

Chapter V

PRESENTATION OF RESULTS AND DISCUSSION

5.1 Results

5.1.1 Dosage of Lime in Raising pH

Raw water ; pH            7.2  
                         Alkalinity 58 ppm.  
                         Hardness 74 ppm.  
                         Turbidity 30 ppm.



Lime (ppm.)	pH	Alkalinity (ppm.)	Hardness (ppm.)	Turbidity (ppm.)
3.2	7.9	68	76	30
8	8.95	78	80	30
16	9.5	84	94	30
32	10.0	108	112	30
48	10.5	118	130	30
80	10.9	146	152	35
112	11.1	160	154	35
160	11.4	186	192	35
240	11.5	290	280	35
320	11.7	400	414	35
480	11.85	620	672	40
640	11.95	846	916	40
800	12.05	1050	1060	40
1120	12.15	1480	1620	45

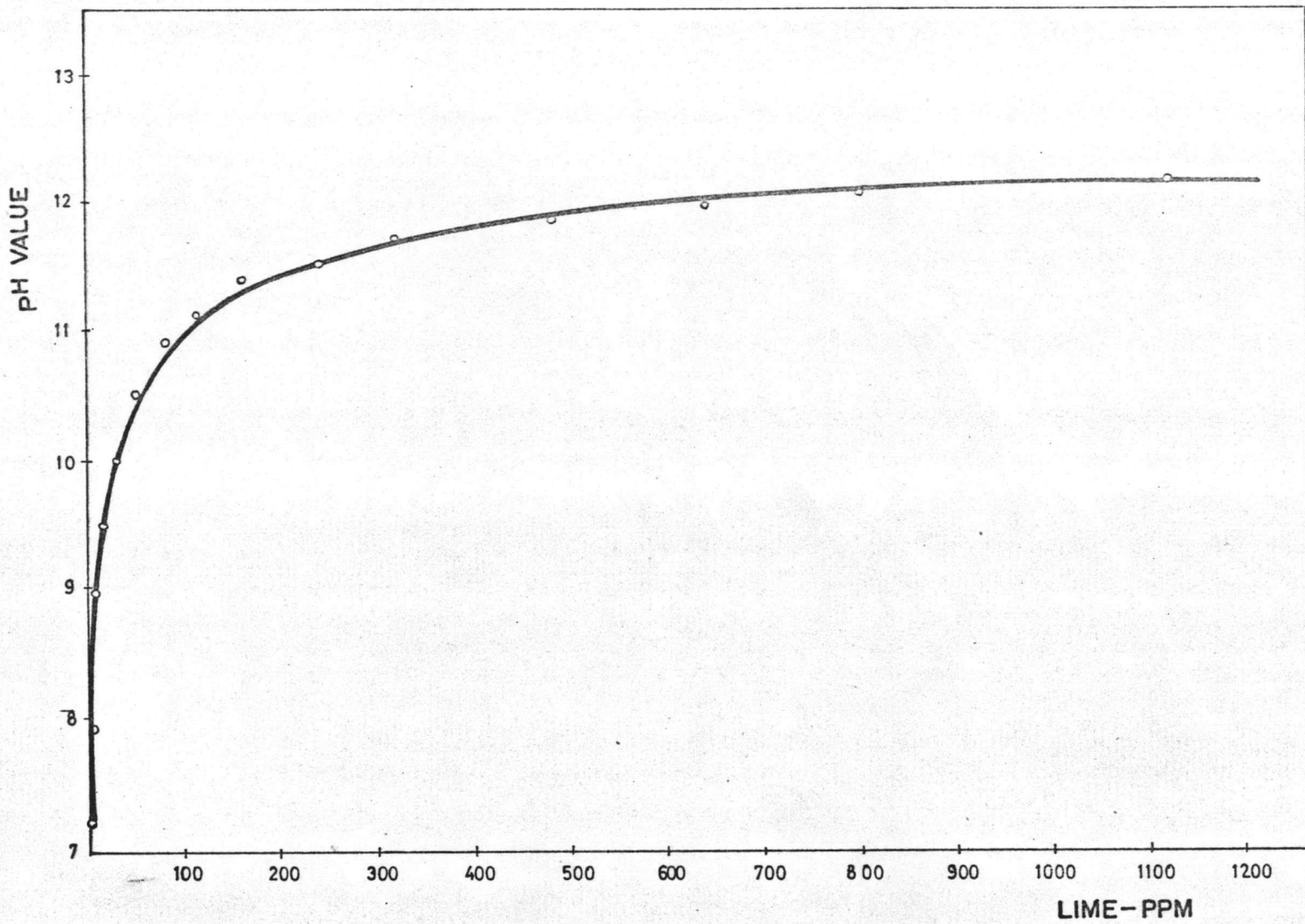


FIGURE 5.1. DOSAGE OF LIME IN RAISING pH.

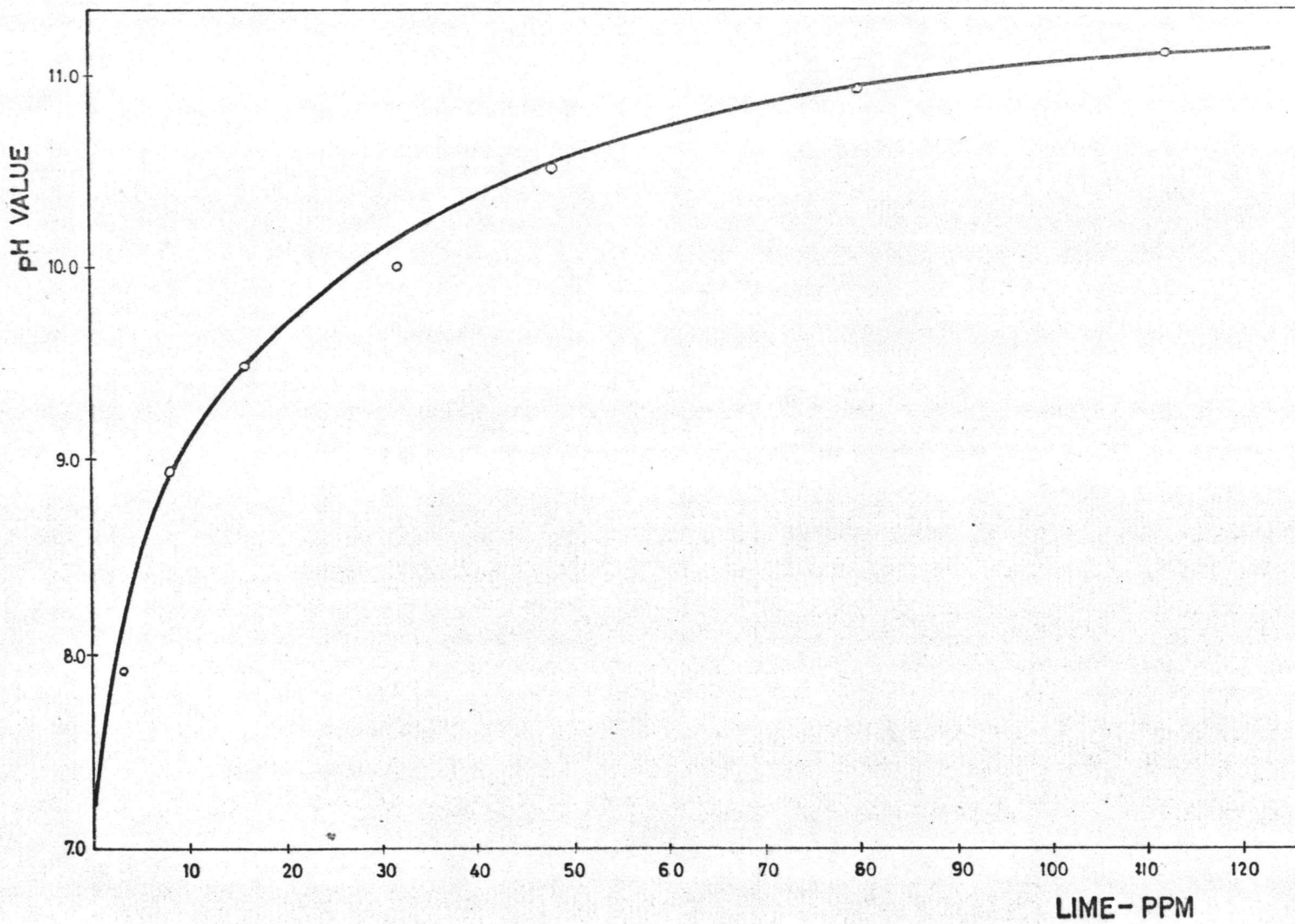


FIGURE 5.2. DOSAGE OF LIME IN RAISING pH

### 5.1.2 Coagulation of Ferrous Sulphate for Various pH Values

Mixing Time : 5 minutes rapid  
25 minutes slow

Floc Index : 0 = no floc  
2 = opalescent  
4 = small specks  
6 = medium  
8 = good  
10 = excellent  
12 = very heavy

Turbidity after flocculation = Turbidity when stoping the stirrer.  
Turbidity after 5 minutes = Turbidity at settling time 5 minutes.  
Turbidity after 15 minutes = Turbidity at settling time 15 minutes.

(DEGREMONT ACFI 1960)

Test No.1,	November 1, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	-	-	-	-	-	-	-
pH Reading		7.05	-	6.95	6.9	6.85	6.8	6.75	6.65
Alkalinity	(ppm.)	60	-	58	55	54	52	50	47
Hardness	(ppm.)	64	-	65	67	66	66	67	66
Turbidity	(ppm.)	30	-	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	-	-	-	-	-	-
Floc index		-	-	0	0	0	0	0	0
Turbidity after flocculation	(ppm.)	-	-	30	30	30	30	30	30
Turbidity after 5 minutes	(ppm.)	-	-	30	30	30	30	30	30
Turbidity after 15 minutes	(ppm.)	-	-	30	30	30	30	30	30
Turbidity reduction ratio after 5 minutes		-	-	0	0	0	0	0	0
Turbidity reduction ratio after 15 minutes		-	-	0	0	0	0	0	0
Percent of turbidity reduction		-	-	0	0	0	0	0	0
Residual iron	(ppm.)	1.0	-	3.5	4.5	5.5	6.0	7.0	8.0
Percent of iron increase		-	-	250	350	450	500	600	700



Test No.2,	November 2, 1971	Raw water	raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	6.0	6.0	6.0	6.0	6.0	6.0	6.0
pH Reading		7.05	8.1	7.55	7.4	7.25	7.15	7.1	7.1
Alkalinity	(ppm.)	62	70	68	66	64	62	62	60
Hardness	(ppm.)	60	62	60	62	62	61	60	60
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	-	-	-	-	-	-
Floc index		-	-	0	0	0	0	0	0
Turbidity after flocculation	(ppm.)	-	-	30	30	30	30	30	35
Turbidity after 5 minutes	(ppm.)	-	-	30	30	30	30	30	35
Turbidity after 15 minutes	(ppm.)	-	-	30	30	30	30	30	35
Turbidity reduction ratio after 5 minutes		-	-	0	0	0	0	0	0
Turbidity reduction ratio after 15 minutes		-	-	0	0	0	0	0	0
Percent of turbidity reduction		-	-	0	0	0	0	0	16.7
Residual iron	(ppm.)	1.0	1.0	3.5	4.5	5.5	6.0	7.0	8.0
Percent of iron increase		0	0	250	300	450	500	600	700

Test No.3,	November 6, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	5.4	5.4	5.4	5.4	5.4	5.4	5.4
pH Reading		7.4	8.65	8.2	8.0	7.8	7.7	7.6	7.5
Alkalinity	(ppm.)	64	71	69	68	66	65	62	60
Hardness	(ppm.)	62	70	72	72	72	72	72	70
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	-	25-0	20-0	18-0	18-0	15-0
Floc index		-	-	0	2	2	4	4	6
Turbidity after flocculation	(ppm.)	-	-	30	60	60	55	50	50
Turbidity after 5 minutes	(ppm.)	-	-	30	45	45	40	40	40
Turbidity after 15 minutes	(ppm.)	-	-	30	30	25	25	20	20
Turbidity reduction ratio after 5 minutes		-	-	0	0.25	0.25	0.27	0.20	0.20
Turbidity reduction ratio after 15 minutes		-	-	0	0.50	0.58	5.55	0.60	0.60
Percent of turbidity reduction		-	-	0	0	16.7	16.7	33.3	33.3
Residual iron	(ppm.)	1.0	1.0	3.5	4.0	6.0	5.0	6.0	6.0
Percent of iron increase		0	0	250	300	400	400	500	500

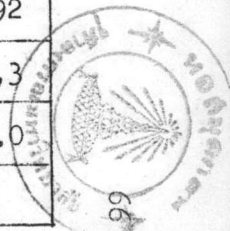
Test No.4,	November 7, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	7.5	7.5	7.5	7.5	7.5	7.5	7.5
pH Reading		7.25	8.95	8.35	8.1	7.95	7.8	7.7	7.6
Alkalinity	(ppm.)	60	70	68	66	62	62	60	60
Hardness	(ppm.)	60	70	70	70	72	70	72	72
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	28-0	28-0	15-0	10-0	7-0	5-0
Floc index		-	-	2	4	6	6	8	10
Turbidity after flocculation	(ppm.)	-	-	25	25	25	20	20	20
Turbidity after 5 minutes	(ppm.)	-	-	20	20	15	10	7	5
Turbidity after 15 minutes	(ppm.)	-	-	15	10	9	6	5	4
Turbidity reduction ratio after 5 minutes		-	-	0.20	0.20	0.40	0.50	0.65	0.75
Turbidity reduction ratio after 15 minutes		-	-	0.40	0.60	0.64	0.70	0.75	0.80
Percent of turbidity reduction		-	-	50.0	66.7	70.0	80.0	83.3	86.7
Residual iron	(ppm.)	1.0	1.0	3.0	3.5	4.0	4.5	5.0	4.5
Percent of iron increase		0	0	200	250	300	350	400	350



Test No. 5,	November 9, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	15	15	15	15	15	15	15
pH Reading		7.35	9.5	9.2	9.0	8.85	8.8	8.7	8.6
Alkalinity	(ppm.)	60	84	80	78	76	74	72	70
Hardness	(ppm.)	58	82	84	82	82	82	84	82
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	15-0	8-0	5-0	4-0	4-0	3-0
Floc index		-	-	4	4	6	6	12	12
Turbidity after flocculation	(ppm.)	-	-	25	20	15	15	10	9
Turbidity after 5 minutes	(ppm.)	-	-	15	10	10	6	5	4
Turbidity after 15 minutes	(ppm.)	-	-	10	9	6	5	4	3
Turbidity reduction ratio after 5 minutes		-	-	0.40	0.50	0.33	0.60	0.50	0.56
Turbidity reduction ratio after 15 minutes		-	-	0.60	0.55	0.60	0.67	0.60	0.67
Percent of turbidity reduction		-	-	66.7	70.0	80.0	83.3	86.7	90.0
Residual iron	(ppm.)	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0
Percent of iron increase				100	100	100	100	100	100

Test No.6,	November 11, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	30	30	30	30	30	30	30
pH Reading		7.4	9.9	9.4	9.25	9.15	9.1	9.05	9.0
Alkalinity	(ppm.)	62	58	52	48	46	46	44	42
Hardness	(ppm.)	56	56	54	56	55	56	54	54
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	5-0	4-30	4-0	3-30	2-30	1-30
Floc index		-	-	4	4	6	6	4	10
Turbidity after flocculation	(ppm.)	-	-	25	20	15	15	15	15
Turbidity after 5 minutes	(ppm.)	-	-	15	10	10	10	8	8
Turbidity after 15 minutes	(ppm.)	-	-	9	8	6	5	3	2
Turbidity reduction ratio after 5 minutes		-	-	0.40	0.50	0.33	0.33	0.47	0.47
Turbidity reduction ratio after 15 minutes		-	-	0.64	0.60	0.60	0.67	0.80	0.87
Percent of turbidity reduction		-	-	70.0	73.3	80.0	83.3	90.0	93.3
Residual iron	(ppm.)	1.0	1.0	1.5	1.5	1.5	1.5	1.5	1.5
Percent of iron increase		0	0	50	50	50	50	50	50

Test No.7,	November 13, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	60	60	60	60	60	60	60
pH Reading		7.1	10.45	10.15	10.1	10.05	10.0	10.0	9.9
Alkalinity	(ppm.)	60	66	62	58	56	55	52	50
Hardness	(ppm.)	60	60	60	62	62	62	62	62
Turbidity	(ppm.)	30	30	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	3-0	3-0	2-30	2-0	1-30	1-30
Floc index		-	-	6	6	8	8	10	10
Turbidity after flocculation	(ppm.)	-	-	35	30	30	30	25	25
Turbidity after 5 minutes	(ppm.)	-	-	15	10	10	10	9	9
Turbidity after 15 minutes	(ppm.)	-	-	8	6	5	4	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.57	0.67	0.67	0.67	0.64	0.64
Turbidity reduction ratio after 15 minutes		-	-	0.77	0.80	0.83	0.87	0.92	0.92
Percent of turbidity reduction		-	-	73.3	80.0	83.3	86.7	93.3	93.3
Residual iron	(ppm.)	1.0	1.0	1.2	1.2	1.2	1.1	1.0	1.0
Percent of iron increase		0	0	20	20	20	10	0	0



Test No.8,	November 14, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.05	11.1	11.0	10.95	10.90	10.9	10.9	10.85
Alkalinity	(ppm.)	60	68	78	80	80	96	102	144
Hardness	(ppm.)	60	78	82	88	88	102	106	148
Turbidity	(ppm.)	30	35	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	2-30	1-30	1-30	1-10	1-0	1-45
Floc index		-	-	4	6	6	8	8	10
Turbidity after flocculation	(ppm.)	-	-	25	25	30	30	25	25
Turbidity after 5 minutes	(ppm.)	-	-	8	5	4	4	3	3
Turbidity after 15 minutes	(ppm.)	-	-	5	4	3	2	2	1
Turbidity reduction ratio after 5 minutes		-	-	0.68	0.80	0.87	0.87	0.88	0.88
Turbidity reduction ratio after 15 minutes		-	-	0.80	0.84	0.90	0.93	0.92	0.96
Percent of turbidity reduction		-	-	83.3	86.7	90.0	93.3	93.3	96.7
Residual iron	(ppm.)	1.0	1.0	0.33	0.33	0.30	0.30	0.25	0.25
Percent of iron decrease		0	0	67	67	70	70	75	75

Test No.9,	November 15, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	220	220	220	220	220	220	220
pH Reading		7.2	11.45	11.45	11.4	11.4	11.4	11.35	11.3
Alkalinity	(ppm.)	60	315	235	215	218	195	210	225
Hardness	(ppm.)	60	200	220	222	224	222	225	228
Turbidity	(ppm.)	30	35	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	1-15	1-0	1-0	0-45	0-45	0-30
Floc index		-	-	6	8	8	8	10	10
Turbidity after flocculation	(ppm.)	-	-	30	30	40	40	40	40
Turbidity after 5 minutes	(ppm.)	-	-	7	5	4	3	3	2
Turbidity after 15 minutes	(ppm.)	-	-	4	4	3	2	2	1
Turbidity reduction ratio after 5 minutes		-	-	0.77	0.83	0.90	0.92	0.92	0.95
Turbidity reduction ratio after 15 minutes		-	-	0.87	0.87	0.92	0.95	0.95	0.98
Percent of turbidity reduction		-	-	86.7	86.7	90.0	93.3	93.3	96.7
Residual iron	(ppm.)	1.0	1.0	0.25	0.25	0.27	0.27	0.30	0.30
Percent of iron decrease		0	0	75	75	73	73	70	70

Test No.10,	November 20, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	--	-	10	15	20	25	30	35
Lime	(ppm.)	-	450	450	450	450	450	450	450
pH Reading		7.2	11.85	11.8	11.8	11.8	11.8	11.75	11.75
Alkalinity	(ppm.)	58	490	510	510	540	470	480	480
Hardness	(ppm.)	66	528	554	544	570	528	524	526
Turbidity	(ppm.)	30	40	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-45	0-40	0-35	0-30	0-25	0-20
Floc index		-	-	8	8	8	10	10	10
Turbidity after flocculation	(ppm.)	-	-	40	45	45	40	60	65
Turbidity after 5 minutes	(ppm.)	-	-	8	7	7	7	6	4
turbidity after 15 minutes	(ppm.)	-	-	4	4	3	3	3	2
Turbidity reduction ratio after 5 minutes		-	-	0.80	0.84	0.84	0.86	0.90	0.94
Turbidity reduction ratio after 15 minutes		-	-	0.90	0.91	0.93	0.94	0.95	0.97
Percent of turbidity reduction		-	-	86.7	86.7	90.0	90.0	90.0	93.3
Residual iron	(ppm.)	1.0	1.0	0.17	0.17	0.20	0.20	0.20	0.20
Percent of iron decrease		0	0	83	83	80	80	80	80

Test No.11,	November 21, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	700	700	700	700	700	700	700
pH Reading		7.4	12.05	12.0	12.0	12.0	12.0	11.95	11.95
Alkalinity	(ppm.)	60	596	860	882	860	854	852	848
Hardness	(ppm.)	64	720	960	980	960	960	930	966
Turbidity	(ppm.)	30	40	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-30	0-30	0-25	0-25	0-25	0-20
Floc index		-	-	10	8	8	8	6	4
Turbidity after flocculation	(ppm.)	-	-	15	20	25	30	35	40
Turbidity after 5 minutes	(ppm.)	-	-	6	6	7	8	8	10
Turbidity after 15 minutes	(ppm.)	-	-	2	3	3	4	5	5
Turbidity reduction ratio after 5 minutes		-	-	0.60	0.70	0.72	0.73	0.77	0.75
Turbidity reduction ratio after 15 minutes		-	-	0.87	0.85	0.88	0.87	0.86	0.88
Percent of turbidity reduction		-	-	93.3	90.0	90.0	86.7	83.3	83.3
Residual iron	(ppm.)	1.0	1.0	0.17	0.20	0.23	0.27	0.30	0.30
Percent of iron decrease		-	-	83	80	77	73	70	70

## RELATION BETWEEN TURBIDITY AND pH

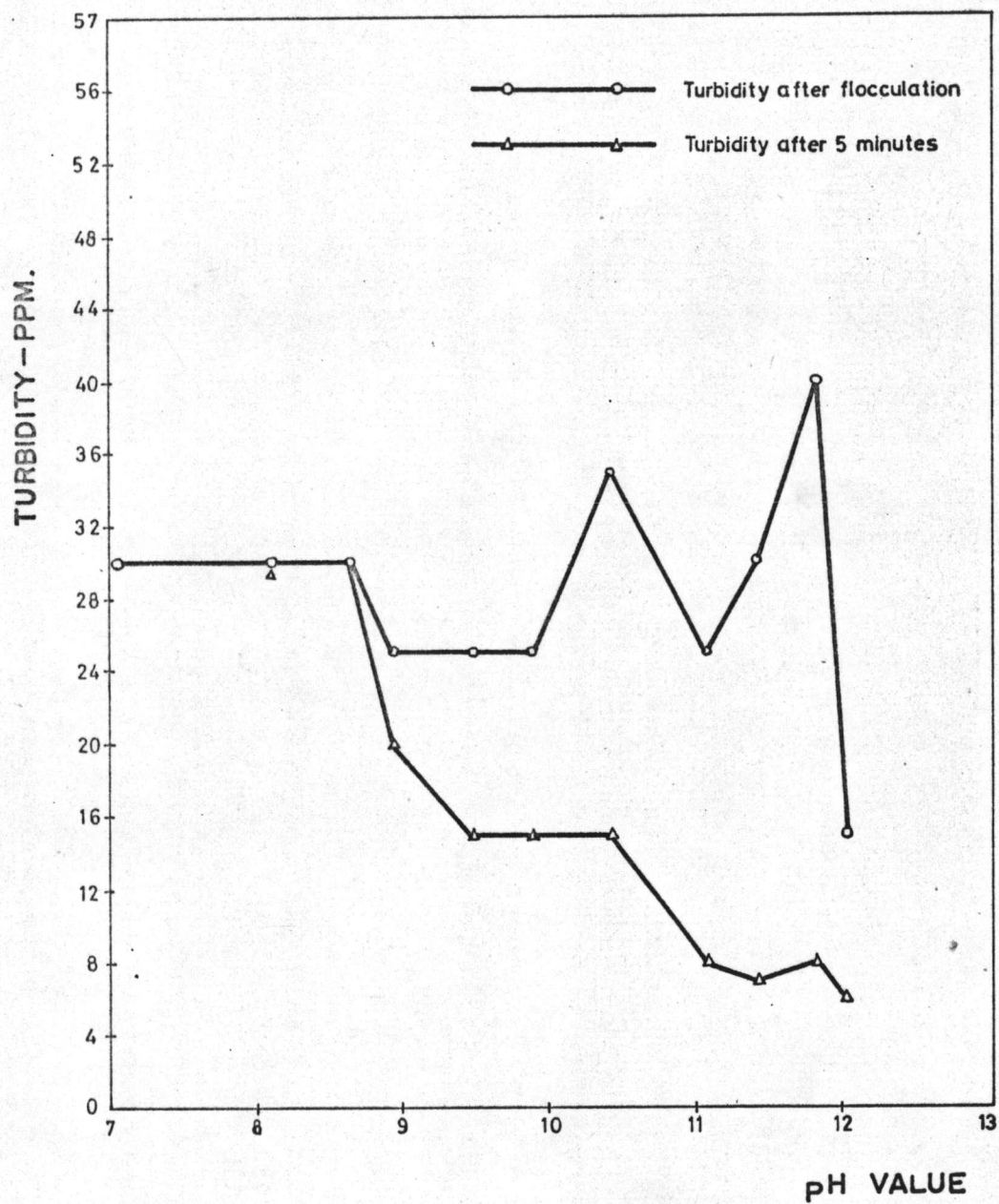


FIGURE 5.3. FERROUS SULPHATE 10 PPM.



## RELATION BETWEEN TURBIDITY AND pH

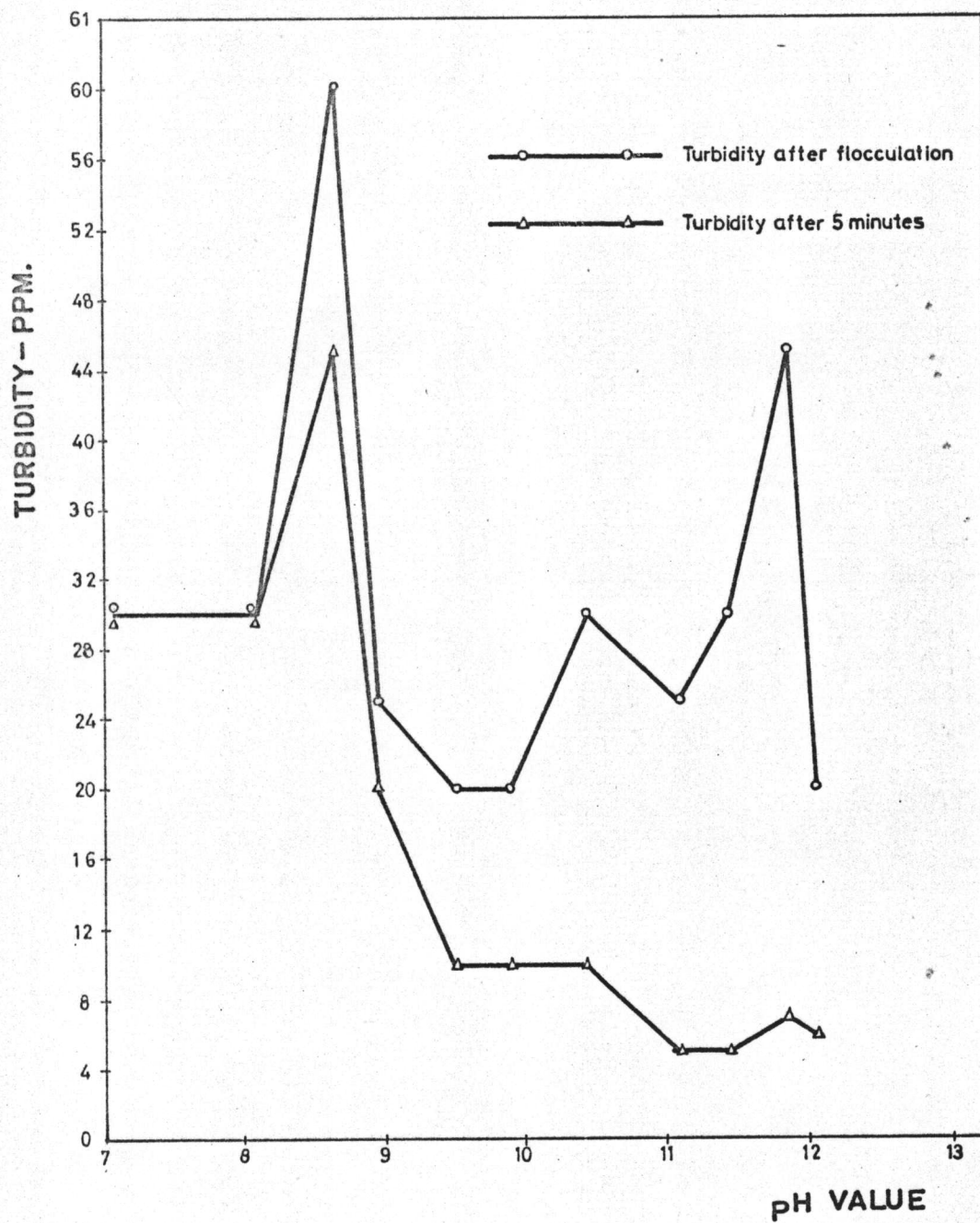


FIGURE 5.4. FERROUS SULPHATE 15 PPM.

## RELATION BETWEEN TURBIDITY AND pH

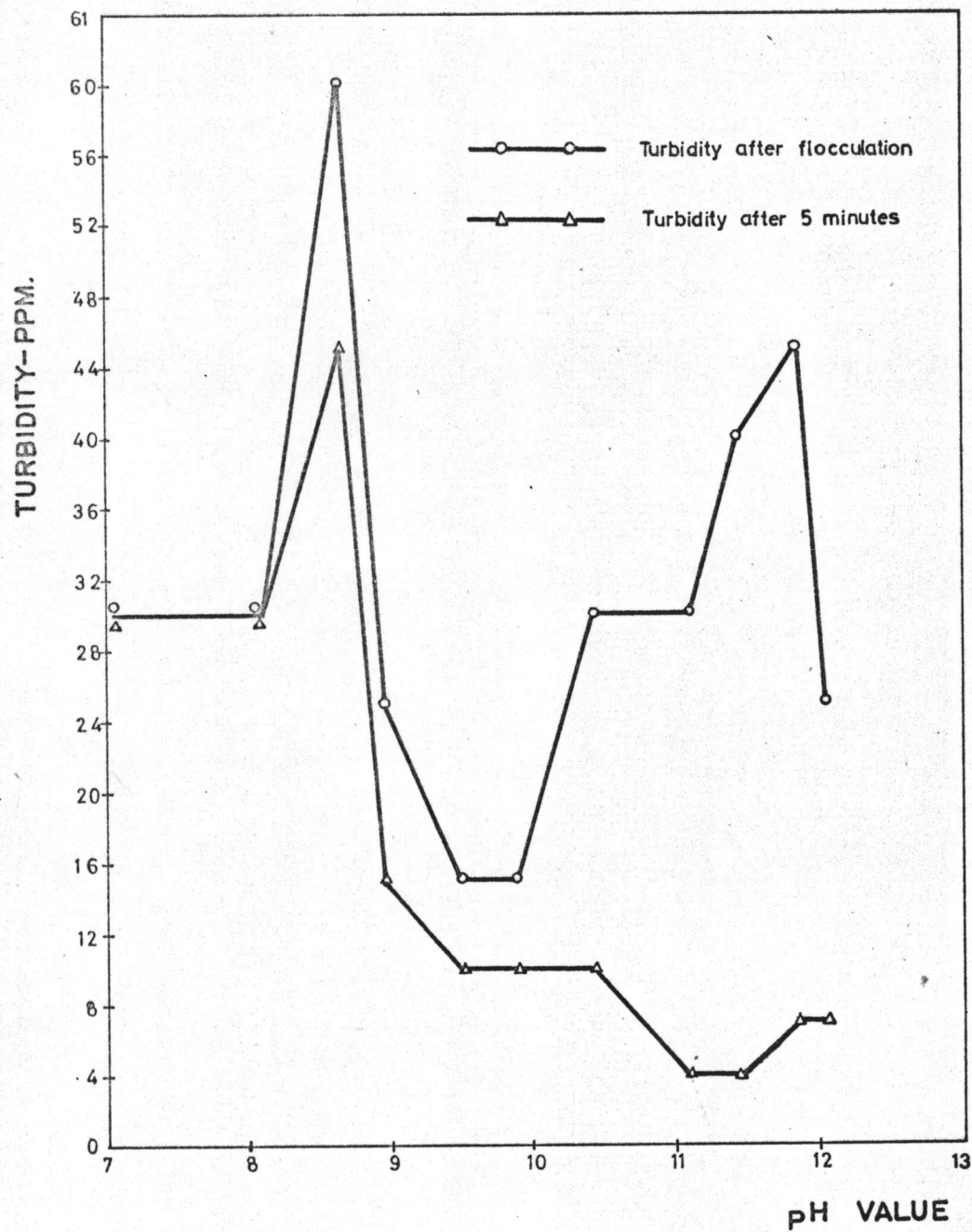


FIGURE 5.5. FERROUS SULPHATE 20 PPM.

## RELATION BETWEEN TURBIDITY AND pH

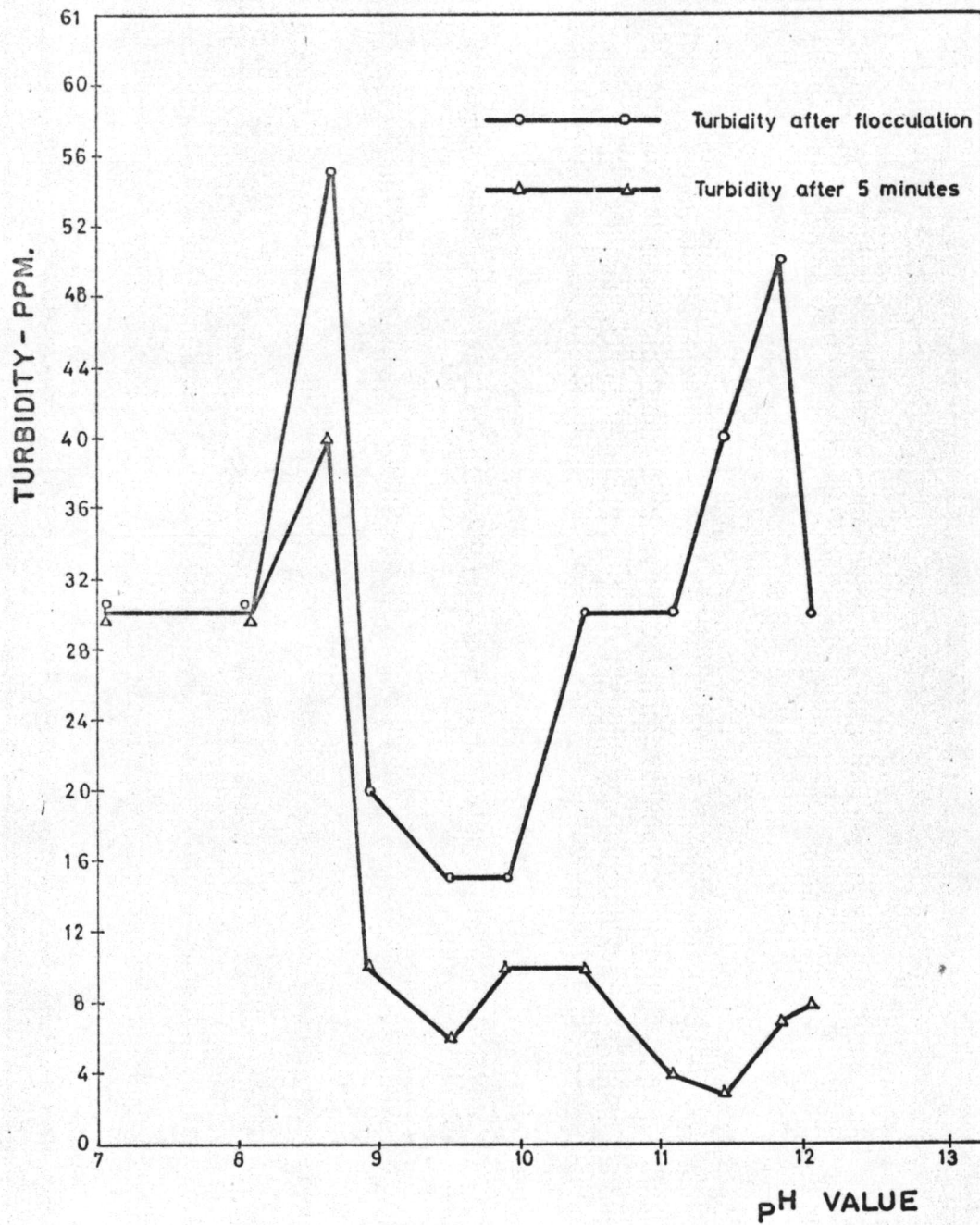


FIGURE 5.6. FERROUS SULPHATE 25 PPM.

## RELATION BETWEEN TURBIDITY AND pH

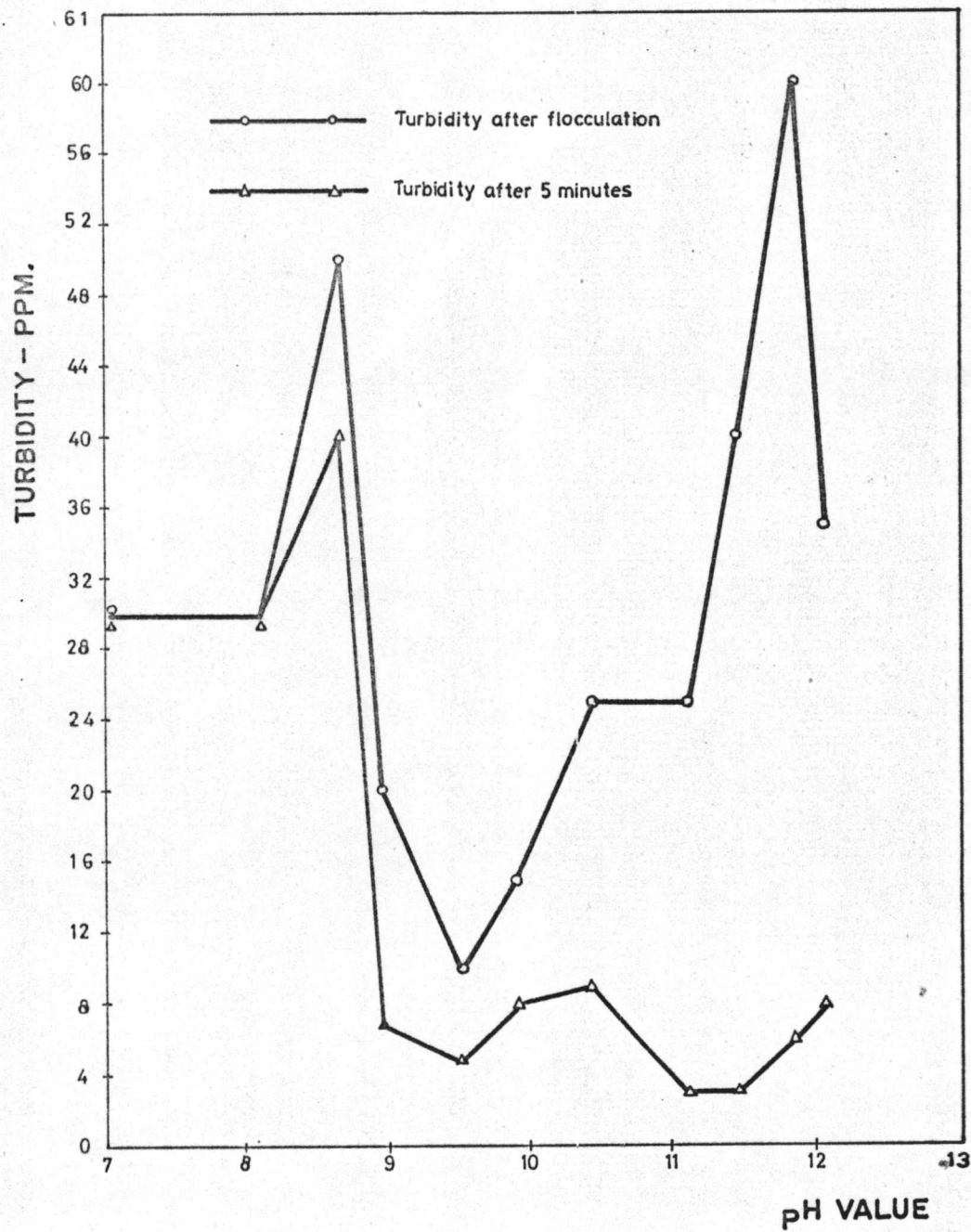


FIGURE 5.7. FERROUS SULPHATE 30 PPM.

## RELATION BETWEEN TURBIDITY AND pH

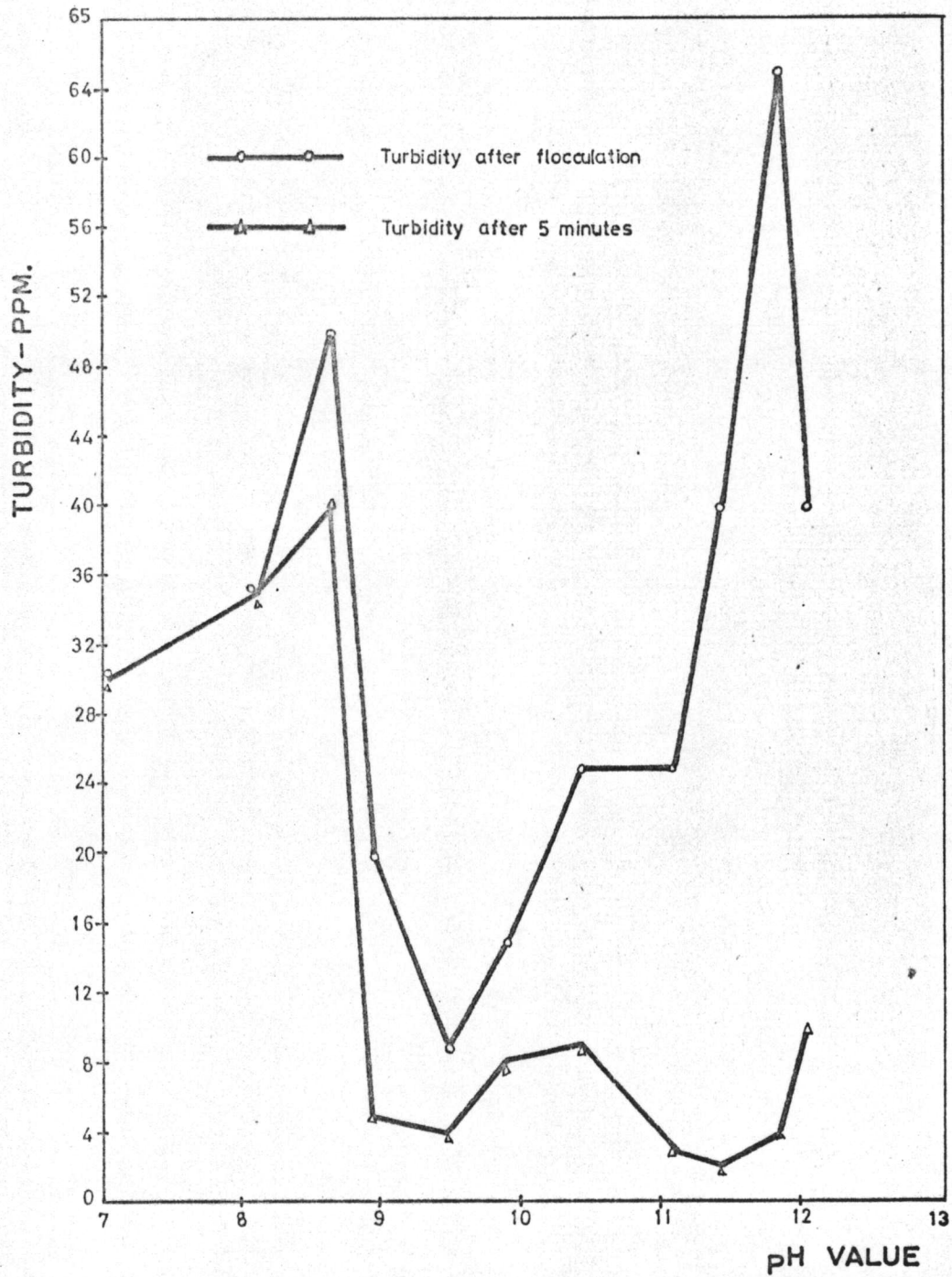


FIGURE 5.8. FERROUS SULPHATE 35 PPM.

RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

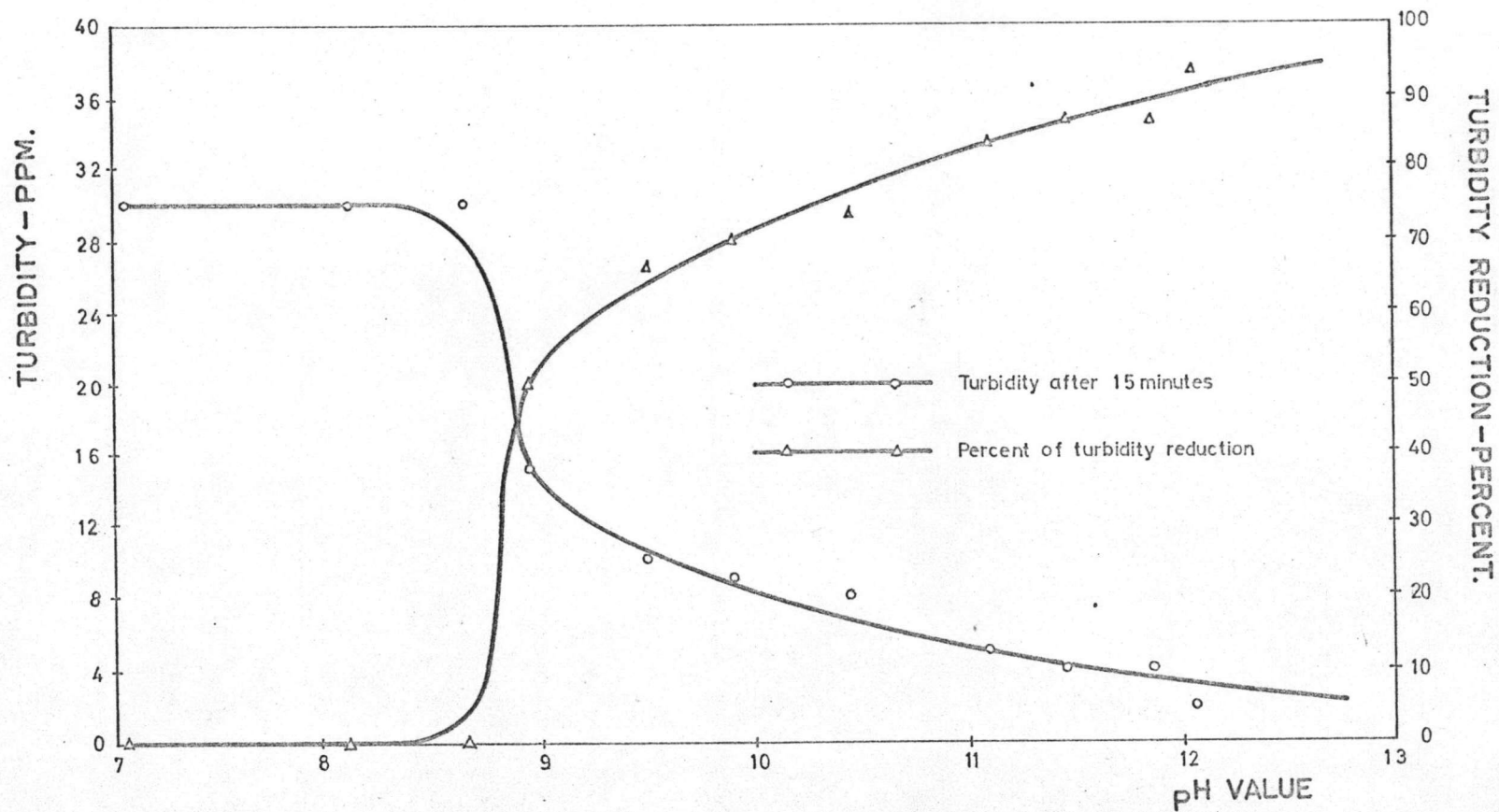


FIGURE 5.9. FERROUS SULPHATE 10 PPM.

RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

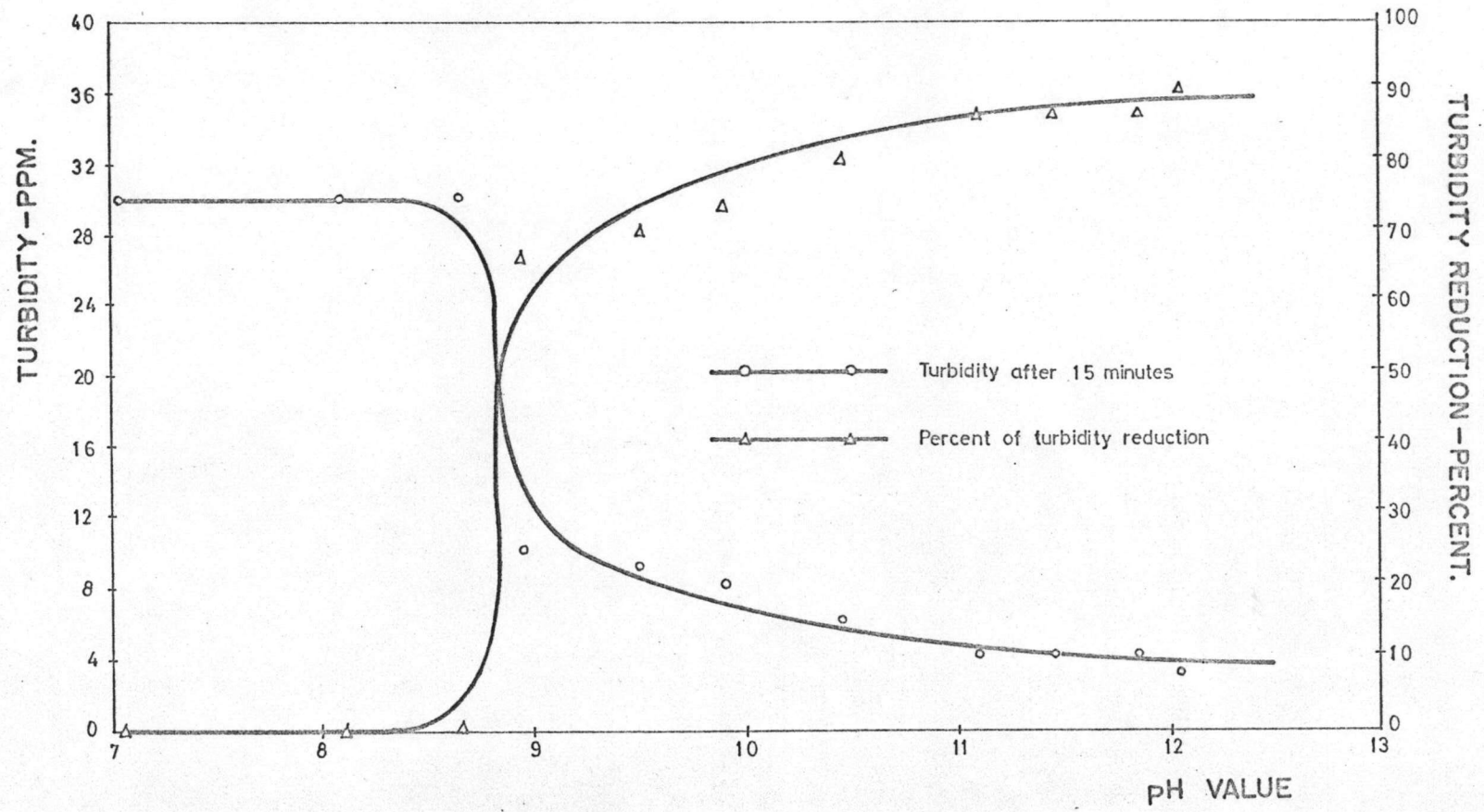


FIGURE 5.10 FERROUS SULPHATE 15 PPM.

RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

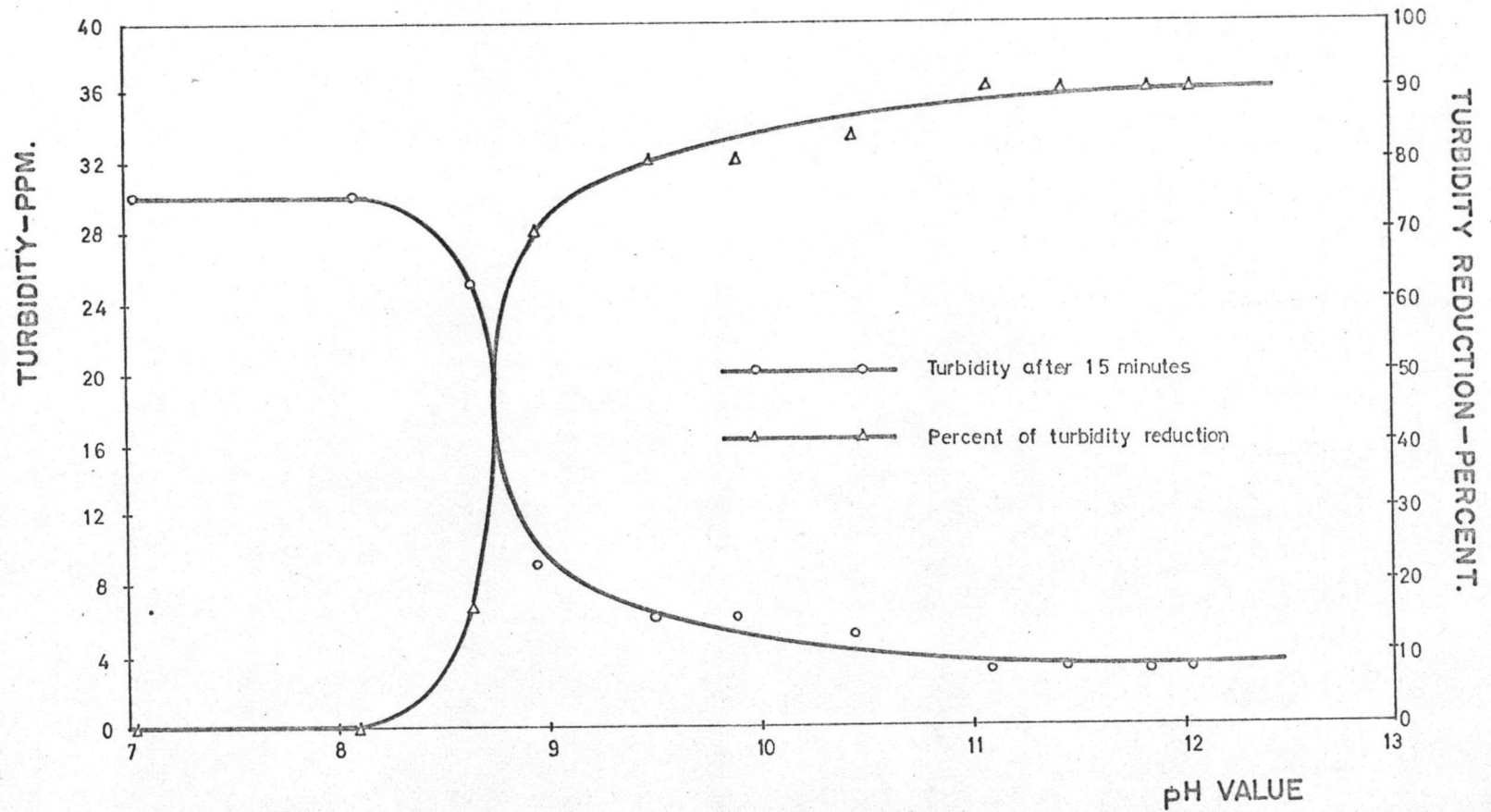


FIGURE 5.II. FERROUS SULPHATE 20 PPM.



RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

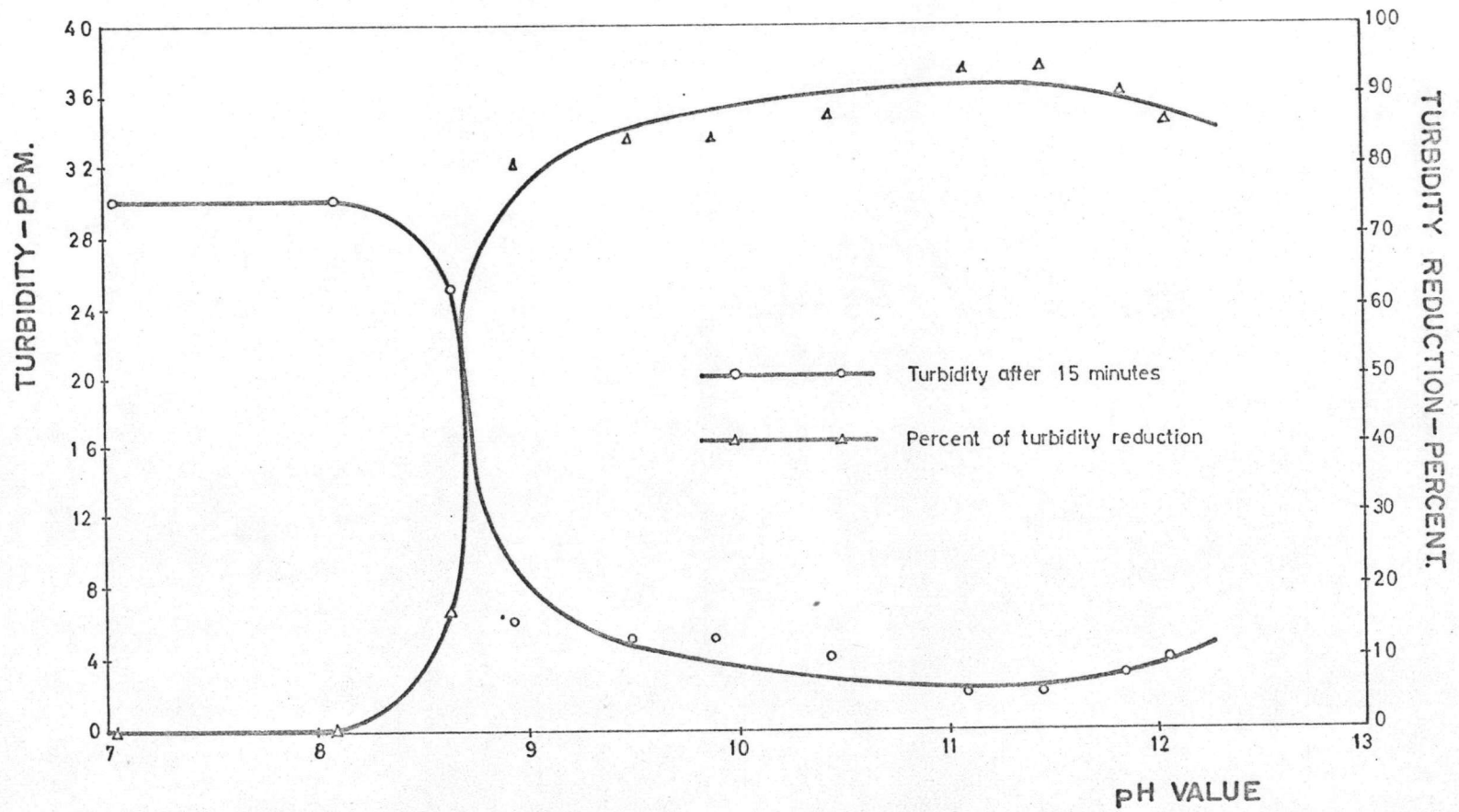


FIGURE 5.12. FERROUS SULPHATE 25 PPM.

RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

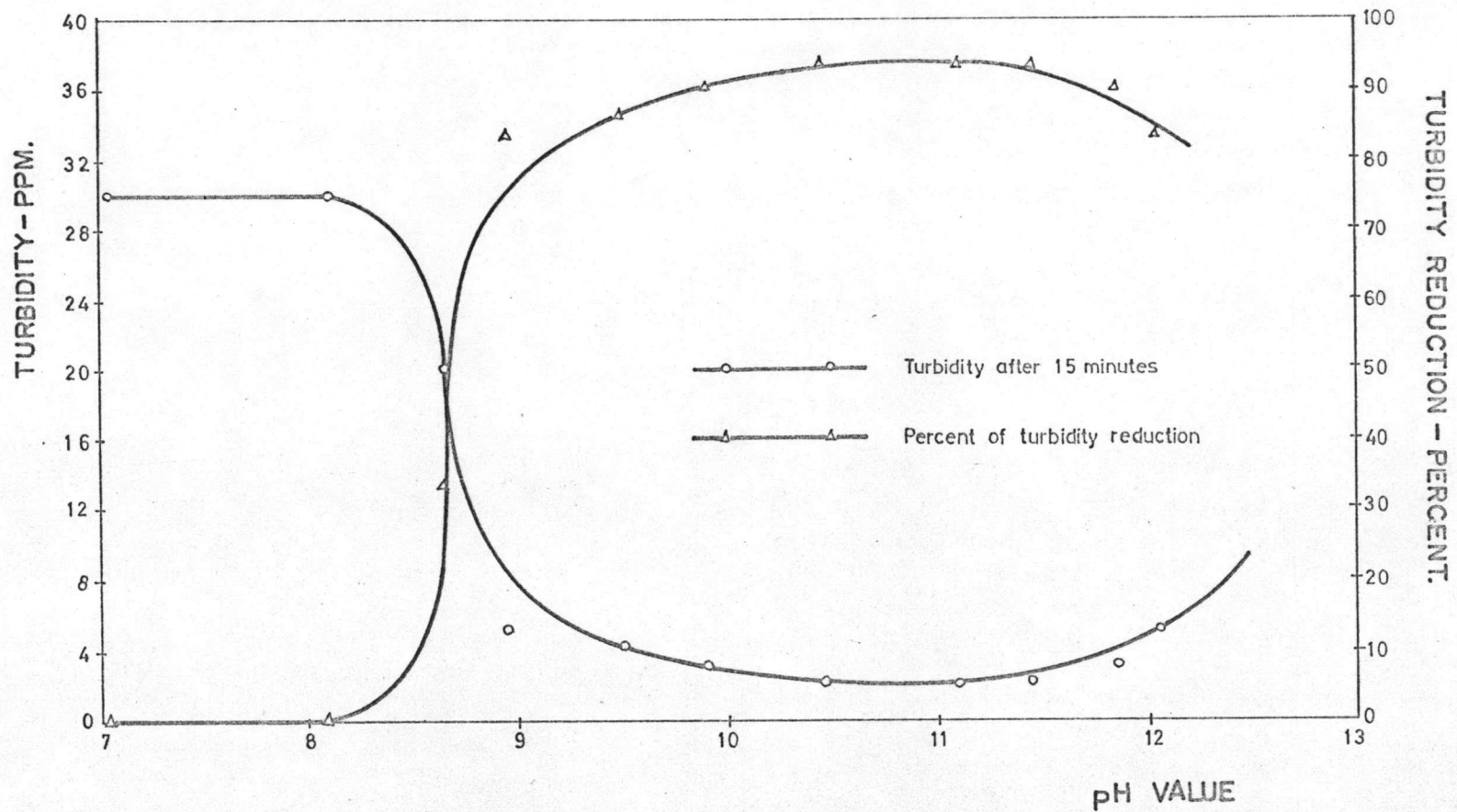


FIGURE 5.13 FERROUS SULPHATE 30 PPM.

RELATION BETWEEN TURBIDITY AFTER 15 MINUTES AND pH.

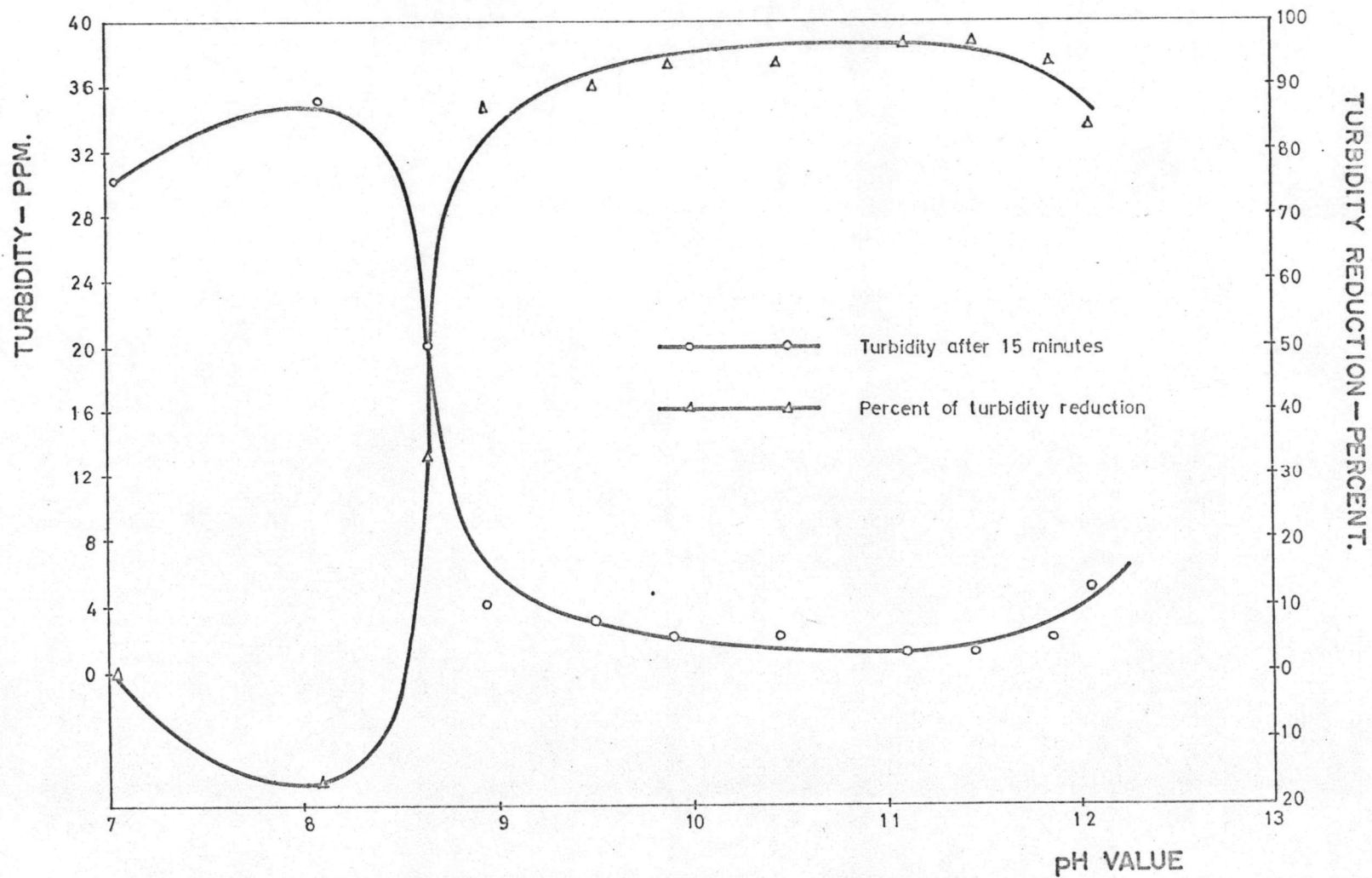


FIGURE 5.14 FERROUS SULPHATE 35 PPM.

RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

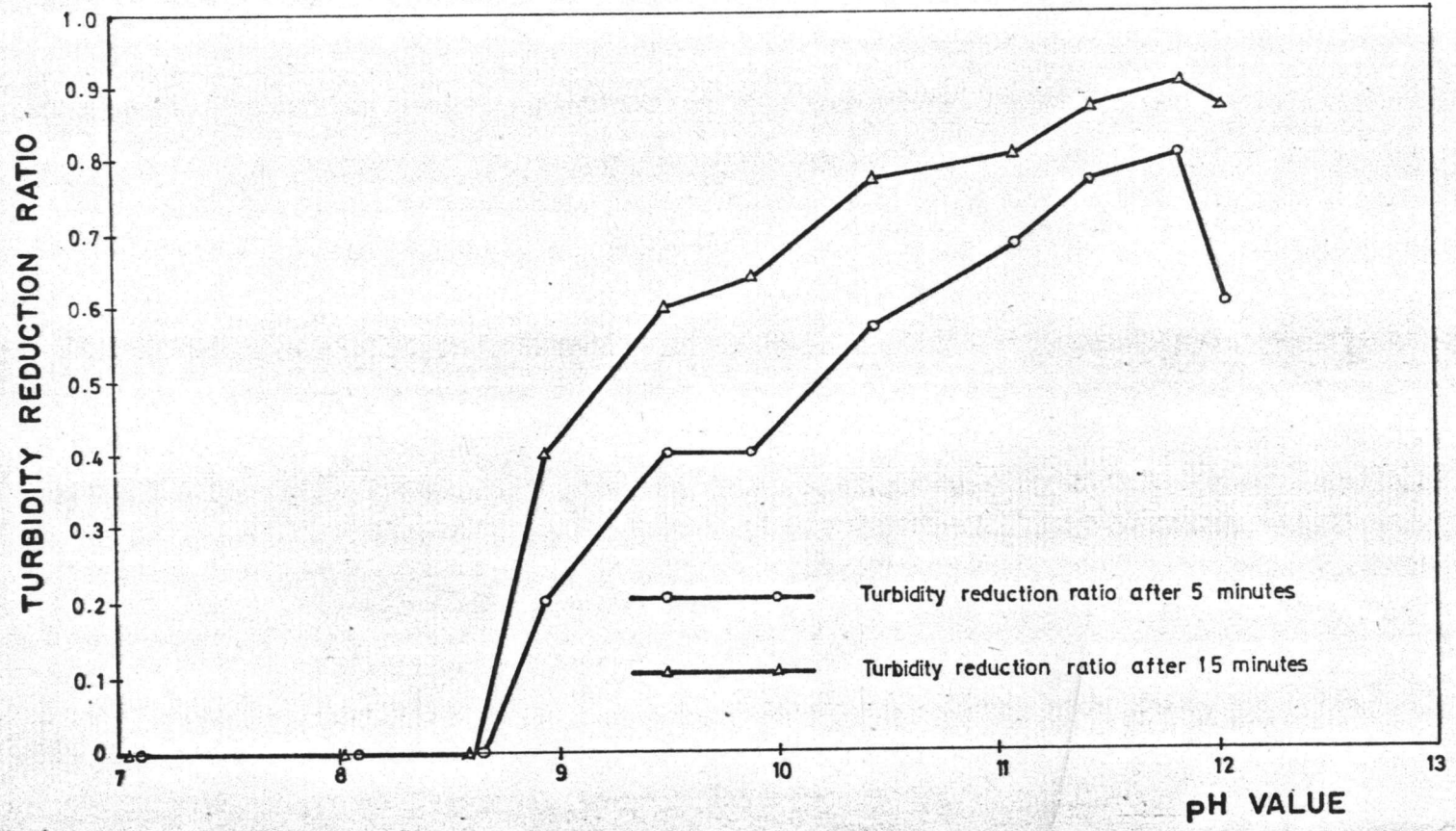


FIGURE 5.15 FERROUS SULPHATE 10 PPM.



RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

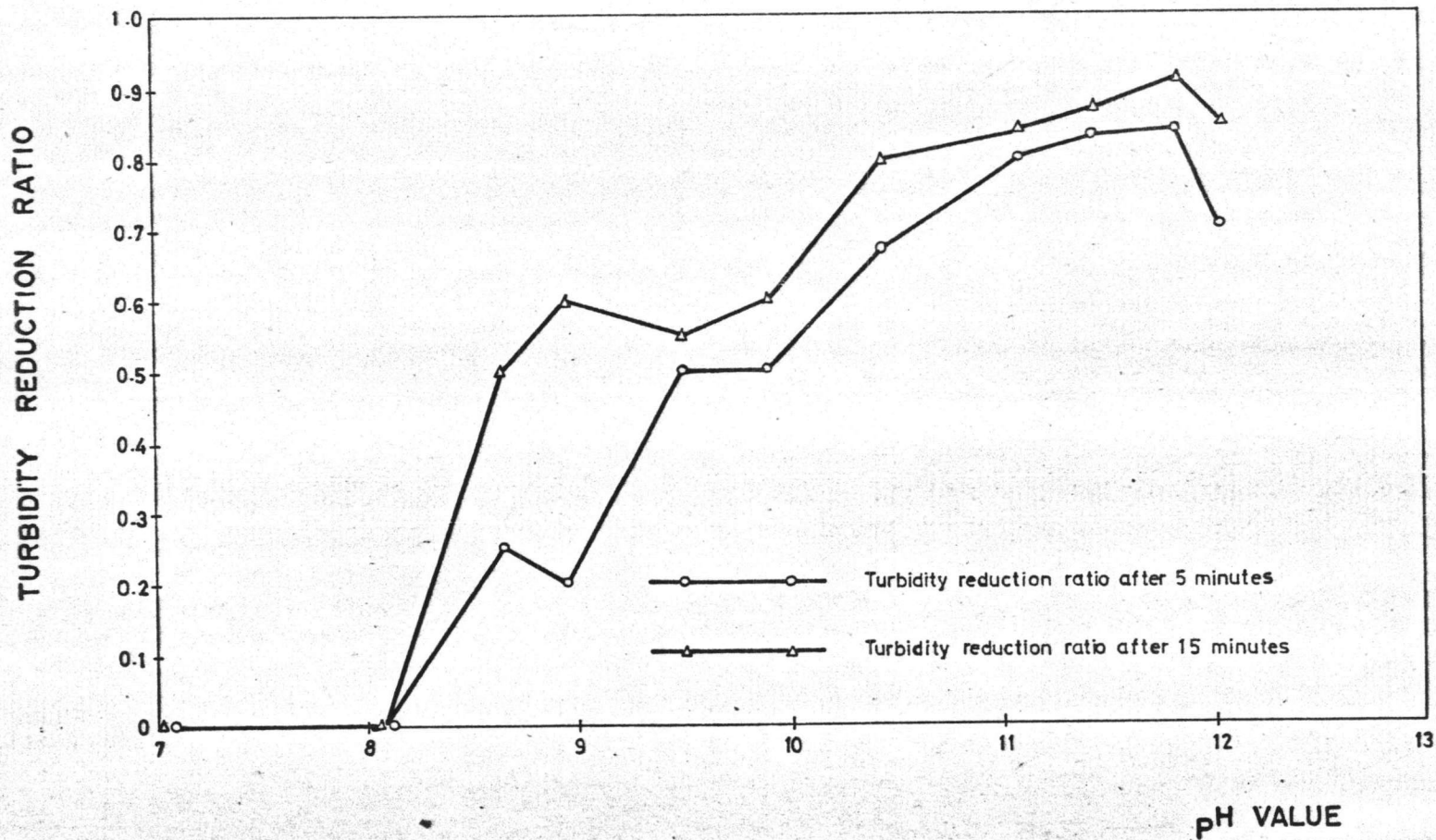


FIGURE 5-16. FERROUS SULPHATE 15 PPM.

# RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

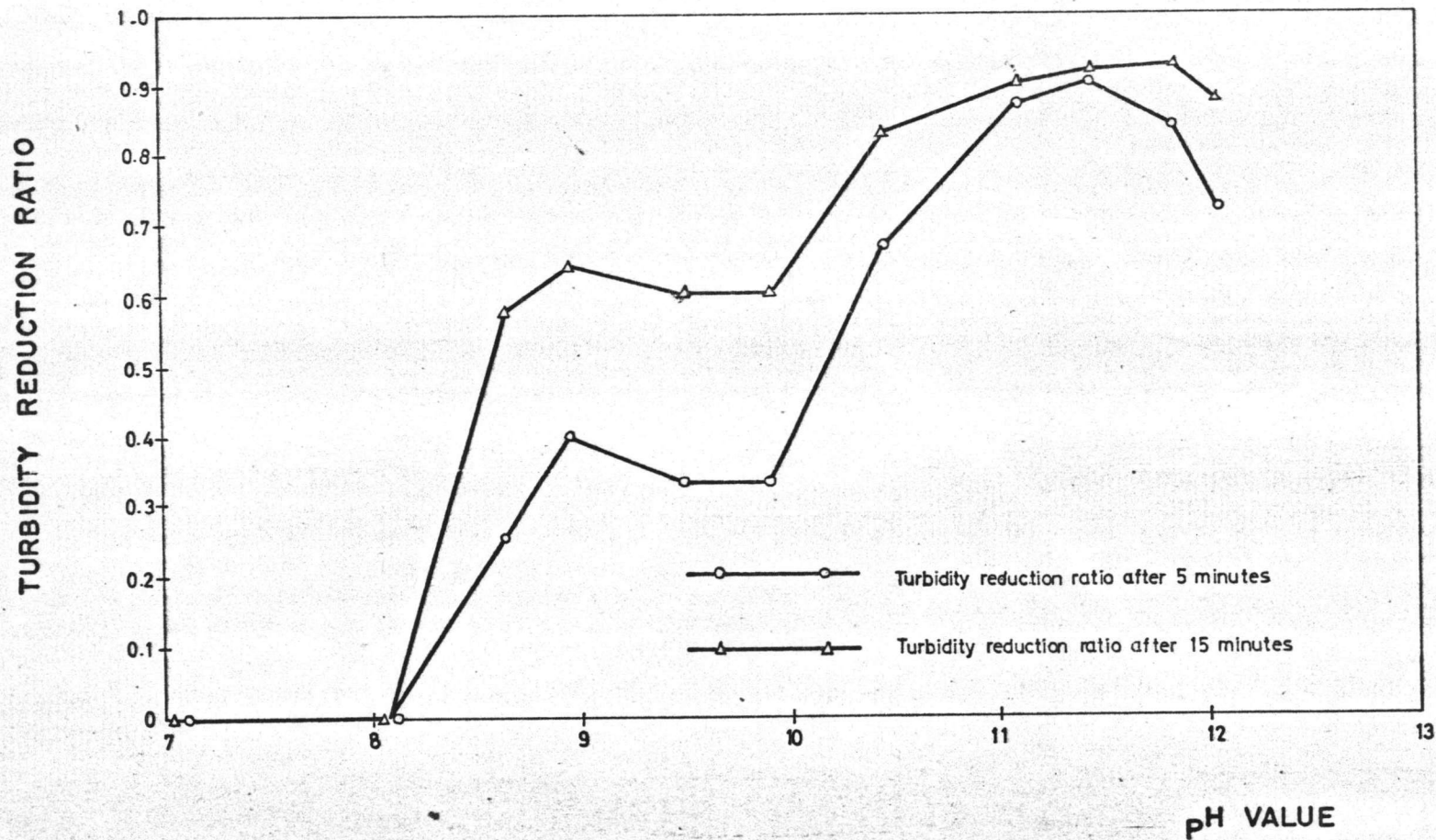


FIGURE 5.17. FERROUS SULPHATE 20 PPM

RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

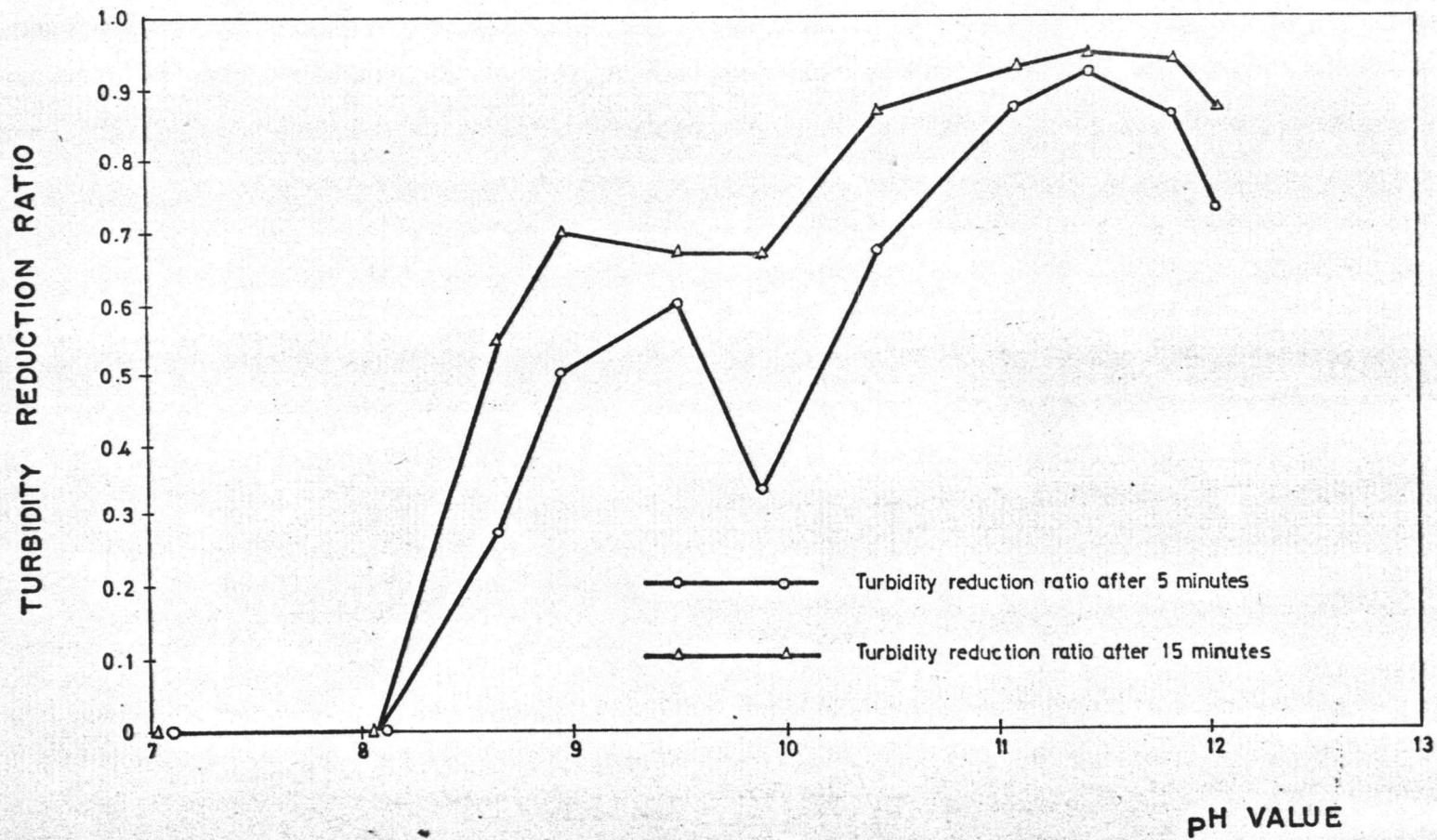


FIGURE 5.18. FERROUS SULPHATE 25 PPM.

# RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

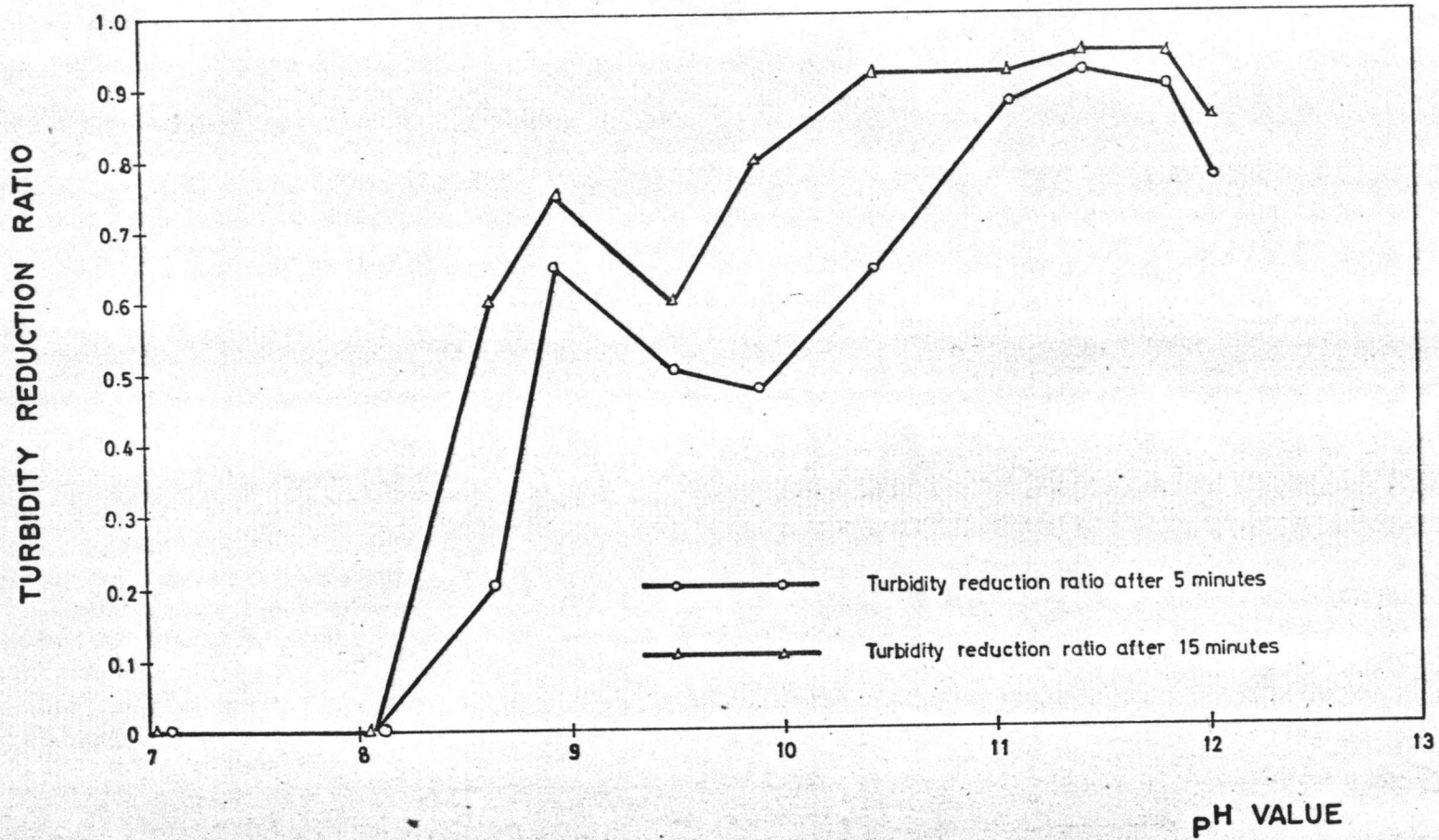


FIGURE 5.19. FERROUS SULPHATE 30 PPM.



# RELATION BETWEEN TURBIDITY REDUCTION RATIO AND pH

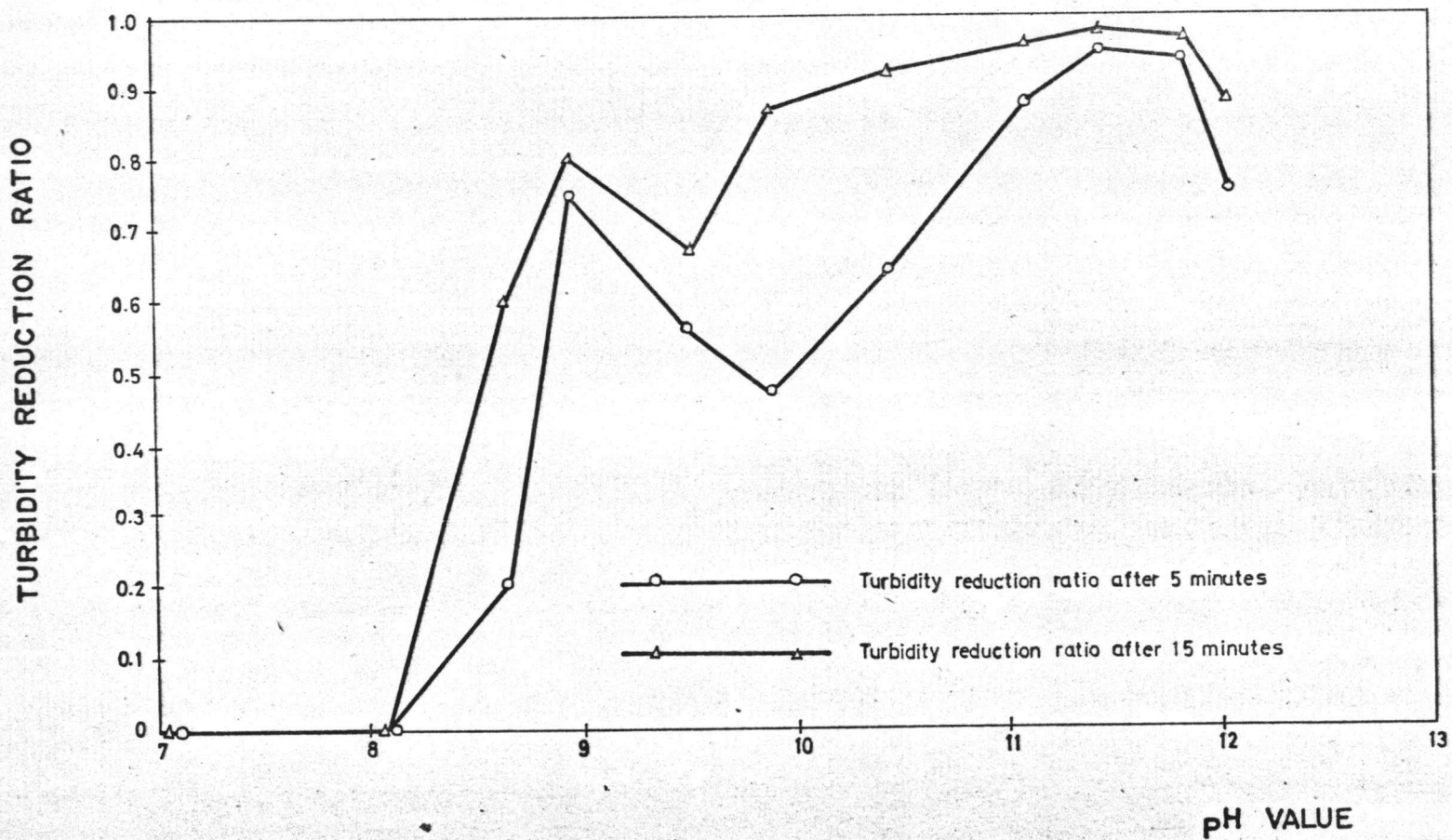


FIGURE 5.20. FERROUS SULPHATE 35 PPM.

## RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH.

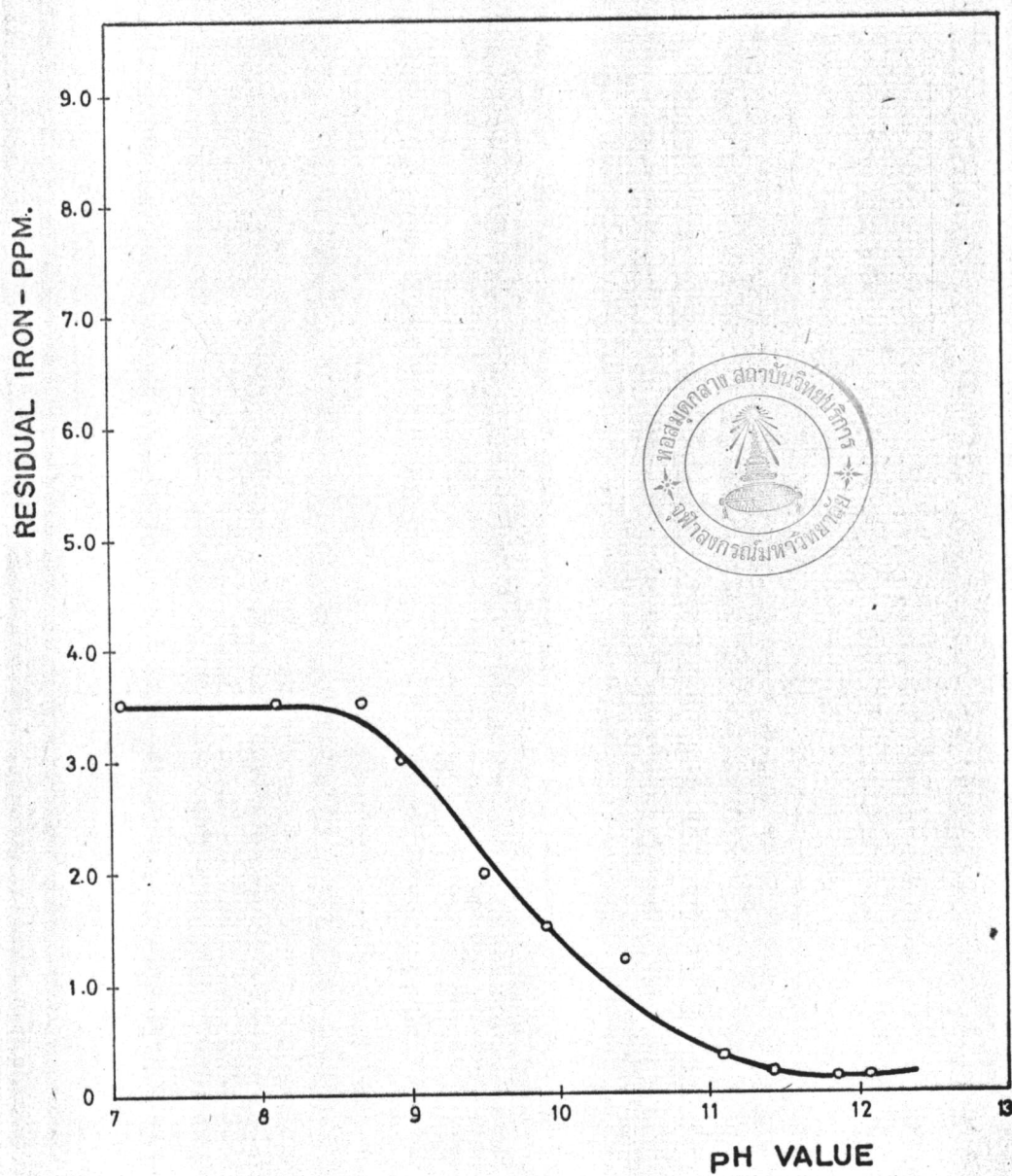


FIGURE 5.21 FERROUS SULPHATE 10 PPM.

RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH.

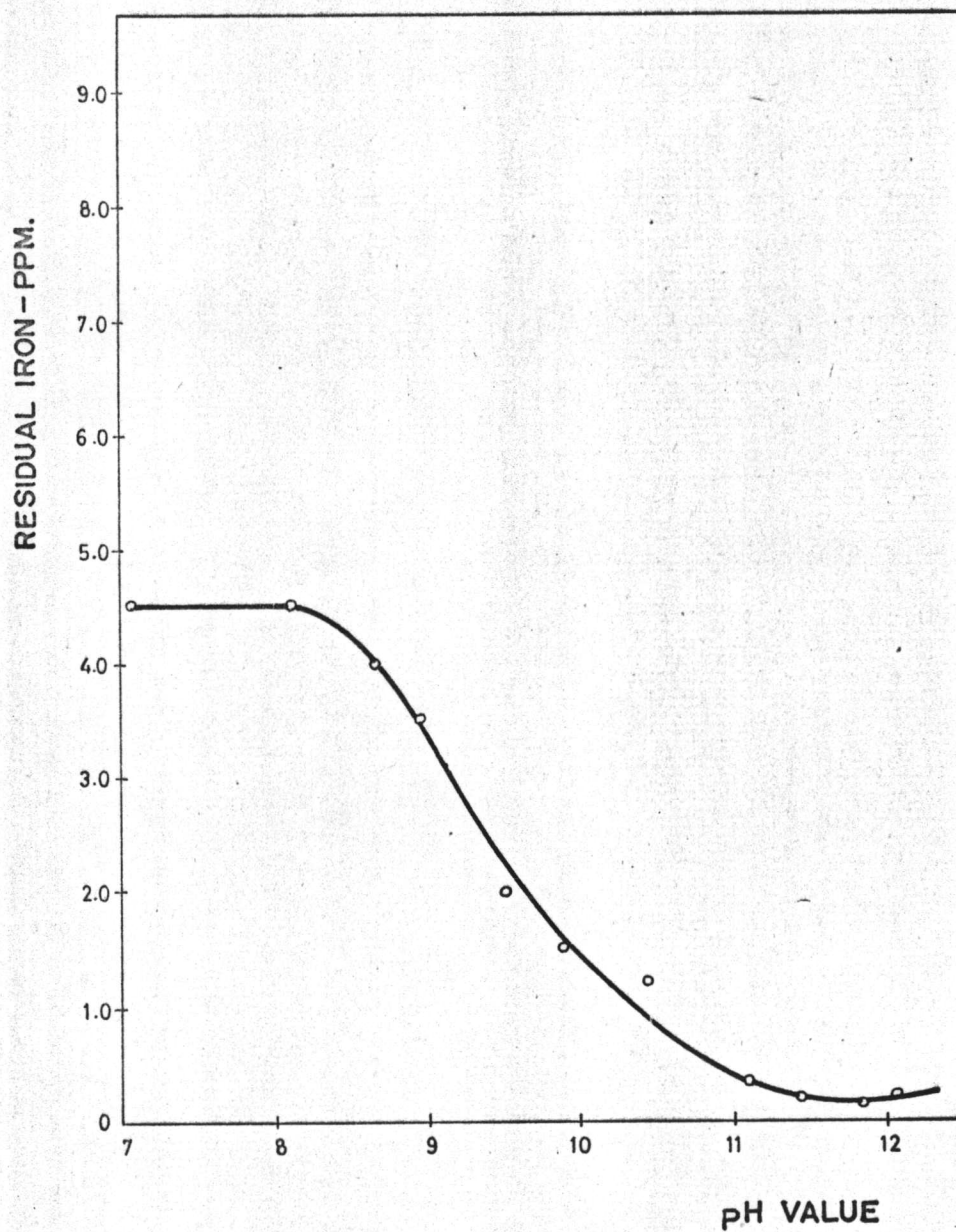


FIGURE 5.22 FERROUS SULPHATE 15 PPM.

RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH.

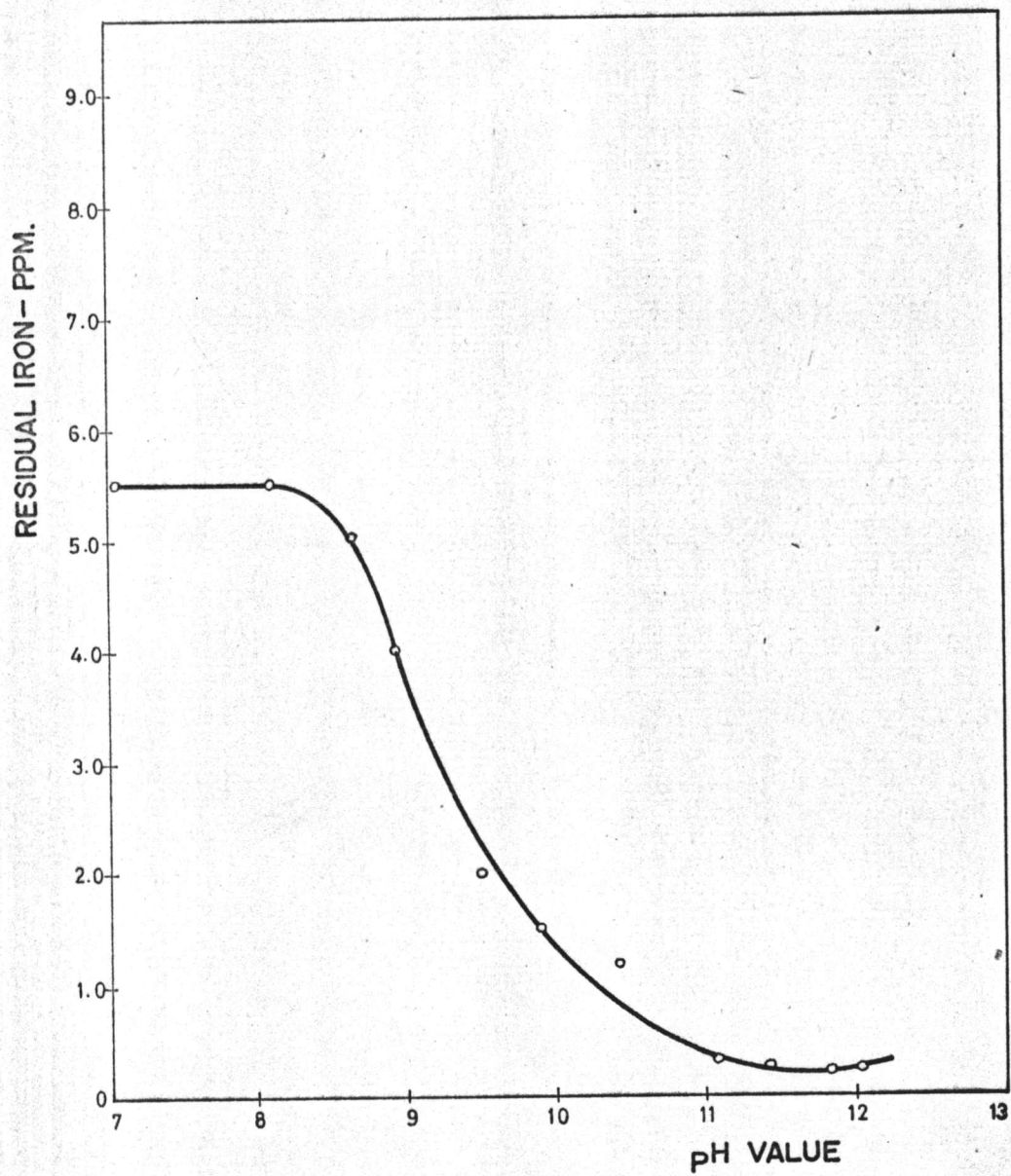


FIGURE 5.23 FERROUS SULPHATE 20 PPM.

RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH.

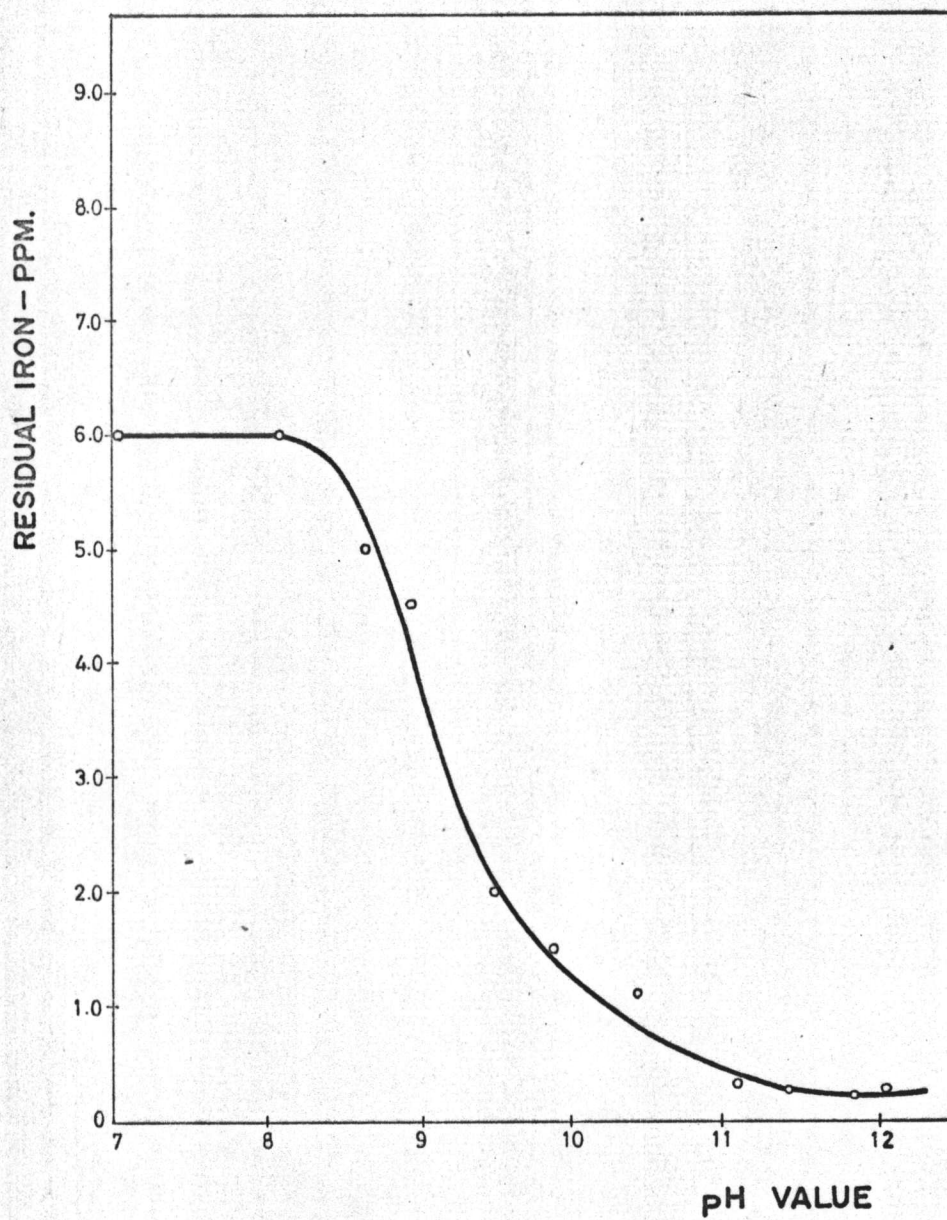


FIGURE 5.24 FERROUS SULPHATE 25 PPM.

RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH .

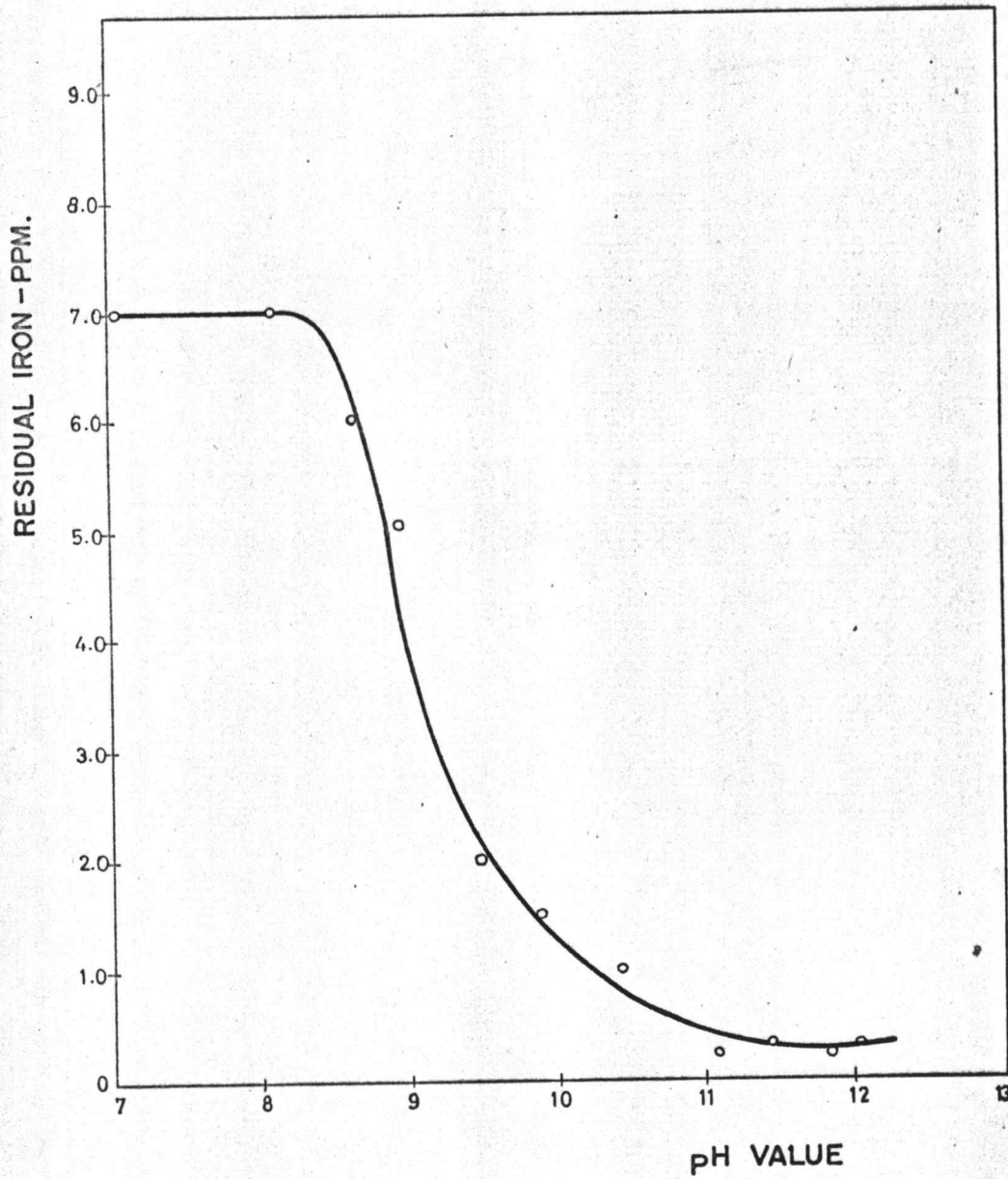


FIGURE 5.25 FERROUS SULPHATE 30 PPM.

RELATION BETWEEN RESIDUAL IRON AFTER 15 MINUTES AND pH.

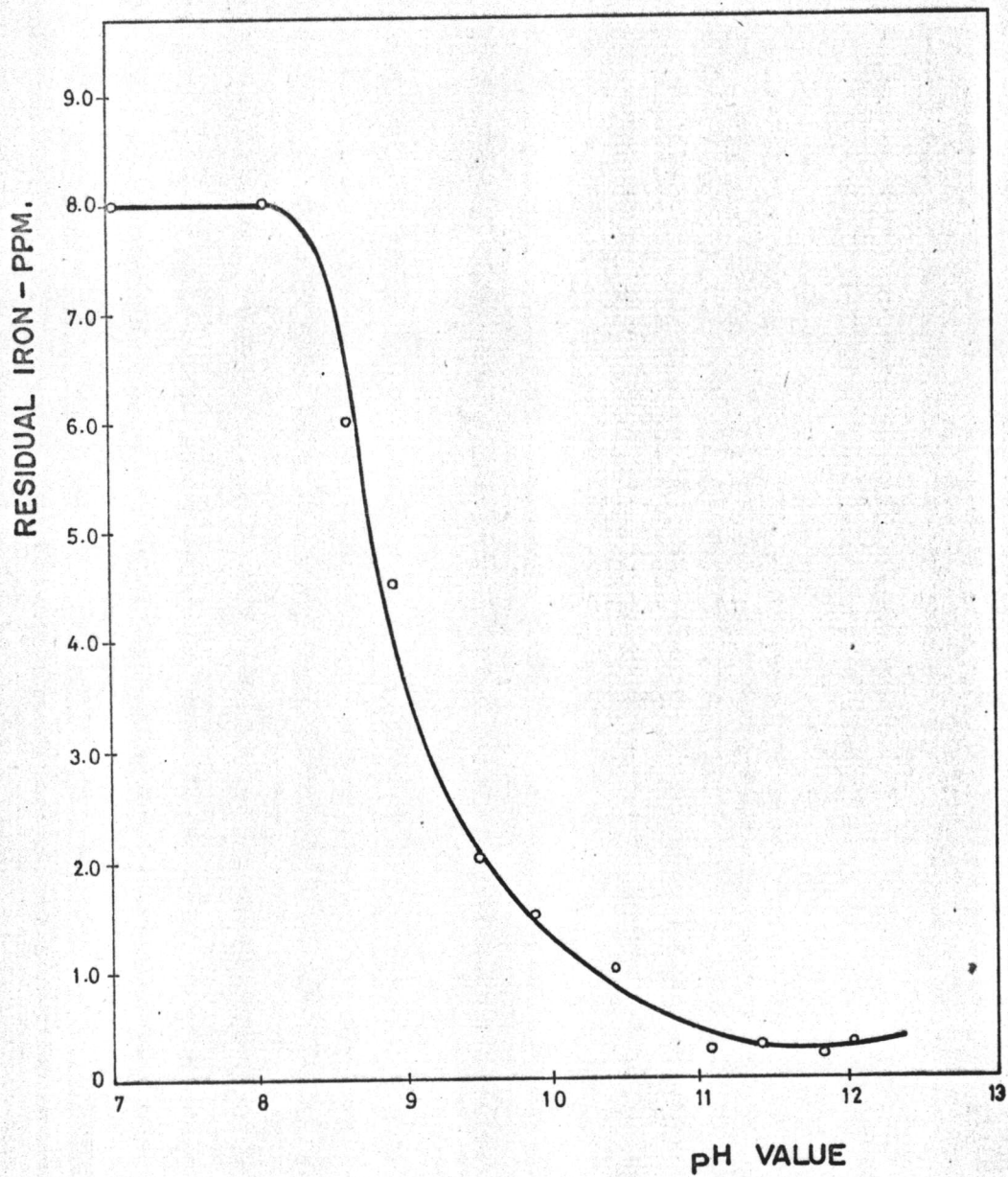


FIGURE 5.26 FERROUS SULPHATE 35 PPM.

## RELATION OF pH VALUES BEFORE AND AFTER COAGULATION

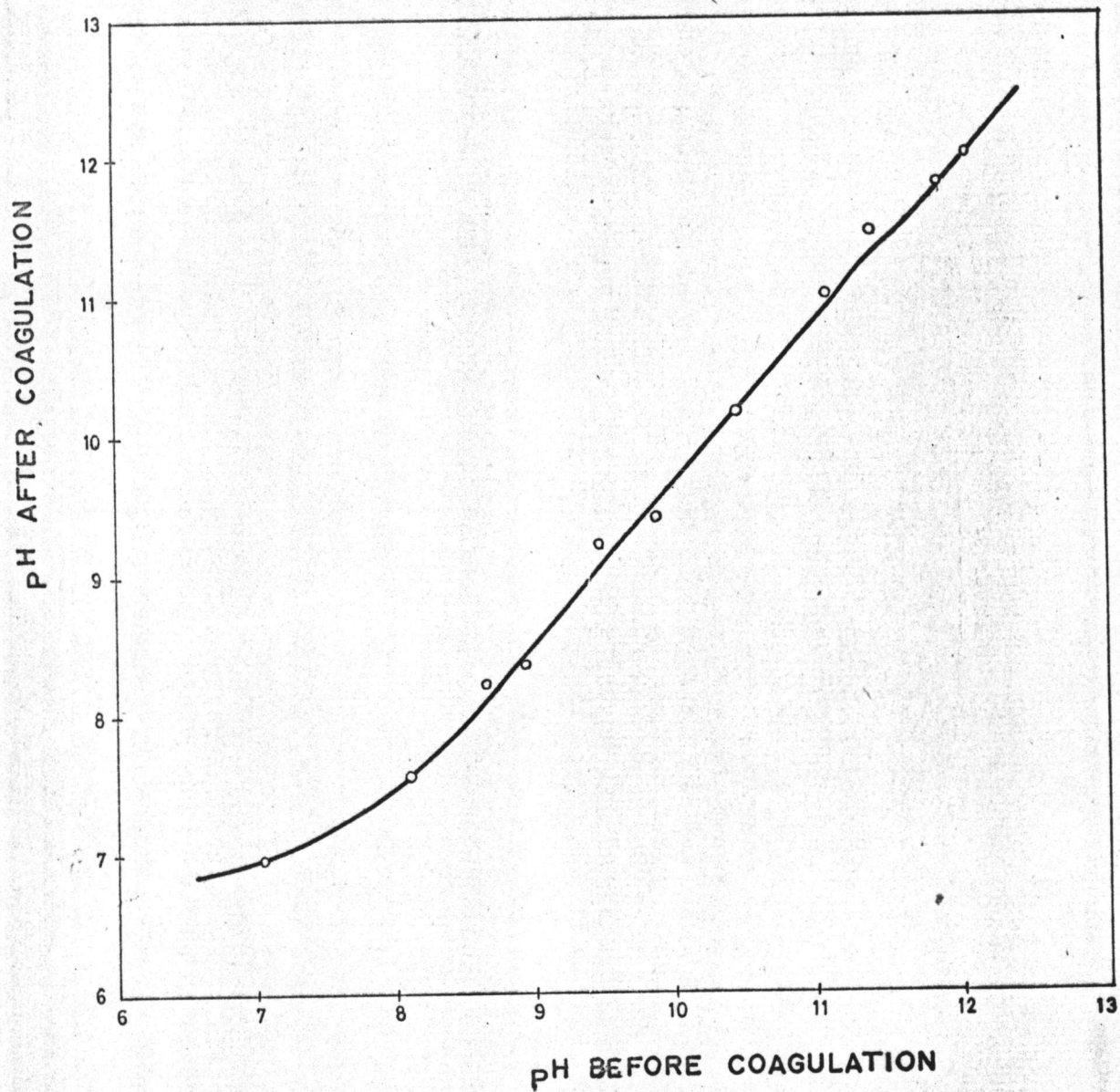


FIGURE 5.27. FERROUS SULPHATE 10 PPM.



## RELATION OF pH VALUE BEFORE AND AFTER COAGULATION

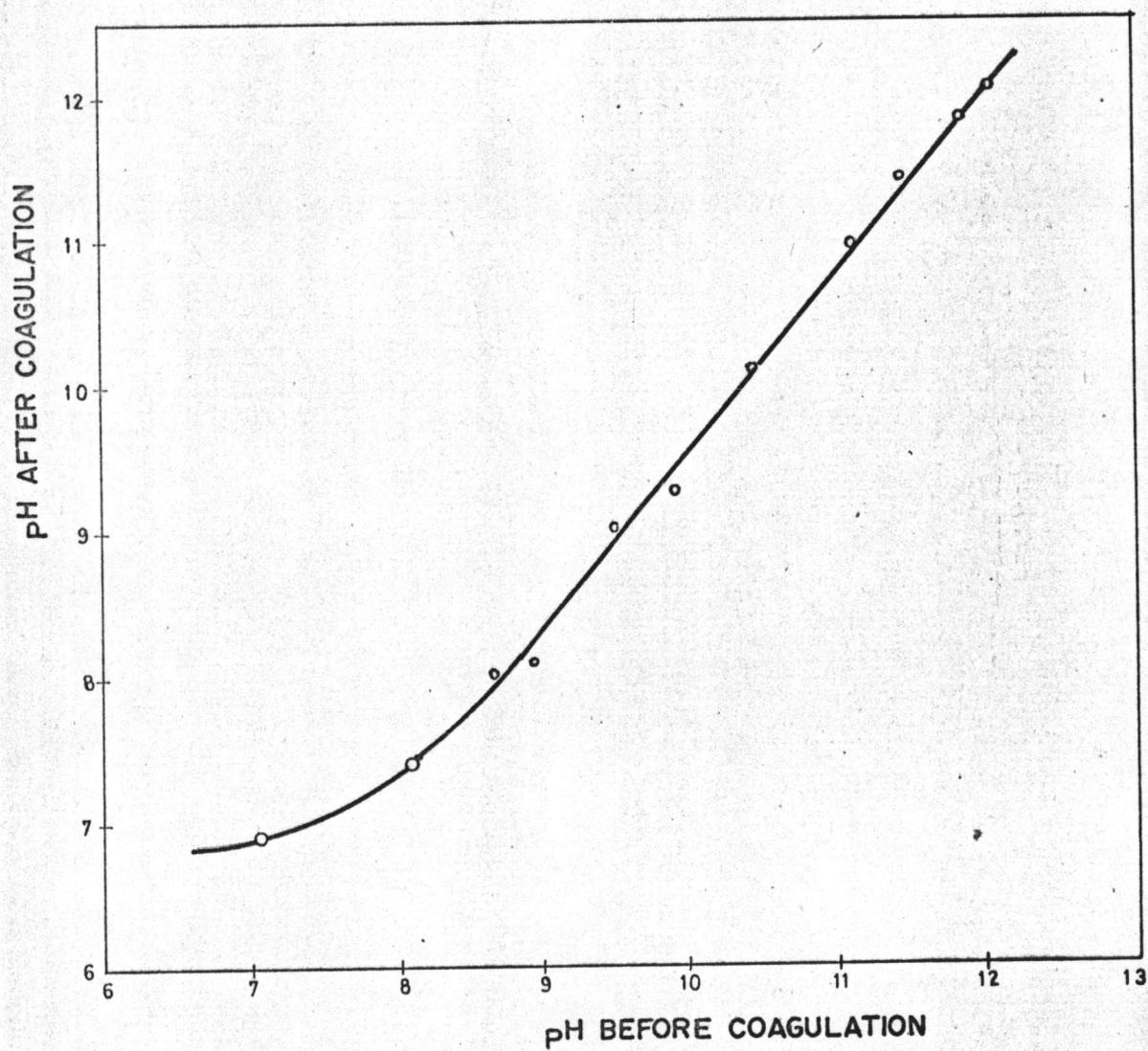


FIGURE 5.28. FERROUS SULPHATE 15 PPM.

## RELATION OF pH VALUES BEFORE AND AFTER COAGULATION

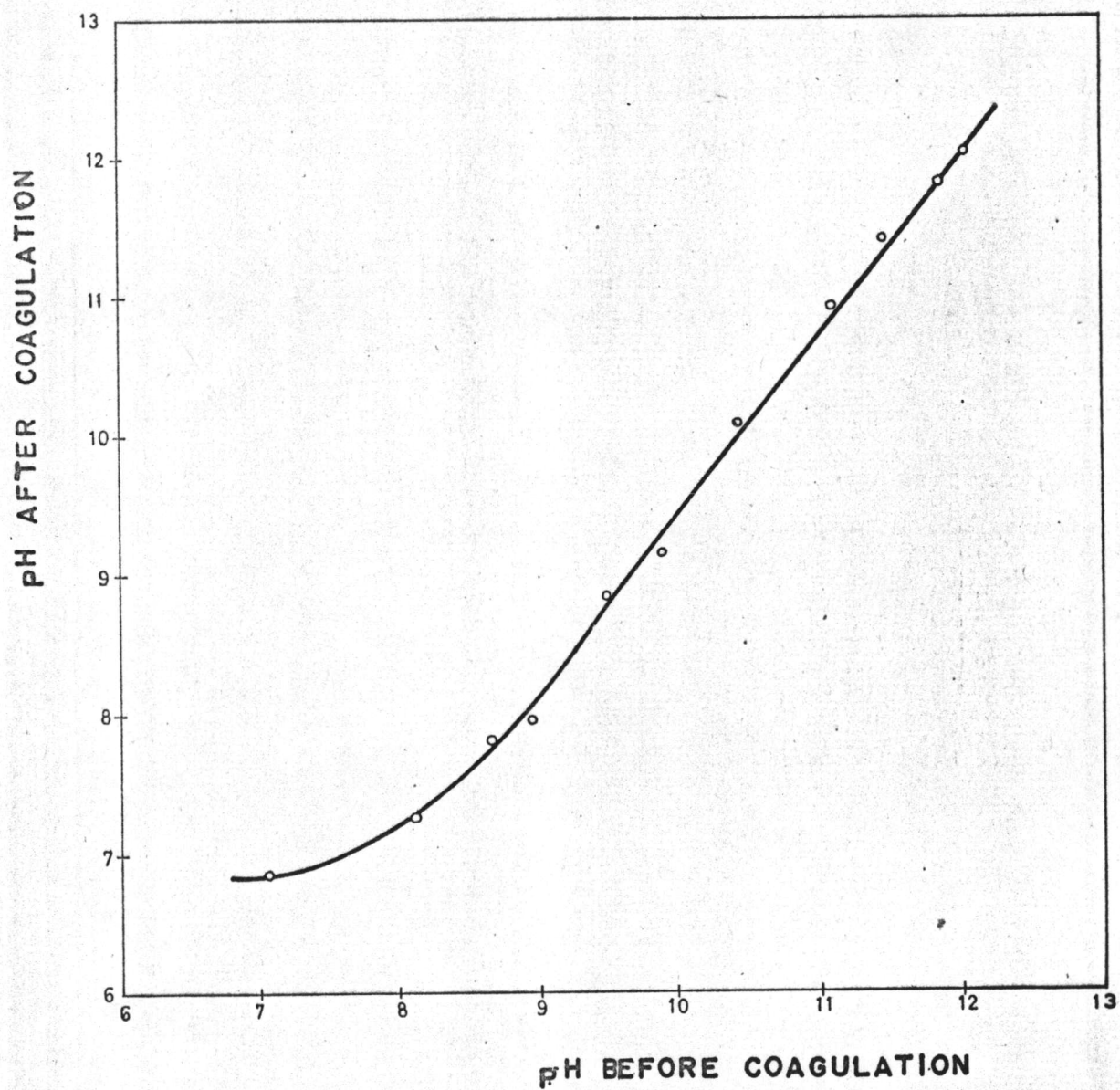


FIGURE 5.29 FERROUS SULPHATE 20 PPM.

## RELATION OF pH VALUES BEFORE AND AFTER COAGULATION

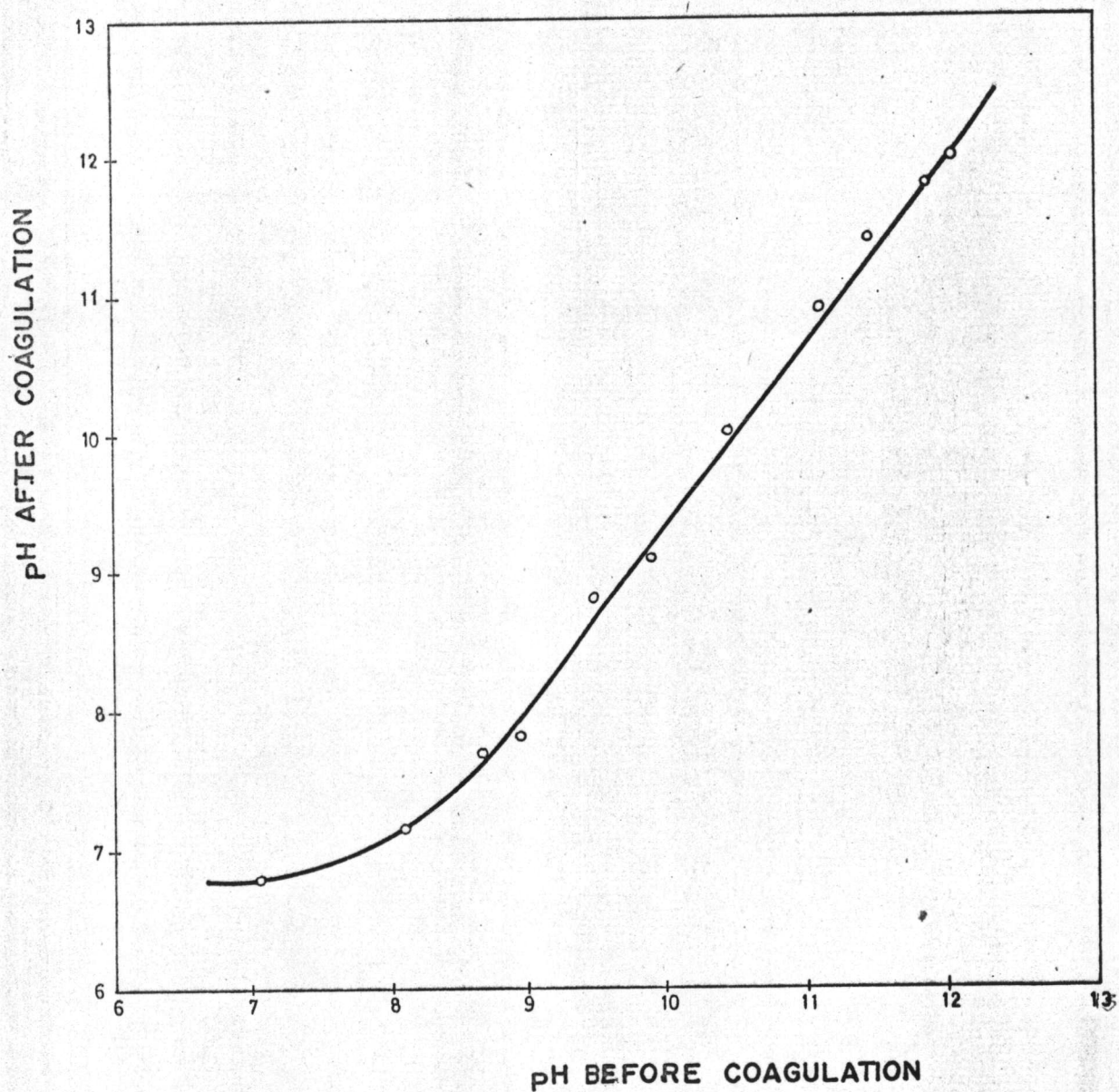


FIGURE 5.30 FERROUS SULPHATE 25 PPM.

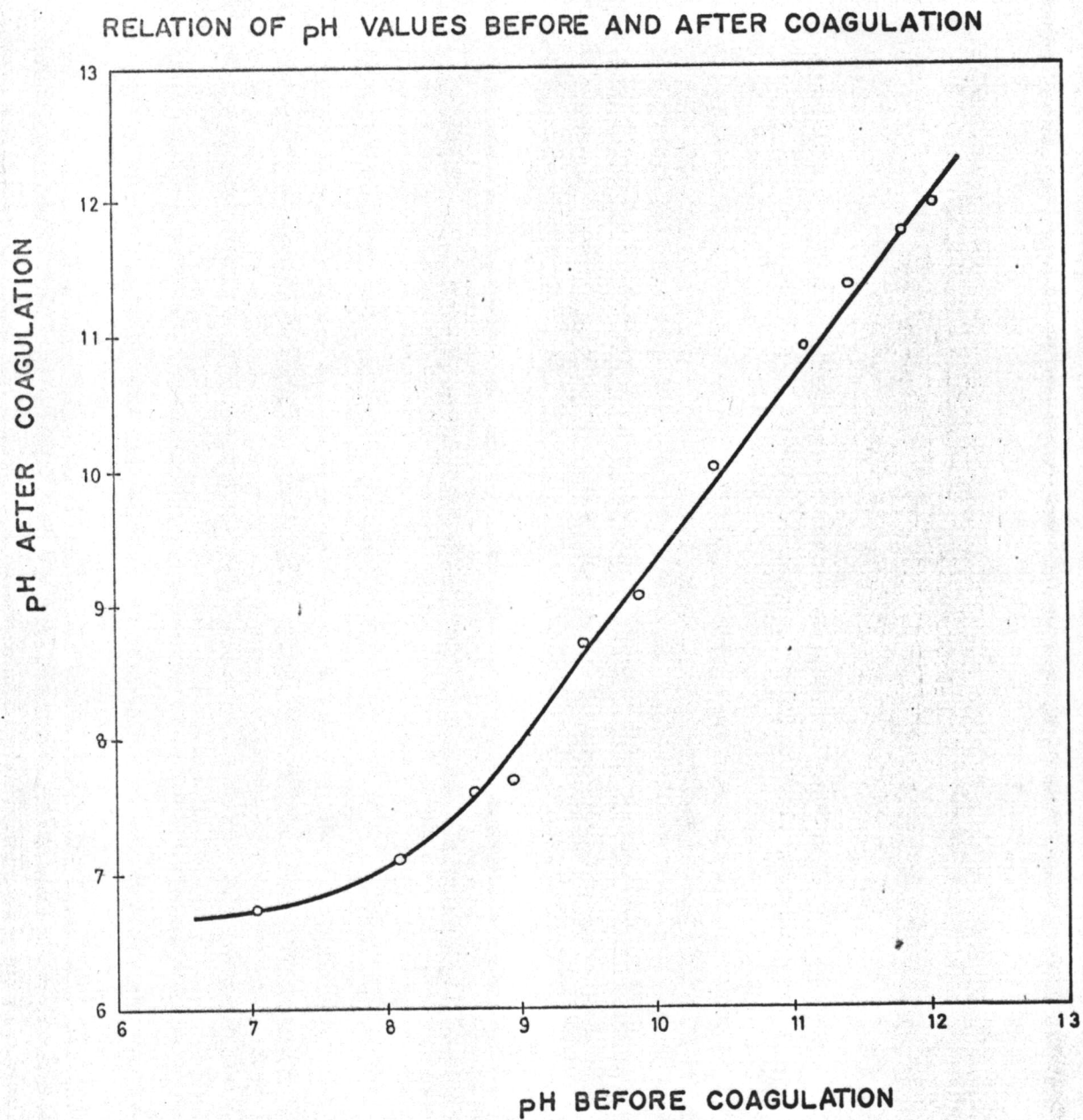


FIGURE 5.31. FERROUS SULPHATE 30 PPM.

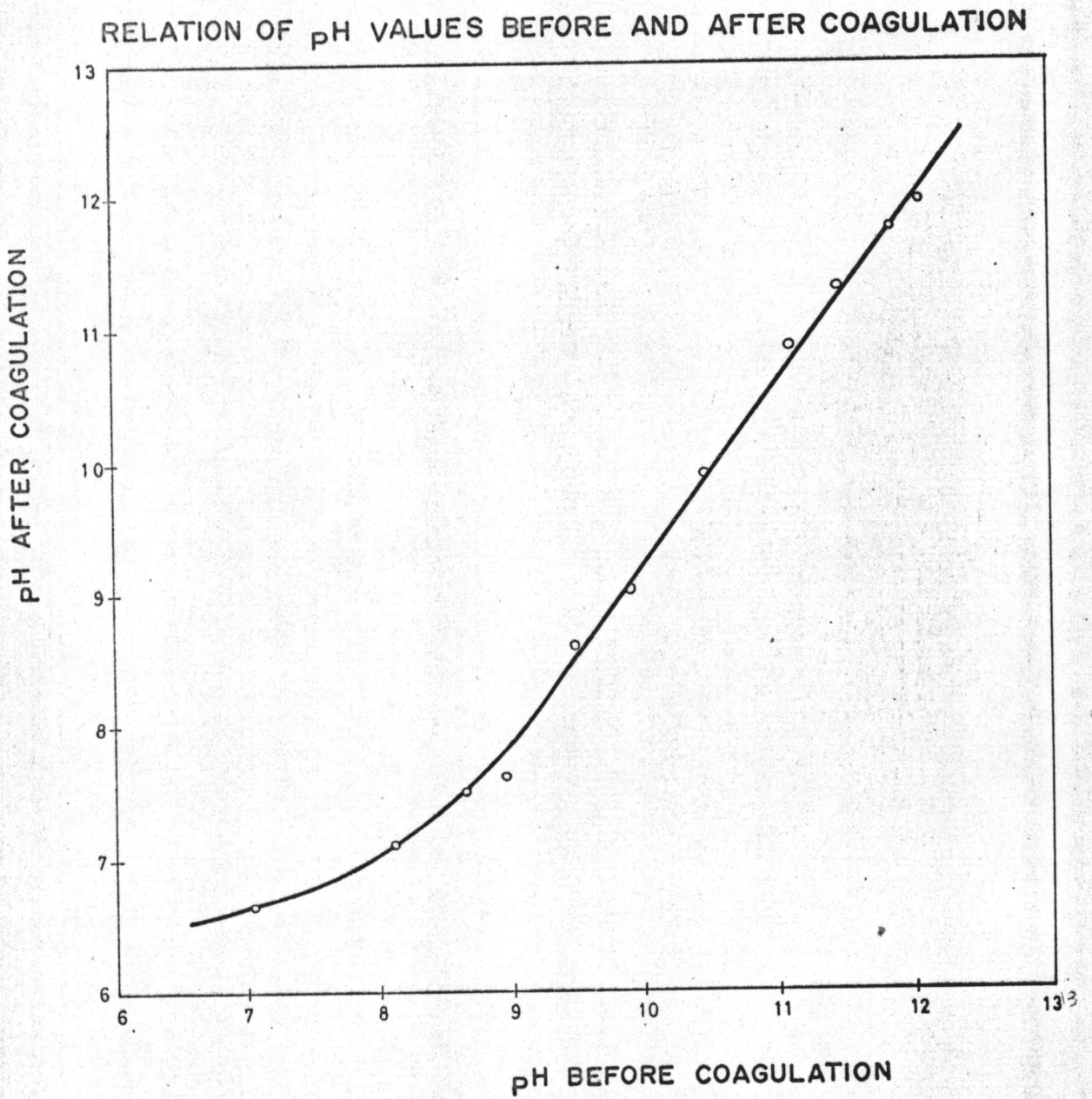


FIGURE 5.32. FERROUS SULPHATE 35 PPM.

### 5.1.3 Dosage of Ferrous Sulphate for Various Turbidity

Mixing Time	:	5 minutes rapid
		25 minutes slow
Floc Index	:	0 = No floc
		2 = opalescent
		4 = small specks
		6 = medium
		8 = good
		10 = excellent
		12 = very heavy

Turbidity after flocculation = Turbidity when stopping stirrer.

Turbidity after 5 minutes = Turbidity at settling time 5 minutes.

Turbidity after 15 minutes = Turbidity at settling time 15 minutes.

(DEGREMONT ACFI 1960)

Test No.12,	December 3, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	5	10	15	20	25	30
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.3	11.05	10.95	10.9	10.85	10.8	10.75	10.75
Alkalinity	(ppm.)	80	100	92	90	90	88	86	82
Hardness	(ppm.)	84	96	90	92	90	88	90	86
Turbidity	(ppm.)	20	20	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	1-40	1-35	1-30	1-20	1-10	1-0
Floc index		-	-	6	6	8	8	8	10
Turbidity after flocculation	(ppm.)	-	-	20	20	20	20	20	20
Turbidity after 5 minutes	(ppm.)	-	-	7	5	5	4	3	3
Turbidity after 15 minutes	(ppm.)	-	-	4	3	2	2	2	1
Turbidity reduction ratio after 5 minutes		-	-	0.65	0.75	0.75	0.80	0.85	0.85
Turbidity reduction ratio after 15 minutes		-	-	0.80	0.85	0.90	0.90	0.90	0.95
Percent of turbidity reduction		-	-	80.0	85.0	90.0	90.0	90.0	95.0
Residual iron	(ppm.)	1.0	1.0	0.30	0.40	0.49	0.49	0.40	0.33
Percent of iron decrease		-	-	70	60	51	51	60	67

Test No. 13,	December 4, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	5	10	15	20	25	30
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.3	11.1	11.05	11.0	10.95	10.9	10.9	10.9
Alkalinity	(ppm.)	82	94	90	88	86	88	84	86
Hardness	(ppm.)	80	100	96	98	94	94	92	96
Turbidity	(ppm.)	30	35	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	1-30	1-30	1-10	1-0	0-50	0-45
Floc index		-	-	4	4	6	6	8	10
Turbidity after flocculation	(ppm.)	-	-	25	25	30	30	25	25
Turbidity after 5 minutes	(ppm.)	-	-	10	8	5	4	4	3
Turbidity after 15 minutes	(ppm.)	-	-	8	5	4	3	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.60	0.68	0.83	0.87	0.84	0.88
Turbidity reduction ratio after 15 minutes		-	-	0.68	0.80	0.87	0.90	0.92	0.92
Percent of turbidity reduction		-	-	73.3	83.3	86.7	90.0	93.3	93.3
Residual iron	(ppm.)	1.0	1.0	0.30	0.30	0.30	0.25	0.25	0.25
Percent of iron decrease		0	0	70	70	70	75	75	75



Test No. 14,	December 9. 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	5	10	15	20	25	30
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.4	11.05	11.0	11.0	11.0	11.0	10.95	10.95
Alkalinity	(ppm.)	82	138	106	108	102	102	106	100
Hardness	(ppm.)	80	114	102	102	98	96	104	100
Turbidity	(ppm.)	40	45	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-25	0-25	0-30	0-30	0-30	0-30
Floc index		-	-	8	8	8	8	10	10
Turbidity after flocculation	(ppm.)	-	-	25	25	25	30	25	25
Turbidity after 5 minutes	(ppm.)	-	-	15	10	6	5	5	5
Turbidity after 15 minutes	(ppm.)	-	-	10	6	3	2	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.40	0.60	0.76	0.83	0.80	0.80
Turbidity reduction ratio after 15 minutes		-	-	0.60	0.76	0.88	0.93	0.92	0.92
Percent of turbidity reduction		-	-	75.0	85.0	92.5	95.0	95.0	95.0
Residual iron	(ppm.)	1.0	1.0	0.30	0.30	0.33	0.33	0.33	0.35
Percent of iron decreases		-	-	70	70	70	67	67	65

Test No.15,	December 10, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	5	10	15	20	25	30
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.6	11.05	11.05	11.0	11.0	11.0	10.95	10.95
Alkalinity	(ppm.)	104	100	104	92	102	104	90	82
Hardness	(ppm.)	96	90	94	88	100	108	90	86
Turbidity	(ppm.)	50	60	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-25	0-25	0-30	0-30	0-35	0-30
Floc index		-	-	6	6	8	8	8	8
Turbidity after flocculation	(ppm.)	-	-	35	30	30	30	30	30
Turbidity after 5 minutes	(ppm.)	-	-	20	15	10	7	6	6
Turbidity after 15 minutes	(ppm.)	-	-	15	8	5	3	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.43	0.50	0.67	0.77	0.80	0.80
Turbidity reduction ratio after 15 minutes		-	-	0.57	0.73	0.83	0.90	0.93	0.93
Percent of turbidity reduction		-	-	70.0	84.0	90.0	94.0	96.0	96.0
Residual iron	(ppm.)	4.0	1.0	0.35	0.30	0.30	0.30	0.30	0.30
Percent of iron decrease		-	-	65	70	70	70	70	70

Test No.16,	December 11, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	--	--	40	15	20	25	30	35
Lime	(ppm.)	--	90	90	90	90	90	90	90
pH Reading		7.45	11.05	11.0	11.0	11.0	10.95	10.9	10.9
Alkalinity	(ppm.)	82	182	134	112	114	100	102	100
Hardness	(ppm.)	82	104	104	104	112	100	102	102
Turbidity	(ppm.)	70	80	--	--	--	--	--	--
Appearance of first floc	(min.-sec.)	--	--	0-30	0-35	0-40	0-35	0-30	0-30
Floc index		--	--	10	8	8	6	6	4
Turbidity after flocculation	(ppm.)	--	--	25	25	30	40	50	50
Turbidity after 5 minutes	(ppm.)	--	--	7	6	7	7	7	7
Turbidity after 15 minutes	(ppm.)	--	--	4	3	3	4	4	4
Turbidity reduction ratio after 5 minutes		--	--	0.72	0.76	0.77	0.83	0.86	0.86
Turbidity reduction ratio after 15 minutes		--	--	0.84	0.92	0.90	0.90	0.92	0.92
Percent of turbidity reduction		--	--	94.3	95.7	95.7	94.3	94.3	94.3
Residual iron	(ppm.)	1.0	1.0	0.30	0.30	0.33	0.35	0.40	0.40
Percent of iron decrease		--	--	70	70	67	65	60	60

Test No.17,	December 13, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	20	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.6	11.1	11.05	11.05	11.0	11.0	10.95	10.95
Alkalinity	(ppm.)	80	168	118	110	102	106	102	102
Hardness	(ppm.)	60	122	110	104	102	102	104	104
Turbidity	(ppm.)	100	120	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-35	0-35	0-40	0-45	0-40	0-35
Floc index		-	-	10	10	10	8	8	8
Turbidity after flocculation	(ppm.)	-	-	35	35	35	40	45	50
Turbidity after 5 minutes	(ppm.)	-	-	7	7	8	8	8	8
Turbidity after 15 minutes	(ppm.)	-	-	4	4	4	5	4	3
Turbidity reduction ratio after 5 minutes		-	-	0.80	0.80	0.77	0.80	0.82	0.84
Turbidity reduction ratio after 15 minutes		-	-	0.89	0.89	0.89	0.88	0.91	0.94
Percent of turbidity reduction		-	-	96.0	96.0	96.0	95.0	96.0	97.0
Residual iron	(ppm.)	1.0	1.0	0.30	0.30	0.30	0.30	0.30	0.30
Percent of iron decrease		-	-	70	70	70	70	70	70

Test No.18,	December 14, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime .	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.5	11.10	11.05	11.05	11.05	11.0	11.0	11.0
Alkalinity	(ppm.)	80	146	112	106	106	102	100	96
Hardness	(ppm.)	84	96	92	94	96	94	92	94
Turbidity	(ppm.)	110	130	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-45	0-50	1-0	1-0	0-45	0-45
Floc index		-	-	8	8	8	10	10	10
Turbidity after flocculation	(ppm.)	-	-	45	45	60	55	60	60
Turbidity after 5 minutes	(ppm.)	-	-	7	7	7	6	6	5
Turbidity after 15 minutes	(ppm.)	-	-	3	3	2	2	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.84	0.84	0.89	0.89	0.90	0.92
Turbidity reduction ratio after 25 minutes		-	-	0.93	0.93	0.97	0.96	0.97	0.97
Percent of turbidity reduction		-	-	97.3	97.3	98.2	98.2	98.2	98.2
Residual iron	(ppm.)	1.2	1.2	0.25	0.27	0.27	0.30	0.30	0.30
Percent of iron decrease		-	-	79.2	77.5	77.5	75	75	75

Test No.19,	December 15, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.5	11.0	10.95	10.95	10.90	10.90	10.90	10.90
Alkalinity	(ppm.)	94	120	92	90	88	82	82	80
Hardness	(ppm.)	82	94	90	90	88	86	86	90
Turbidity	(ppm.)	130	150	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-25	0-30	0-35	0-40	0-40	0-45
Floc index		-	-	8	8	8	8	10	10
Turbidity after flocculation	(ppm.)	-	-	50	40	40	40	45	70
Turbidity after 5 minutes	(ppm.)	-	-	6	6	6	6	6	6
Turbidity after 15 minutes	(ppm.)	-	-	2	2	2	2	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.88	0.85	0.85	0.85	0.87	0.91
Turbidity reduction ratio after 15 minutes		-	-	0.96	0.95	0.95	0.95	0.96	0.97
Percent of turbidity reduction		-	-	98.5	98.5	98.5	98.5	98.5	98.5
Residual iron	(ppm.)	1.2	1.2	0.25	0.25	0.25	0.27	0.27	0.27
Percent of iron decrease		-	-	79.2	79.2	79.2	77.5	77.5	77.5

Test No.20,	December 16, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.45	11.05	11.0	11.0	11.0	11.0	10.95	10.95
Alkalinity	(ppm.)	84	108	96	96	90	90	100	96
Hardness	(ppm.)	70	88	82	88	84	82	80	82
Turbidity	(ppm.)	150	170	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-35	0-40	0-40	0-45	0-50	0-50
Floc index		-	-	8	8	8	10	10	10
Turbidity after flocculation	(ppm.)	-	-	65	60	80	55	55	65
Turbidity after 5 minutes	(ppm.)	-	-	8	8	8	8	6	6
Turbidity after 15 minutes	(ppm.)	-	-	2	2	2	3	2	2
Turbidity reduction ratio after 5 minutes		-	-	0.88	0.87	0.90	0.85	0.87	0.91
Turbidity reduction ratio after 15 minutes		-	-	0.97	0.97	0.98	0.95	0.96	0.97
Percent of turbidity reduction		-	-	98.7	98.7	98.7	98.0	98.7	98.7
Residual iron	(ppm.)	1.2	1.2	0.30	0.30	0.30	0.30	0.30	0.30
Percent of iron decrease		-	-	75	75	75	75	75	75

Test No.21,	December 20, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.65	11.0	10.9	10.9	10.85	10.8	10.75	10.7
Alkalinity	(ppm.)	84	136	86	80	70	58	60	58
Hardness	(ppm.)	68	72	70	62	64	60	60	60
Turbidity	(ppm.)	180	200	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-25	0-30	0-50	0-50	0-40	0-40
Floc index		-	-	6	6	6	6	8	8
Turbidity after flocculation	(ppm.)	-	-	60	80	95	70	70	70
Turbidity after 5 minutes	(ppm.)	-	-	8	9	8	7	7	7
Turbidity after 15 minutes	(ppm.)	-	-	3	4	4	4	3	3
Turbidity reduction ratio after 5 minutes		-	-	0.87	0.89	0.92	0.90	0.90	0.90
Turbidity reduction ratio after 15 minutes		-	-	0.95	0.95	0.96	0.94	0.96	0.96
Percent of turbidity reduction		-	-	98.3	97.8	97.8	97.8	98.3	98.3
Residual iron	(ppm.)	1.3	1.3	0.30	0.30	0.30	0.30	0.33	0.33
Percent of iron decrease		-	-	76.9	76.9	76.9	76.9	74.6	74.6



Test No. 22,	December 21, 1971	Raw water	Raw water and Lime	Jar No.					
				1	2	3	4	5	6
Ferrous sulphate	(ppm.)	-	-	10	15	20	25	30	35
Lime	(ppm.)	-	90	90	90	90	90	90	90
pH Reading		7.35	11.0	10.95	10.9	10.9	10.9	10.85	10.85
Alkalinity	(ppm.)	86	120	100	92	90	90	88	88
Hardness	(ppm.)	80	98	90	84	84	90	86	84
Turbidity	(ppm.)	200	230	-	-	-	-	-	-
Appearance of first floc	(min.-sec.)	-	-	0-30	0-35	0-35	0-40	0-45	0-50
Floc index		-	-	6	6	8	6	6	6
Turbidity after flocculation	(ppm.)	-	-	55	60	55	65	80	100
Turbidity after 5 minutes	(ppm.)	-	-	6	8	7	8	8	8
Turbidity after 15 minutes	(ppm.)	-	-	2	3	2	4	4	4
Turbidity reduction ratio after 5 minutes		-	-	0.89	0.87	0.87	0.88	0.90	0.92
Turbidity reduction ratio after 15 minutes		-	-	0.96	0.95	0.96	0.94	0.95	0.96
Percent of turbidity reduction		-	-	99.0	98.5	99.0	98.0	98.0	98.0
Residual iron	(ppm.)	1.3	1.3	0.20	0.20	0.20	0.20	0.20	0.20
Percent of iron decrease		-	-	84.6	84.6	84.6	84.6	84.6	84.6

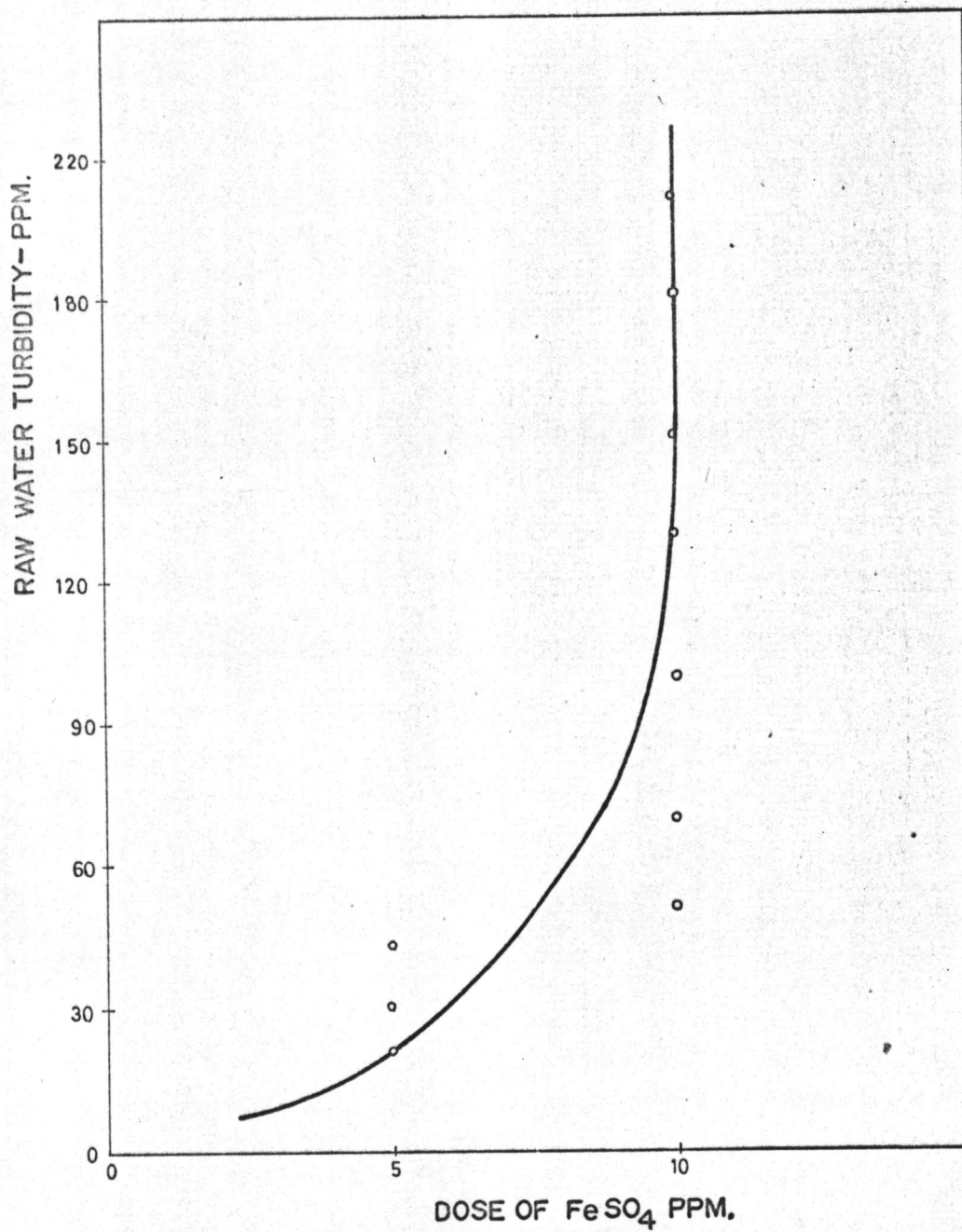


FIGURE 5.33 TURBIDITY CURVE FOR THE APPLICATION OF FERROUS SULPHATE.

5.1.4 Dosage of Sulphuric Acid in Decreasing pH

Initial Water ;    pH                    11.0  
                         Alkalinity        90    ppm.  
                         Hardness            86    ppm.

H <sub>2</sub> SO <sub>4</sub> (ppm.)	pH	Alkalinity (ppm.)	Hardness (ppm.)
30	10.7	66	90
50	9.6	58	100
60	9.1	58	110
70	8.3	50	140
80	7.2	42	150
90	6.6	40	156

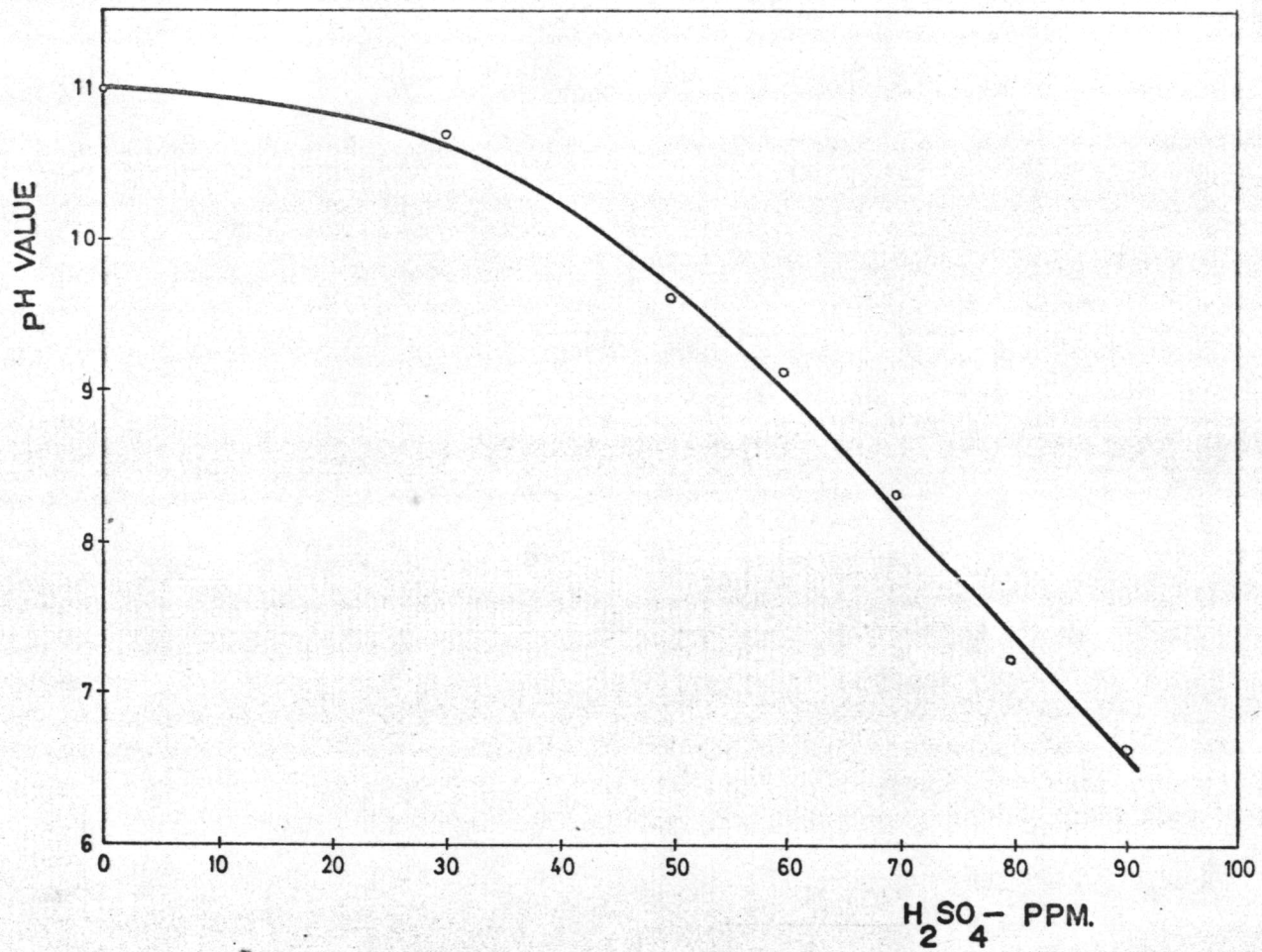


FIGURE 5.34. DOSAGE OF H<sub>2</sub>SO<sub>4</sub> TO DECREASE pH VALUE

## 5.2 Discussion

The results of the experiments are include in the Test No. through NO.22.

Coagulation obtained by using ferrous sulphate showed acceptable resulted only when lime is added.

The first test shows the results obtained when varying dosages of lime was used. It is also seen that the pH values will be increased when lime is added to the raw water sample.

By adding 3.2, 8.0, 16.0 and 32.0 ppm. of lime to 1 litre of raw water which has initial pH of 7.2 the pH of raw water will increase to 7.9, 8.95, 9.5 and 10.0 respectively as shawn in Figure 5.1 and Figure 5.2 represent the dosage of lime in raising pH in range from 0 to 120 ppm. which use in this experiment.

Comparison of the results in test No.1 shows that ferrous sulphate alone did not give a floc at pH 7.05. Good coagulation with ferrous sulphate can be obtained only by using lime in raising pH. Alkalinity is required to increase pH of the water and thus obtain the optimum range for iron-lime coagulation.

From test No.4 it is seen that 10 ppm. of ferrous sulphate and 7.5 ppm. of lime will provide a clear water.

On Figure 5.9-5.14 present the amount of ferrous sulphate found in floc at various pH values with a given ferrous sulphate dosage. It is clearly shown that the pH value increase the turbidity remain is decrease. These graph are also show the turbidity remain after 15 minutes at various pH and present the percent of turbidity reduction to consider. From graphs the optimum value that gave the good results of flocculation was in the pH range 9.0-12.0. If the pH value less than 9.0 it gives the poor result as shown in graph. A pH upper than 12.0 it form the floc in a short time and floc may be broken by the stirrer again.

To considered the turbidity after flocculation and turbidity after 5 minutes at various pH value are presented in Figure 5.3-5.8, it is shown that at pH about 9.5-10.0 giving a result of turbidity after flocculation and after 5 minutes too low it show that floc is heavy and



it had settled to a lower part during stirrer which is unsatisfactory for our consideration because of floc will settle in mixing chamber, instead of in the sedimentation chamber.

Figure 5.15-5.20 present the relation between turbidity reduction ratio and pH at a given dosage. From graphs the value of turbidity reduction ratio increase when the pH is increase. If turbidity reduction ratio is **low**, floc may be settled in the mixing chamber. So that the value of the turbidity reduction ratio in the **high** range was the value to consider.

These experiments for the raw water, the residual iron was presented in Figure 5.21-5.26 and these graphs illustrated the fact that, although the coagulation is maintained the good floc, the results of residual iron are not satisfied. In the case of pH above 11.0 that give the result of residual iron less than 0.3 ppm., at pH 7.0-10.5 it had a residual iron increase from raw water. It is shows that at this pH range the ferrous sulphate dose which we added as a coagulant is to increase the iron in the water.

For determining the pH values of settled water referring to the pH before coagulation as shown in Figure 5.27-5.32, some of them shown that at pH 11.0 before coagulation can be reduce to 10.8 after coagulation for ferrous sulphate dose 35 ppm.

Various degrees of turbidity needed various amounts of ferrous sulphate dosage at pH value 11.0 as represent in Figure 5.33 which is obtained from tests NO.12-No.22. In this case fine clay from Pathum Thance was used to increase the turbidity.

It is obvious, from Figure 5.33, that as the turbidity increased the dosage of ferrous sulphate needed also increased. This is evident since turbidity is caused by suspended matter such as clay, silt and finely divided organic matter, etc. Thus if the turbidity or amount of suspended matter is high, then the ferrous sulphate needed to precipitate this matter be also high. This Figure also shows the amount of ferrous sulphate needed when the turbidity of water is known.

By adding sulphuric acid at various dosage to the settle water

it will decrease the pH value as shown in Figure 5.34. The purpose of this experiment was to decrease pH value which so high to the limit of standard for drinking water. In this test adding sulphuric acid 30, 50 and 60 ppm. to 1 litre of settle water which has initial pH of 11.0, the pH will be decrease to 10.7, 9.6 and 9.1 respectively.

From the experiment it shows that to used ferrous sulphate as a coagulant for raw water from Klong Prapa to produce a water supplied in the limit of standard for drinking water, to used lime 90 ppm. for raising pH to 11.0, ferrous sulphate dose 10 ppm. to produce water had turbidity after 15 minutes 5 ppm., residual iron 0.30 ppm., and to using  $H_2SO_4$  80 ppm. to reduced the pH value to 7.35

These experiments as well as those discussed above all point to the fact that to coagulate the water in a short period of 30 minutes velocity of 60 to 80 revolution per minute for rapid mix and 30 revolution per minute for slow mix.

Today in our country, the costs of coagulation with ferrous sulphate is more expensive than alum. Thus, in the future to treat water supplied, if ferrous sulphate is recovered from waste picking liquors at iron and steel mills, and using it as a coagulant will be more saving in costs and as in eliminating a by-product waste disposal problem.