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Acid rain in Kwangju, Korea (Precipitation intensity and persistent time)

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The analyzed results of observed precipitation and its pH in Kwangju for 262 days from Jan. 1, 1991 to Dec. 31, 1995 are as follows.

The annual mean pH was 5.7, and the monthly mean pH values of January-May and November were less than 5.6 in Kwangju. The ratio of acid rain for these periods was about 48.1%, almost half that of the total observed days. In March, the pH was 5.4 and the ratio of acid precipitation was 69%, an especially serious situation. In the spring, the pH value was 5.5, thus weakly acidic. The pH of precipitation tended to decrease with greater precipitation. The relation between persistent time and pH of precipitation is variable, but if the persistent time is long, the pH is constant and low. It is fortunate that there is an increasing trend of pH in interannual variation, but it is thought important that the amplitude of variation of pH in 1995 was high and the pH value was 4.1 in October and November. Because heavy and persistent precipitation effects the accumulation of acidity, more concern about acid rain is needed.
Key words :

1. Introduction

The natural precipitation indicates a weak acidity about of pH 5.65 owing to atmospheric composition. Thus acid rain is defined for both precipitation and dry deposition in which the pH is lower than 5.65 (Regens and Rycroft 1988).

It is possible that acid rain occurs naturally, but it has become a global environmental issue because of manmade pollutant materials. The precipitation pH values are different according to time and space, but it is known that they are affected by increases in anions such as SO_4^{2-}, NO_3^- and Cl^-, as well as changes in atmospheric elements (Park 19 91, Kang 1992). Yamaguchi et al. (1989) explained that the increases of SO_4^{2-}, NO_3^- due to urbanization bring about acid rain, while So et al. (1996) pointed out the SO_4 and NO_2 concentrations in the air over the major cities of Korea. Park et al. (19 89) and Son, Chung et al. (1992) presented the relationship between pH of precipitation and ions and variation of pH over time. Song et al. (1992) explained the variations of ions, correlations between ions and temporal variation of pH. Bachmann et al. (1993) conducted research on the chemical composition concentration in relation to rain droplets, and Garnett (1980) studied the variations of air quality in relation to wind speed.

According to their research, pH of precipitation, atmospheric chemical composition, and relation between acid rain and ions are almost the same. Thus, if it is assumed that there are similar chemical composition and variations in Kwangju also, we can infer that the pH of precipitation has similar patterns of concentration and variation distribution.

From this viewpoint, this study analyzed the pH pattern of precipitation and its variation for the observed precipitation in Kwangju.

2. Observations and data

Precipitation was observed every hour from Jan. 1, 1991 to Dec. 31, 1995, and the mean pH values of the accumulated precipitation were measured.

Table 1. Measurement of pH of precipitation (unit : 0.1).

1991	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Jan	7											53	52	53	53											53		29
	21	51	51	51	52	52	52	52	52	52	52															52	52	127
Feb	9															56	53		50						51	53		68
	10	52	55		52																					53		86
	14																				52	49				51		32
	15						52	49	48	47	48	48	49	49												49		92
	22						56																			56		64
	27											54	50	48	48		49									50	52	32
Mar	7														47	47		49	48	46	46	46	46	43		46		126
	8							43	44	44	44								44	43	42					43		152
	10																				40	40	42	44		42		256
	11		41	43	44													46	45							44		122
	15																		57	51				54		54		17
	16		60	53																						57		12
	22			54	50	47	48	49						50	51	49	49									50		138
	25				49	49	49	49	49		48	49														49		84
	26																				48	48				48	48	48
Apr	13			50	52	49	50																			50		75
	17												43	43	42	42	43	44	43	44	49	51	50	49	49	46	48	1506
May	6						49	48																		47		52
	7						51	48																		50		26
	24									54	55															55		108
	26								57																	57		43
	27					56	56	57		57																57		40
Jun	1														59	54	55	54		58	55	55	56			56		292
	2	57	55	56						56	57	56	56	55												56		518
	3							57																		57		37
	8																							59	58	59		28
	9	54	55	55	54	55	59	56	55	58	56	57														56		1033
	11																	58								58		60
	12	59																								59		112
	29									59			59													59		47
	30																				58				58	58		42
Jul	1			59	59					59							58									59		95
	4		60	58	58	59				60								60	58		57	57				59		441
	7			57	58		59	58	57	59																58		285
	8												60	60	59	59	59					55	55	55	56	58		193
	9													57	56	56	58	57								57		382
	10			56	57	57	58	58	60	59	58	60		59												58		1042
	11				60	60										57	55	55		59		58				58		678
	15					54	57														56		55	57		56		619
	25											60		59			58					57	55			58		54
	30				53	53	52																			55		198
	31																		58	57						58	57	553
Aug	1	56	55													55										55		578
	2			55			56	56		57							56		56							56		141

〈Table 1.〉 continued

1991	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
	4									57	55	56			57		57						56			56		120
	9	49	49	47	48		49	50	51	50	57	56	56													51		408
	10												56	57												57		33
	22																	59		58	58					58		49
	23																				58					58	56	127
Sep	5												55	56	54	52			53			56				54		935
	6								50	50	53	54	52													52		106
	26																						53			53		137
	27							55	56		59	58	60	61	60	59										59	54	431
Dec	24														54	63	59	55	49	47						55		101
	28													54	54		55			55						55	55	61
M_T	57	54	53	53	53	54	54	53	53	55	54	55	54	54	53	54	55	54	51	52	52	52	52	52	54		53	
1992	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Feb	3		44	45	50	51	65	66	46	45					47	49										51		165
	29	52	52	53			52	49	51	51	47	47	47	46												50	50	149
Mar	2												45	47	47	48	50									47		47
	5																	45	45	46	46	46				46		134
	17	53	55																							54		83
	18												56													56		102
	20												52													52		81
	21			53																						53	51	40
Apr	8																				52	52	52			52		120
	9				53	57	55	59	57												54	55	59	59	57	57		224
	10	56	57	57					57	57																57		148
	21																						54	53	54	54		88
	29																				59	61	50	47	47	53	54	56
Jun	12						55			54	56	51	50		47	48	47									51		1270
	16		47	49	50	52	53	52		52		51	50	49	47	49	50	50		50		51		52		50		702
	17																								53	53		254
	19											59														59		35
	31	53																								53	53	55
Aug	14								50	49	49	46	45					53	51	50						49		315
	16																		65							65		66
	26																	59	55	53						56		280
	27										57	55	52	51												54	56	338
Sep	1						57	55	56	55																56		221
	7																						52	53	52	52		130
	8												54			55										55		120
	24					54	53	52	50	50	50	52	53	51	51	54	55	53	54	54	54		54		54	53		664
	28																						54	52	53	53		57
	29	53	53	52				51	54	54																53	54	138
Nov	19																	55	52		60					56		100
	20									70		69														70	63	12
Dec	6									57	55	55	54	55												55		147
	11						57																			57		300
	23		65	70	64	63																				66		290
	24			66	70	65	63	67																		66		130
	27									60	45	43	46	44	45											47	58	105
M_T	38	53	53	55	56	56	56	55	53	54	51	53	50	50	49	50	50	52	53	50	53	52	53	52	53		52	

1993	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Jan	9				56																					56		46
	14									47	12	42														46		11
	18								67	69	68															68	57	33
Feb	11												57													57		12
	16												46		52	45	47		47	46	51	46				48		270
	21										68	62	53													61	55	150
	6													55	56	58	60	59	58							58		703
	24							50	51	50	53	55	54	53	54	54										53	55	214
Apr	23				58																					58		15
	28				56	54	55	57	56			58									57	56	53			56	57	185
May	1																	65	63							64		201
	2		65	63	57	58							51	55	55											58		257
	6								68	49					55	55										57		75
	9														71	57	55	55	52	48	50					55		172
	13																			60	55	50	48			53		129
	14					51		57																		54		58
	17											61	61	60		59										60		141
	21														56											56	57	107
Jun	1														61		60	60	55							59		44
	2														64	62	58	62	56	50	48	46	46	46	46	53		346
	13				52	53	52	51	51	51																52		208
	22																			63						63		49
	28			62				60	54	50			50	44	43	52										52		408
	29						65	65	58	56																61	57	257
Jun	1								68	67																68		38
	11															55	55	54	54	53						54		302
	12			57		52	52						52	52												53		1430
	13																			55	58	59	60	58		58		467
	16																							54	57	56		30
	17	56	53	57	55							56														55		175
	26											56	56	56	57											56	57	147
Aug	1												64	61	61											62		645
	7								56	51		52														53		94
	8			56	53																					55		137
	10				68	69	69	67																		68		146
	12																						69	67		68		94
	13	62	55	51	50	50	58	59																		55		918
	16									66	63	63		65	64	64	64	58	54			62	63			62		315
	18																50	49	48							49		28
	19					51																				51		13
	25						69	68	66											68	67					68		96
	26		59	54	55	55	55		61	60																57	59	582
Sep	16															67	67	62	62	62				63		64		195
	17	62	63	60			61						65	65	64	51		55	55							60	62	107

〈Table 1.〉 **continued**

1993	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Oct	29								58	54	54	50														54		522
	30																							58	58	58	56	48
Nov	6																	57	59	58	55	54				57		189
	10													59	60											60		48
	13		52			53	44	43	46						52							62	62			52		240
	23												61	60	60	59	59	59								60		560
	30														50	49	50	51								50	56	119
Dec	3					60	57	55	55	54																56		450
	10	10	64	65	61	60	62	66	68																	64		104
	21									59	60	60	61	60	63											61		140
	22												62	62												62	61	230
M_T	55	61	59	58	56	56	59	58	58	56	58	56	57	58	58	56	57	58	58	56	55	54	57	58	54		57	
1994	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Jan	17																	59	59	60	59					59		90
	18																								61	61		30
	21							61	61																	61		60
	22							59				59											60			59		570
	23		60	60						60	60															60	60	60
Feb	9		55	53	46	46				50	50	51														50		340
	11									63	62															63	56	2430
Mar	12	57	48	50	50	49	50																			51		123
	22								70	66	64	62	61	59	56			60	53							61		104
	24									60	57	56														58	57	630
Apr	6															59			55							57		37
	12	65	59	58	59	60																				60		231
	18									67	66	63	65													65		40
	20									69	66	57	56	56												61		77
	22		68	63			40																			57		50
	23		60	41																						51	58	20
May	3														56	64			67	62	61	59	56			61		110
	10																					61	57	57		58		140
	11		54	56	57	65	68							49	45											56		201
	14					66	63	63		54			53		52	53	54	55	54	54	53	52				56		321
	15									53	55	53														54		36
	24														66	67								66		66		14
	25											68	65		68											67	60	15
Jun	8														69	69		69	68							69		43
	18									67	66					62	64	65	65							65		130
	22																	60	47	48		61				54		19
	27									65	58	55		59	58	60	65	69	65							62		340
	30			70	60	69	67	65	62	66	69	70														65	63	114
Jul	27				65	64											64									64	64	18

〈Table 1.〉 continued

1994	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Aug	1	56	46	47	56	55	64	56	65	71	71	58	53													58		546
	3		59	56		59																				58		161
	10					59				53	52	49	48	54	56	54	50		55	53	57					53		611
	12	65				60	52	52	52	56																56		202
	16	68	67	67	67	67																				67		448
	19																60	53								57		33
	26			59	55																					57	58	16
Sep	5					56								53	46	56	65									55		265
	24								66	61			59													62	59	123
Oct	11												66	64	64	63	60	60	60	56	57	58	56	56	51	59		318
	12	63	63	63	65	57	62																			62		158
	21	43	44	43	66	62	49	49	47	47																50	57	265
Nov	17																					69	52	49		57		87
	18	53	52					47	47	50	51															50	53	231
Dec	8																				60	42	40	43	48	47		49
	9	48	48	50	46																					48		144
	14													71	70	57	46	45	43							50	50	25
M_T	46	58	56	56	58	60	57	57	59	60	61	58	58	58	59	60	59	60	58	56	58	57	54	54	53		57	
1995	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
Jan	3																	70	60	47	45	44				53		77
	5						68	56	43			52						67	60				64	57		57		45
	15																		73	73						73		210
	21																						67	57	50	58		83
	22	50	49	48	47	46																				48	58	157
Feb	1 2			69				71	73	70	61	57	55	53	50	49	49	49	48			65	63	65		59		231
	25			71	74	74															71	71		74	74	73		18
	28										71	71	67	66	63	51	55	55	56							65	65	98
Mar	9														67	58	52	52	50	49	48	47				53		102
	10		72	60																						66		26
	12								74	69																72		19
	15																						60	52	48	53		33
	16	62	60		69	62	59																			64		51
	24	57	58																		65	62	62	55	55	59	61	4848
Apr	9			66	54	44	45																			52		34
	11															72	60	56	58							62		65
	13																								74	74		11
	14	53	58	56		70	61																			63		73
		0																										
	21												69	64	56	61	51	56	54	54	54	52	48		42	55		421
	22														47	44	41	43	43	46	45	44	45	44	48	45	58	471
Mar	10									69	64	64	71		71	63	62									66		104
	13															68	53	53								58		112
	15					68										53	47	49	47	45	42	43	43			58		112
	20				65	61	60	57	57	58	59	59	58	58	58	65	61	65	63							60		235

1995	LST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	M_D	M_M	P
	21																	56		66	70					64		16
	28																	61								61	60	112
Jun	3	59	58	58	54	53																				56		424
	13				67	57	52	50											70	68	68	67	66	65		63	60	99
Jul	2				70	69		69	67	67	71			71			70	67	65	63	60	59	59			66		123
	7					68	66	66	60	60	60	61	58			61				68						63		199
	8			45		54																				50		78
	12													68				70	67							68		28
	19								79	76	71	70		65												72		49
	21										61	62														62		302
	23										70		68	66	62				71							69		112
	24	-																					53	49		51	63	243
Aug	1					70																				70		20
	9								66						58		50	48	51							55		197
	19							72	73	72		73														73		168
	20					73	74			73	75	75		73		73		75								74		261
	24	72	71		71		73	72	71							72	61								70	70		238
	25	69	61												74			74		74	73					71		141
	26													74	75	74	75									75		281
	27	74																								73	70	30
Sep	9													77	59											68		18
	13								68	69	63	61	55	54	60	60										61		36
	23			70	71	68	60		64	63																66	65	158
Oct	3																64			71	58					64		24
	15				60	59	66	67	59	70	66															64		92
	31					76	62								64	63						64				66	65	40
Nov	1	66	67	65	67																					66		25
	2	50																								50		12
	7															51		55								53		58
	8									59	56	42	46													51		32
	10								41																	41		22
	13																				53	49	45			49		75
	14	42	42																							42		63
	19																	43								53		18
	23																				58	62				60		19
	24		60	56																	50					55	51	27
Dec	4													70	50		62	66								62		28
	5		74			67										68	71						63	61		67		56
	8		68																							68		12
	24															76	76		75	74	73	72	72			74		21
	28																						71	74		73		16
	29		73	74	73	73								74	74		75	75	75	75	75	75	76			74	70	49
M_T	66	61	63	62	64	63	62	64	64	68	65	62	61	66	62	62	61	59	60	62	59	58	60	57	58		62	

For the time series analysis, the observations were made every hour on the hour regardless of when precipitation started. However, in cases where precipitation lasted less than one hour, the observation was done in adjacent hours. When precipitation continued over one day, the precipitation days were separated at midnight, but the precipitation frequency was concluded to one. In cases where it rained several times in one day, if it doesn't rain over 3 hours, the precipitation frequency was separated and estimated. The grades of precipitation intensity accord with the analysis method of Korea Meteorological Administration. During the observation period the number of precipitation days totaled 580 in Kwangju, but the measurements of acidity were made for 262 days out of the total (Tables 1 and 2).

3. Analysis and Results

3.1 Precipitation amount and frequency of precipitation

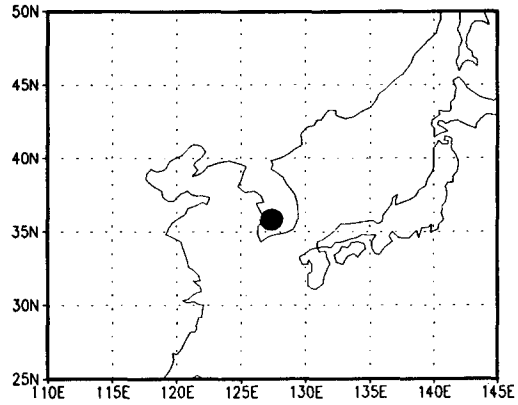

Fig. 1. Observation location

During the research period, the total number of precipitation days was 580, the average annual number of precipitation days was 116, and the everage monthly total precipitation amount was 1098.3 mm. The monthly precipitation amount and number of precipitation days are shown in Fig. 2 (Table 3).

Table 2. Number of precipitation according to pH of precipitation

Precipitation – Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
	~≤01	52	36	33	32	27	28	39	46	24	25	32	52	426
Daily	~≤ 10	2	6	14	5	15	8	12	16	15	2	7	6	108
Precipitation	~≤ 30	0	0	0	2	3	6	10	14	2	2	0	0	39
(P_D, mm)	~≤ 80	0	0	0	0	0	0	0	1	1	0	0	0	2
	~≤100	0	0	0	1	0	1	3	0	0	0	0	0	5

Table 3. Precipitation amount and precipitation frequency

Year	1991		1992		1993		1994		1995		Mean	
Month	P_M	No	P_M	No	P_M	No	P_M	No	P_M	No	P_M	No
Jan	287	12	154	11	252	10	307	10	423	11	285	11
Feb	451	14	251	8	666	9	324	7	349	4	408	8
Mar	1002	14	672	12	813	6	357	7	281	8	625	9
Apr	1714	4	681	13	246	5	433	8	1117	10	838	8
May	297	6	1105	8	1140	10	866	11	755	10	833	9
Jun	2138	11	485	8	1309	9	658	9	964	6	1111	9
Jul	4613	18	2334	9	3001	15	788	8	1100	14	2367	13
Aug	1544	15	2320	12	4233	22	2246	15	1514	13	2371	15
Sep	1859	8	1838	17	354	6	390	3	405	8	969	8
Oct	32	3	262	9	586	6	824	7	172	4	375	6
Nov	338	7	297	9	794	10	325	3	351	10	421	8
Dec	530	11	582	15	327	11	246	8	231	13	380	12
Total	14805	123	10981	131	13721	119	7764	96	7644	111	10983	116

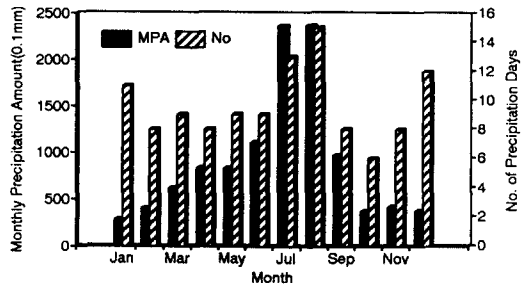

Fig. 2. Precipitation amount and precipitation frequency

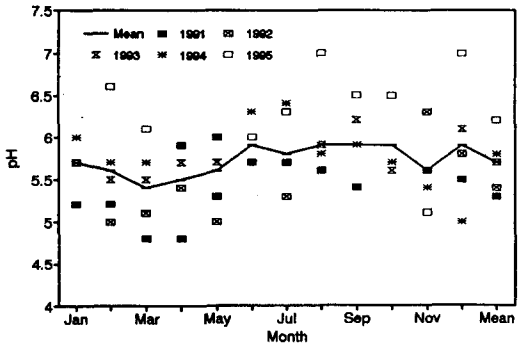

Fig. 3. The variation of monthly mean pH of precipitation

3.2 pH of precipitation

Of the total number of precipitation days, 1302 time observation was achieved for 262 days. Using these data, the monthly mean pH of daily accumualted precipitation was estimated and Table 4 and Fig. 3 show the results.

$$\log pH_M = \frac{1}{N}\sum_{D=1}^{31} \log pH_D$$

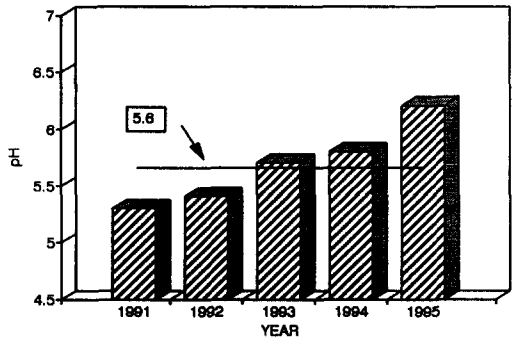

Fig. 4. Interannual variation of pH

where pH_M is the mean pH and pH_D is the pH of daily accumulated precipitation.

The monthly mean pH was 5.4 in March, which was the lowest, even lower than the 5.6 in January, Februaty, April, May and November. According to Table 4, the pH of precipitation has been reduced since 1991 (Fig. 4).

3.3 The ratio of acid rain

The analyzed pH band frequencies of daily accumualted precipitation are shown in Table 5 and Fig. 5. The ratio of strong acid rain of which the daily mean pH is less than 4.5 was about 2.7%, but it of acid rain under pH 5.6 is about 48.1% for nearly half the total observed days. Table 6 and Fig. 6 show the monthly distribution of pH.

In Fig. 6, the ratio of acid rain to total precipitation in March is 69%, the highest followed by more than 50% in January, November, February and September. The reason for the low frequency of acid rain in the summer season and in Decem-

Table 4. Monthly mean pH of precipitation.

Year \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1991	5.2	5.2	4.8	4.8	5.3	5.7	5.7	5.6	5.4	//	5.6	5.5	5.3
1992	//	5.0	5.1	5.4	5.0	//	5.3	5.6	5.4	//	6.3	5.8	5.4
1993	5.7	5.5	5.5	5.7	5.7	5.7	5.7	5.9	6.2	5.6	5.6	6.1	5.7
1994	6.0	5.7	5.7	5.9	6.0	6.3	6.4	5.8	5.9	5.7	5.4	5.0	5.8
1995	5.7	6.6	6.1	5.9	6.0	6.0	6.3	7.0	6.5	6.5	5.1	7.0	6.2

P_M : monthly precipitation amount (0.1 mm)

Table 5. pH distribution of precipitation

Year \ pH	~≦4.5	~≦5.0	~≦5.6	5.6<~	Sum
1991	3	10	22	22	57
1992	0	7	23	8	38
1993	0	4	22	29	55
1994	0	5	10	31	46
1995	4	5	11	46	66
Sum	7	31	88	136	262
(%)	(2.7)	(11.8)	(33.6)	(51.9)	(100)

Table 6. Monthly pH of precipitation

pH — Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
~≦4.5	0	0	3	1	0	0	0	0	0	0	3	0	7
~≦5.0	2	5	6	2	4	0	2	2	0	1	4	3	31
~≦5.6	4	5	9	7	10	8	11	13	10	1	5	5	88
5.6< ~	9	6	8	11	15	14	18	22	7	6	7	12	136
Sum	15	16	26	21	29	22	32	37	17	8	19	20	262

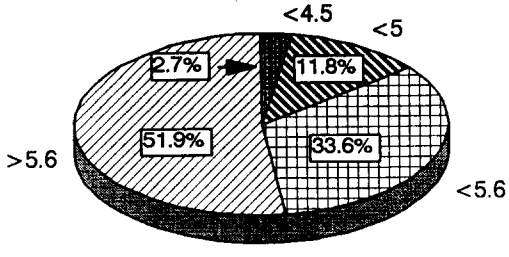

Fig. 5. pH distribution of precipitation

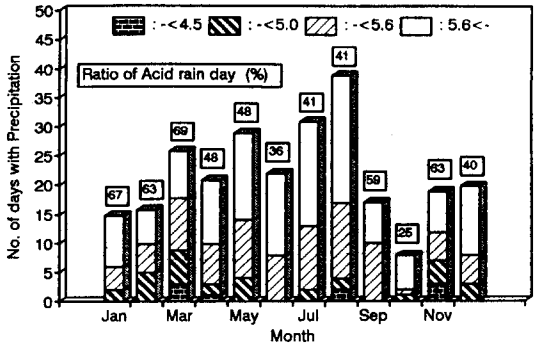

Fig. 6. Monthly ratio of acid rain

ber can be explained by rain washout; however, the low rates of acid rain and pH in October are different from other research results. The changes

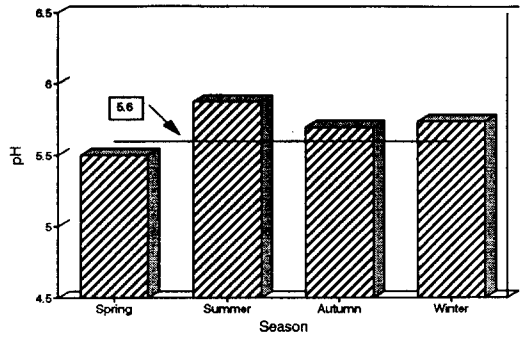

Fig. 7. Seasonal pH of precipitation

of meteorological variables in Korea are districted by each season. Taking this into consideration, we have divided the observations into four separate seasons : spring (Mar., Apr. and May), summer (Jun., Jul. and Aug.), autumm (Sep., Oct. and Nov.) and winter (Jan., Feb. and Dec.) and examined the ratio of acid rain to pH of precipitation (Table 7, Figs. 7 and 8). The seasonal mean pH showed that spring had the lowest acid rain of 5.50, becoming higher to autumm, winter, and summer. In Fig. 8, it can be seen that the ratio of acid rain is lowest in spring. Table 8 and Fig. 9 show the daily varia-

Table 7. Seasonal pH (pH_{time} seasonal mean pH observed at every hour; pH_i : pH at voluntary time; $pH_{Monthly}$: seasonal mean values using mean pH of daily accumulated precipitation; pH_{Di} : pH on voluntary day; n: total number of observed time or day in season

pH — Season	Spring	Summer	Autumn	Winter	Mean
Time Mean	5.56	5.92	5.63	5.81	5.73
Monthly Mean	5.50	5.87	5.69	5.73	5.70

Table 8. Daily variation of pH

LST / Season	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Spring	6.0	5.8	5.5	5.5	5.6	5.4	5.3	5.9	5.8	5.7	5.8	5.7	5.4	5.6	5.5	5.5	5.4	5.2	5.1	5.2	5.1	5.1	5.1	5.3
Summer	6.1	5.7	5.6	5.8	5.9	5.9	5.9	6.1	6.0	6.1	5.8	5.5	6.0	6.0	6.0	5.8	6.0	5.9	5.8	5.9	5.7	5.8	5.6	5.7
Autumn	5.4	5.5	5.8	6.6	6.1	5.7	5.2	5.4	5.8	5.7	5.5	5.7	6.0	5.5	5.7	6.0	5.5	5.6	6.0	5.6	5.9	5.4	5.5	5.4
Winter	5.3	5.8	5.9	5.8	6.0	5.9	5.9	5.5	5.6	5.7	5.4	5.4	5.7	5.5	5.7	5.8	6.0	5.8	6.0	6.1	5.8	6.4	6.1	5.7
Annual	5.7	5.7	5.7	5.9	5.9	5.7	5.6	5.7	5.8	5.8	5.6	5.6	5.8	5.7	5.7	5.8	5.7	5.6	5.7	5.7	5.6	5.6	5.5	5.5

Table 9. pH as precipitation categories

Daily Precipitation	~≦10	~≦30	~≦80	~≦100	100< ~
pH	5.84	5.71	5.60	5.45	5.45

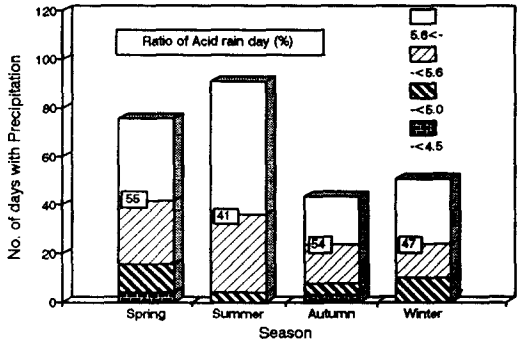

Fig. 8. The ratio of acid rain in season

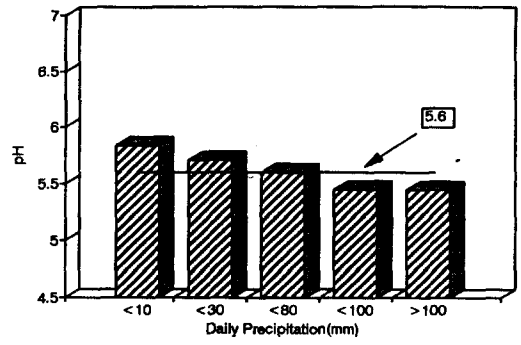

Fig. 10. pH as precipitation categories.

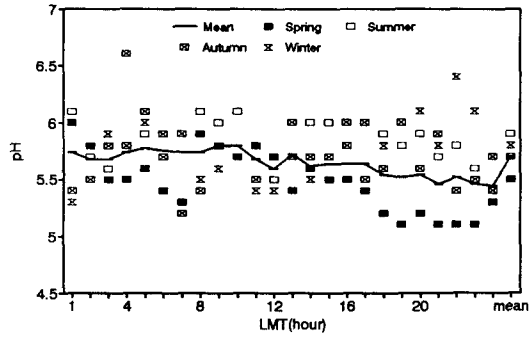

Fig. 9. Daily variation of pH

tion of pH.

The pH value reaches its peak from 9~10 a.m. each day and lessens gradually that.

3.4 pH and intensity of precipitation

To confirm the relation between precipitation amount and pH, the daily precipitation amount and daily mean pH were analyzed (Table 9, Fig. 10).

The greater the precipitation amount, the lower the pH. This is contrary to the theory which states that the pH of precipitation varies with the ion and TSP variation in the atmosphere. This is difficult

Table 10. The number of acid rain days as precipitation categories.

$pH-P_D$	~≦10	~≦30	~≦80	~≦100	100< ~	Sum
~≦4.5	3	3	1	0	0	7
~≦5.0	14	12	4	0	1	31
~≦5.6	30	37	16	2	3	88
< ~	69	45	20	0	2	136
Sum	116	97	41	2	6	262

P_D : daily precipitation amount (mm)

Table 11. The number and ratio of acid rain days as precipitation categolies

Time	~≦1	~≦3	~≦6	~≦12	12< ~	Sum
~≦4.5	2	3	1	1	0	7
~≦5.0	1	7	11	13	2	34
~≦5.6	11	40	38	13	3	105
< ~	69	27	58	47	22	156
Sum	41	108	97	49	7	302
pH	5.75	6.55	6.40	5.56	5.70	

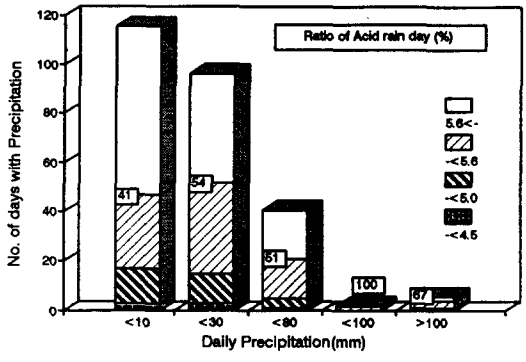

Fig. 11. The number of acid rain days and the ratio of acid rain days as precipitation categories.

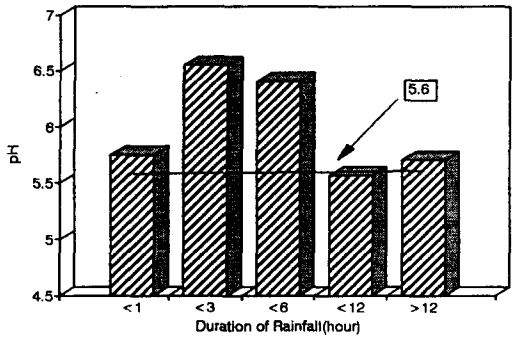

Fig. 12. pH according to duration of rain

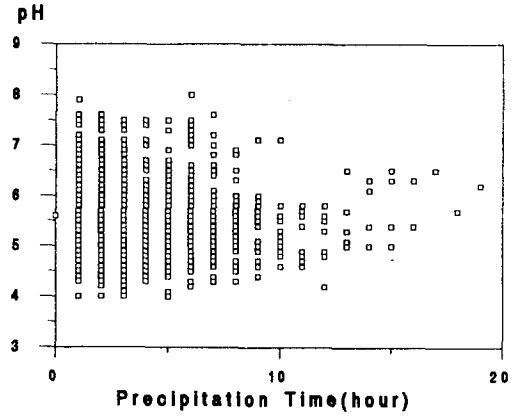

Fig. 13. Distribution of pH according to the duration of rain

to conclude beacuse there are rare cases in which the daily precipitation is over 100 mm, but the ratio of acid rain is high when the daily precipitation amount is also high (Table 10, Fig. 11).

3.5 The relation between duration and pH of precipitation

It is generally, known that the pH value is high, that is the acidity is low, if the duration of precipitation is long. To confirm this, the frequency of pH, mean pH and distribution of mean pH accroding to duration of rain were obtained (Table 11, Figs. 12 and 13).

By Fig.12 and Fig.13, it is difficult to conclude the relation between duration of precipitation and pH. But according to the result; when the duration of precipitation is six houres, somewhat a long time, the pH have a small vlaue. If precipitation persists for six-twelve hours, the mean pH indicates weak acidity. If the duration of precipitation is long, the pH continues at a constant value. It is thought that the result is made since the increased pH to constant level is diluted by increased precipitation over the passage of time and neutralized by absorbing of alkalic material.

4. Results

The results of analysis observed precipitation and its pH in Kwangju for 262 days from Jan. 1, 1991 to Dec. 31, 1995 are as follows :

The annual mean pH was 5.7, and the monthly mean pH values of January-May and November were less than 5.6 in Kwangju. The ratio of acid rain for these periods was about 48.1%, almost half that of the total observed days. In march, the pH was 5.4 and the ratio of acid precipitation was 69%, an especially serious situation. In the spring, the pH value was 5.5 thus weakly acidic. The pH of precipitation tended to decrease with greater precipitation. The relation between persistent time and pH of precipitation is variable, but if the persistent time is long, the pH is constant and low. It is fortunate that there is an increasing trend of pH in interannual variation, but it is thought important that the amplitude of variation of pH in 1995 was high and the pH value was 4.1 in October and November. Because heavy and persistent precipitation effects the accumulation of acidity, more concern about acid rain is needed.

Acknowledgment

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남한의 광주광역시에서 산성비에 관한 연구

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(1996년 10월 30일 접수)

1991년 1월 1일부터 1995년 12월 31일 기간중 262일 동안 광주지방에서 관측한 강수와 강수의 pH를 분석한 결과는 다음과 같다.

광주지방의 연평균 pH는 5.7이고, 1월~5월과 11월의 pH도 5.6 이하였다. 또한, 연평균강수일중 산성강수일의 비율은 48.1%이었고, 관측시간에 따른 산성강수 시간의 비율도 50%이상이 관측 되었다. 따라서 일년중 반의 강수일과 반의 강수시각에 산성우가 내린셈이다. 특히, 3월의 월평균 pH는 5.4이고, 산성 강수의 비율은 69%나 되어 매우 심각하다. 계절별로는 봄, 가을, 겨울 및 여름 순으로 산성도가 높고, 봄철 강수의 평균 pH는 5.5로 약산성우이다.

pH의 일변화는 뚜렷한 특징이 없었으며, 가장 강한 산성우는 1991년 3월10일에 관측된 pH 4.0이었다. 강수의 지속 시간과 pH의 관계는 일정하지는 않으나 관측의 결과에서는 지속 시간이 길 때 pH가 낮게 나타났으며, 강수가 오랫동안 지속될 경우 일정한 pH값을 나타내었다.

pH의 경년변화에서 pH가 상승하는 경향이 있음은 다행한 일이다. 그러나 1995년의 경우 pH의 변화가 진폭이 큰 점과 11월 10일의 pH 4.1은 중요한 의미가 있다고 사료된다. 또한, 많은 강수와 지속적 강수는 산성도의 누적에 상승 효과가 있어 산성우에 대한 관심이 더욱 요구된다.