Fill sample cell
7. Wipe outside of cell
8. Place in instrument and cover
9. Adjust scale range
10. Dilute (if necessary)
11. Read and record NTU
12. Clean sample cell
13. Calculate (if necessary)

CALCULATIONS

$$NTU = \frac{A \times (B + C)}{C}$$

Where A = NTU of dil. sample
B = ml of water added
C = ml of undil. sample

TURBIDITY

The above procedure summary is designed as a laboratory aid. It may be cut out and attached to a 5" X 7" index card for convient reference at the laboratory bench. To protect the card you may wish to cover it, front and back, with clear, self-adhesive shelf paper or similar clear material.

TURBIDITY TEST

WORKSHEET

Directions: Place an "X" by the best answer. There is only one best answer for each question.

1. Turbidity is:

   a)_____ always equal to suspended solids content.

   b)_____ an optical property which causes light to scatter.

   c)_____ an optical property which causes fluorescence.

   d)_____ measured routinely as mg/l.

   e)_____ only used in potable water treatment.

2. Turbidity is most commonly expressed as:

   a)_____ JTU's.

   b)_____ mg/l.

   c)_____ %.

   d)_____ NTU's.

   e)_____ ppm.

3. The best description of the path that light follows through a nephelometric turbidimeter is:

   a)_____ light source, sensing device, sample, slit.

   b)_____ sample, light source, slit, sensing device.

   c)_____ light source, sample, slit, sensing device.

   d)_____ light source, sensing device, slit, sample.

   e)_____ sensing device, slit, sample, light source.

4. Turbidity standards are made from:

a)_____ formazin.

b)_____ copper.

c)_____ phosphate.

d)_____ silica.

e)_____ chloride.

5. Turbidity standards may be obtained:

a)_____ by purchasing prepared, sealed standards.

b)_____ filtering double-distilled water.

c)_____ preparing fresh in the laboratory.

d)_____ a and b above.

e)_____ a and c above.

6. Turbidity-free water can be used:

a)_____ to dilute samples.

b)_____ to prepare standards in the laboratory.

c)_____ as a buffer to prevent etching of glass.

d)_____ a and b above.

e)_____ a and c above.

7. Which of the following is not a precaution regarding sample collection and preservation?

a)_____ avoid debris.

b)_____ avoid rapidly settling coarse material.

c)_____ get a representative sample.

d)_____ store 24 hours in dark.

e)_____ add HCl to hold longer than 24 hours.

8. Which of the following is not part of the turbidity test procedure?

a)_____ calibrate the instrument.

b)_____ allow air bubbles to escape from the sample cell.

c)_____ wipe sample cell carefully.

d)_____ dilute if greater than 80 NTU's.

e)_____ read proper scale.

9. What is the turbidity of a sample if 15 ml was diluted with 35 ml of turbidity-free water and the diluted sample read 12 NTU's?

$$NTU = \frac{A \times (B + C)}{C}$$

a)_____ 4 NTU's

b)_____ 40 NTU's

c)_____ 80 NTU's

d)_____ 43 NTU's

e)_____ none of the above