WASH- OUT OF AIR POLLUTANTS BY THE SOUTHWEST MONSOON RAIN OVER VISAKHAPATNAM

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ABSTRACT: The wash- out of air pollutants by rain, which is of considerable relevance to a monsoonal country like India, was studied. Rain water samples were collected from ten selected stations in Visakhapatnam city during South West monsoon of 2014. The natural scavenging effects of rain and the wash- out factor with respect to ambient sulphur dioxide pollution were also estimated. The wash- out effects were found to be dependent upon the intensity of the rain, the interval between two spells of rain and the amount of pollutants present in the atmosphere.

Key Words: Washout factor, Rain water, South west monsoon and Sulfur dioxide

INTRODUCTION

The activities of man lead to a change in the general atmosphere near the earth's surface and this change may result in the persistence of certain pollutants like sulphur dioxide , oxides of nitrogen , carbon monoxide , sodium, potassium and chloride . These substances interfere with the comfort of the people, cause or tend to cause ill-health and also adversely affect flora and fauna. Further, in the polluted atmosphere a number of chemical reactions take place producing secondary pollutants which add to the unpleasant properties. The problem of air pollutants is not so alarming in India as in the developed countries, but recently it has assumed a serious form in certain urban pockets owing to industrial activity. Nature is a very effective self cleansing agent. The pollutants are carried away and diluted by winds, diffused by heat, absorbed by vegetation and land and washed out by precipitation. Wet precipitation particularly rain is considered quite effective in washing out gaseous pollutants and particulate matter.

Owing to the importance of the chemical composition of rain- water in geochemistry, agriculture, meteorology and environmental pollution, considerable work has been reported from India. In the present study, made in Visakhapatnam city, the chemical composition as well as the wash-out of the air pollutants is reported. The city of Visakhapatnam is situated at 17°42^{1} north latitude and 82° 18^{1} east longitudes, a highly industrialized coastal metropolitan city on the east coast of India. The average rainfall of Visakhapatnam is 955 mm per year and per month is 79.6 mm.

MATERIAL AND METHODS

Ten sampling points well- distributed throughout the Visakhapatnam city were selected according to criteria laid down by A .C Stern (1972) so that an average picture of chemical composition of rain- water could be obtained. The rain water was collected in cleaned and washed polyethylene container fitted with a funnel of 16 cm diameter. The container was mounted on wooden boxes and placed on the top of the buildings at height of 9-16 m from the ground level .Adequate precautions were taken for the catch of precipitation, so that local interferences could be minimized. The samples were collected from each station as early as possible after the rain. All the samples were filtered through what man No.42 filter paper to remove the suspended and undisclosed materials. The filtrate was analyzed for P^H, sodium, potassium, sulphate and chloride. The P^H value was recorded on a Beckman P^H meter. The sodium and potassium ion concentrations were determined with flame photometer using the standard techniques. The chloride was precipitated as silver chloride with silver nitrate and nitric acid at the resulting turbidity was measured at 560 mμ with a spectrophometer. The sulphate content was determined by using the turbidity method. First of all the P^H of the samples was adjusted to 4.0 and then sufficient barium chloride was added to precipitate sulphate ion completely in the presence of a conditioning media contains glycerol's, sodium chloride, hydrochloric acid and alcohol. The resulting turbidity was measured with a spectrophometer at 420 mμ. The washout factor W (Peirson, 1973) was calculated as:

W = Concentration in rain- water (μg/kg)/Concentration in air (μg/kg)

The concentration of sulphate in the air was calculated from the sulphation rate measured by using the standard lead peroxide candle method.

Table 1: Chemical Composition of rain water in different locations in Visakhapatnam city

Station Name	July-October Date	P^H	SO4 Mg/lit	Cl Mg/lit	Na ppm	K ppm	No3 Mg/lit
	July 1	6.5	14.0	4.0	8	2.8	1.32
	July12	6.9	9.5	0.25	6	3.3	0.75
	Aug 1	6.7	7.5	8.0	6	5.5	1.62
	Aug 21	6.6	20.02	1.25	3	4.5	0.05
	Sep 26	6.3	9.5	0.5	17	2.0	1.0
	Sep 27	6.5	40.9	0.9	8	2.2	0
IE Mariipalem	Oct11	5.6	12.5	0.6	11	5.5	0
	Oct18	5.9	16.23	0.9	6	5.0	0

	July 1	6.4	2.8	5.3	6	3.0	0.25
	July12	6.1	2.0	2.20	3	5.3	0
N.S.T.L	Aug 1	6.6	10.4	3.5	6	4.8	0.30
	Aug 21	6.01	5.2	3.2	3	4.3	1.15
	Sep 26	7.9	5.2	1.77	6	5.3	0
	Sep 27	7.0	5.4	1.06	5	3.6	0
	Oct 11	6.4	8.5	2.5	6	3.8	1.20
	Oct 18	6.2	7.6	3.2	6	3.9	0.40
	July 1	5.80	53.2	25.79	8	2.3	0.28
	July12	7.25	9.6	0.90	6	2.3	0.80
	Aug 1	6.80	54.0	10.63	8	3.6	0.19
	Aug 21	6.50	14.0	0.88	3	5.8	0.87
	Sep 26	6.10	14	0.89	11	3.8	0
OLD POST OFFICE	Sep 27	6.30	15.2	0	11	5.8	1.20
	Oct11	7.2	25.0	7.5	6	3.8	1.40
	Oct18	7.4	16.5	7.10	11	5.8	0.50
	July 1	6.8	10.5	9.5	6	3.3	0.5
	July12	6.9	12	8.4	3	3.5	0.3
	Aug 1	6.7	15.0	12.5	8	2.3	0
	Aug 21	6.6	5.0	14.6	6	2.4	0
	Sep 5	6.3	12.0	15.6	6	1.70	0.2
INS Virabahu	Sep 15	6.4	7.2	9.5	4	1.20	0.1
	Oct 5	6.1	8.5	10.5	4	2.0	0.1
	Oct10	6.3	10.5	12.5	3	2.1	0.05
	July 1	6.0	1.5	1.2	4	3.3	1.1
	July12	6.1	1.4	1.5	5	3.6	0.5
	Aug 15	5.9	3.4	1.3	3	2.2	0.01
	Aug 22	5.8	5.6	1.2	6	2.6	0.05
	Sep 12	6.3	2.1	0.5	4	3.1	0.4
Seethammadhar	Sep 19	6.4	2.0	0.6	3	3.0	0.3
a	Oct12	6.2	1.5	1.0	5	2.5	0
	Oct 24	6.0	0.5	1.1	3	2.4	0
	July 1	6.1	7.2	4.0	16	5.5	1.63
	July14	6.2	10.0	1.80	14	4.5	0.63
	Aug 2	5.7	14.8	12.0	15	5.2	0.73
Gnanapuram	Aug13	5.9	7.2	0.90	16	5.1	1.75
	Sep 10	5.8	5.2	9.3	10	4.5	2.70
	Sep 21	5.6	26.8	4.0	8	5.0	2.1
	Oct 15	5.5	14.5	12.0	8	4.8	1.5
	Oct 24	5.6	10.2	1.8	12	5.2	1.35
	July 5	5.7	6.5	1.5	8	4.5	1.7
	July15	5.8	12.0	1.6	12	4.3	1.06
	Aug 17	5.6	15	0.5	7	5.1	1.5

	Aug 18	5.8	19	0.9	14	5.0	1.16
	Sep 12	5.7	14	1.2	15	4.9	1.4
Gajuwaka	Sep 20	5.8	13.2	0.12	8	4.8	1.5
	Oct 6	6.0	19	1.2	9	4.7	1.3
	Oct17	6.1	20.5	1.6	8	4.6	1.4
	July 15	6.5	58.0	8.4	17	3.3	1.32
	July 23	6.2	37	2.7	7	2.3	0.75
	Aug 18	6.12	52	4.4	3	5.8	1.62
	Aug 19	6.6	12.4	1.8	3	4.3	0.05
	Sep 7	6.9	76.0	3.54	8	5.0	1.0
	Sep 13	6.5	20	2.5	6	4.0	0
Mulagada	Oct15	6.6	6.8	5.31	11	4.0	0
	Oct17	5.39	9.2	2.03	8	4.5	0
	July 18	5.94	19.0	13.03	11	4.0	0.40
	July28	6.68	9	6.60	6	2.8	1.22
	Aug 9	6.44	8.0	39.0	17	3.6	0.20
	Aug 12	5.6	12.0	1.77	6	4.5	1.87
	Sep 11	6.80	11.2	1.77	8	3.8	0.30
Jagadamba	Sep 13	5.20	12.0	1.5	6	3.6	0
	Oct 5	6.70	16.0	1.65	9	4.0	0
	Oct15	5.6	14.0	1.55	11	4.2	0
	July 15	6.21	10	6.0	14	2.3	0.75
	July 23	6.50	12.0	1.80	11	2.8	1.03
Andhra	Aug 9	6.28	22.8	2.0	23	3.3	0.15
University	Aug 18	6.65	8.4	13.29	3	5.0	1.0
	Sep 7	6.9	10.0	11.52	11	4.8	1.0
	Sep 11	6.1	9.0	1.77	6	4.8	0.25
	Oct 5	5.8	9.5	1.77	6	4.5	0
	Oct10	5.6	8.0	1.65	11	3.6	0

Table 2: MEAN AND RANGE OF CHEMICAL COMPOSITION OF RAIN WATER OVER VISAKHAPATNAM

Sampling point	pH	Na(ppm)	K(ppm)	So4(mg/lit)	Cl^- (mg/lit)	$No3^-$(mg/lit)
Mulagada	4.625 (3.5-5.66)	7.428 (3-14)	4.242 (2.3-5.8)	60.285 (6.82-132.0)	4.025 (1.80-8.4)	0.677 (0.05-1.62)
Jagadamba	6.468 (5.4-7.32)	8.142 (3-17)	4.214 (2.5-8.0)	21.142 (8-19.2)	9.430 (1.77-39)	0.578 (0.26-1.87)
Old Post Office	6.876 (5.58-8.8)	7.800 (3-11)	4.160 (2.3-6.8)	21.840 (8.8-54)	6.372 (0.88-25.7)	0.568 (0.22-1.87)
N.S.T.L.	6.551 (6.0-7.91)	5.363 (3-8.0)	3.845 (2.3-5.3)	5.236 (0-12)	3.460 (0.88-16.4)	0.331 (0-1.2)
Gnanapuram	6.367 (5.79-6.71)	5.750 (3-11)	4.475 (2.8-7.3)	13.500 (7.2-29.6)	7.200 (0.9-22.1)	0.585 (0.05-1.5)
INS Virabahu	6.172 (5.5-6.63)	9.875 (3-20)	4.0 (2.0-5.5)	14.50 (2.0-28.0)	6.226 (1.77-12.0)	0.63 (0.2-1.2)
Andhra University	6.642 (5.9-6.9)	9.0 (3-23)	3.972 (2.3-4.8)	16.981 (2-52)	14.537 (1.77-60.2)	0.298 (0-1.03)

Table3. **Mean and range of the ionic rations of the constituents**

Sampling point	Na/K	So4/Na	So4/K	So4/Cl	Cl/Na
Mulagada	2.307 (0.51-4.242)	9.679 (0.61-19.46)	14.35 (3.34-37.28)	14.593 (3.34-37.28)	0.651 (0.18-1.46)
Jagadamba	1.915 (0.83-2.75)	2.325 (1.50-4.23)	4.306 (2.22-9.0)	4.476 (1.44-9.03)	0.859 (0.22-2.29)
Old post office	2.003 (0.789-3.478)	2.772 (0.90-6.65)	4.885 (2.32-9.17)	7.610 (1.23-15.90)	0.827 (0.08-3.21)
N.S.T.L	1.461 (0.56-2.4)	0.990 (0.46-1.86)	1.526 (0-3.73)	2.483 (0-0.6779)	0.683 (0.146-2.73)
Gnanapuram	1.305 (0.66-2.14)	2.405 (1.20-3.33)	2.813 (1.60-4.05)	4.173 (1.33-6.0)	0.893 (0.30-2)
INS Virabahu	2.706 (0.60-4.16)	1.626 (0.65-4.46)	4.222 (0.40-13.4)	3.685 (0.55-10.37)	0.768 (0.09-2)
Andhra University	2.465 (0.62-6.08)	1.831 (0.66-3.25)	4.428 ()0.41-10.40	2.270 (0.745-5.64)	1.276 (0.29-2.61)

Table 4: Average range of chemical composition of rain water over the Indian cities

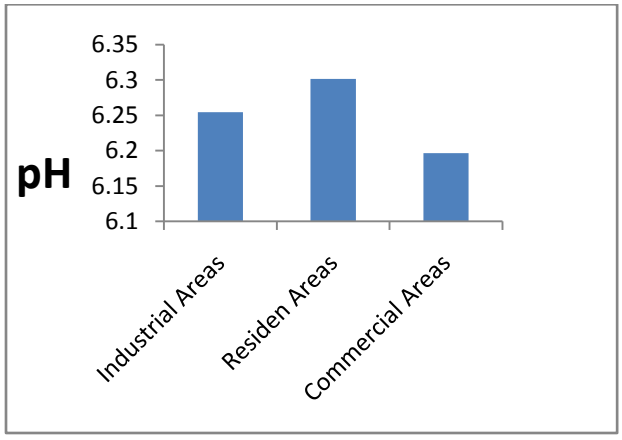
Constituent	Visakhapatnam	Ahmadabad	Calcutta
pH	6.243 (3.50-8.90)	7.84 (6.90-0.1)	6.63 (6.8 – 5.5)
Na	7.622 (3.0 - 28.0)	7.57 (0.10 – 38.5)	1.17 (3.26 – 0.32)
K	4.129 (2.0 – 8.0)	1.79 (12.8 – 0.25)	0.43 (1.96 - Trace)
So4	21.926 (0 – 132.0)	1.39 (7.87 – 0.38)	3.73 (7.72 – 0.73)
Cl	7.82 (0.88 – 60.21)	2.51 (9.75 - Trace)	2.87 (10.92 – 0.5)

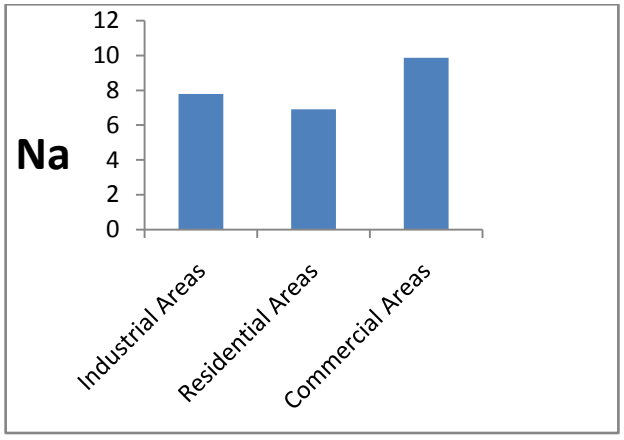
Table 5: Average concentrations of SO4 in air and washout factor of µg x 10^4

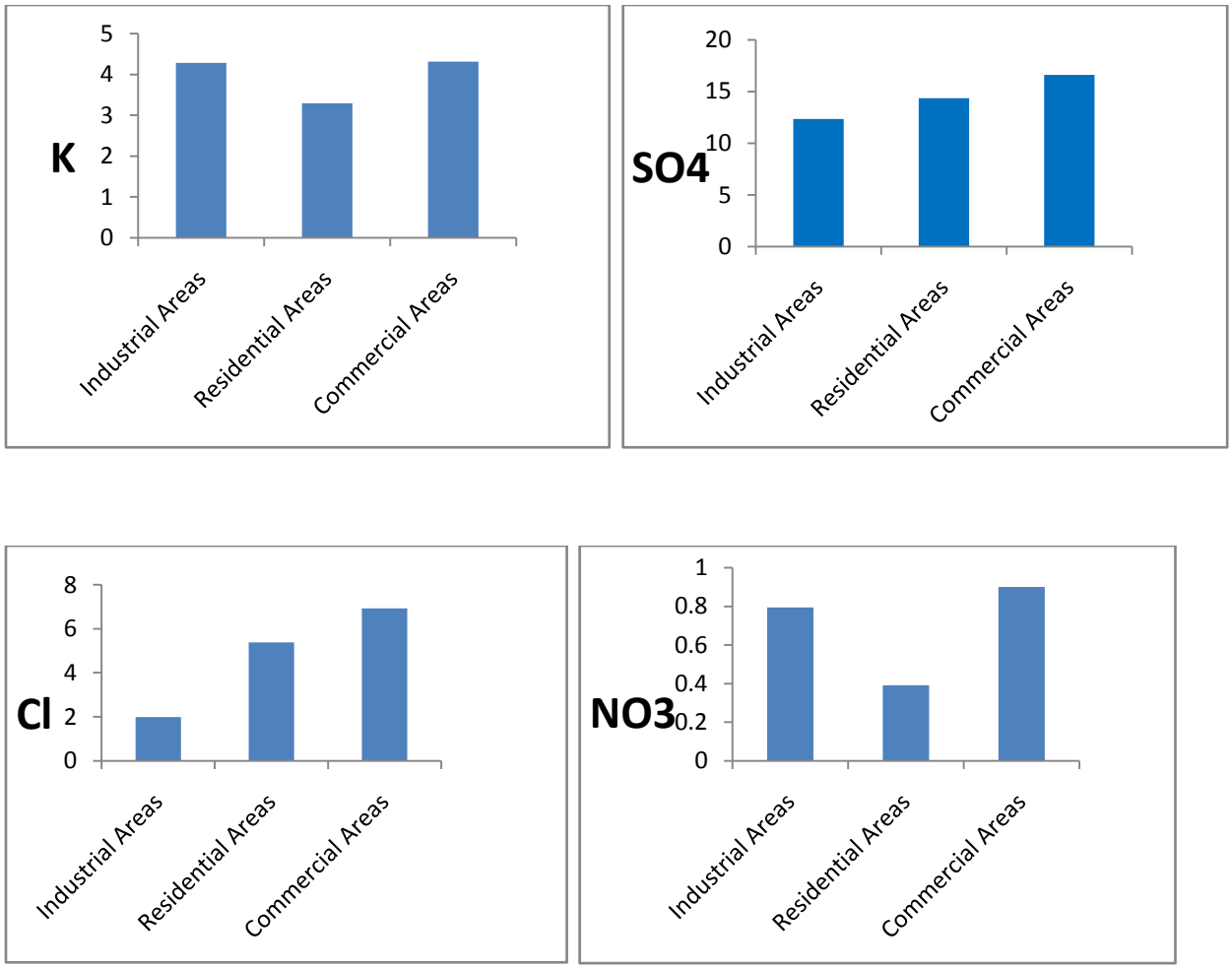
Sampling point	SO4 in air µg/lit	SO4 in water µg/lit	Washout factor µg x 10^4
Mulagada	0.1362	60285	44.26
Jagadamba	0.1051	21142	20.11
Old post Office	0.1021	21840	21.39
N.S.T.L	0.0753	52360	69.53
Gnanapuram	0.0740	13500	18.24
INS Virabahu	0.0690	14500	21.01
Andhra University	0.0531	16981	24.61

Figures

Pollutants concentration over Industrial, Residential and Commercial areas







RESULTS AND DISCUSSIONS

The data regarding the chemical composition of rain- water for different places in Visakhapatnam are given in table: 1.It is referred that the interval between two showers determines to a large extent the pollution wash-out. For example, when the showers were on two subsequent days, viz.18th and 19th September 2014, the pollutant wash- out on the second day was very much less. This smaller amount may be attributed to the fact that there was not sufficient pollution built-up in the atmosphere after the previous spell of rainfall. From the table :2 it is observed that the mean P^H value of rain water is less (more acidic) at Mulagada than at reaming places i.e. the P^H value in industrial area in much less than both in commercial area and residential areas. The concentration of sulfates is also greater at industrial area than at both commercial areas in between the concentration of sulfates in commercial areas is in between those values in industrial and residential areas. The highest value of sulfate in industrial areas is due to fact that large amount of pollutants emitted from the industrial chimneys. In commercial areas the concentration of sulfate is mainly due to traffic emissions. The sodium and chlorine concentrations at Jagadamba, Gnanapuram and Old post office are higher than the

concentrations at Mulagada, Seethammadhara. This is obviously due to the fact that these sampling points are in the vicinity of the coast, where as Mulagada, Seethammadhara are far away from the coast. The concentrations are lower than their corresponding sodium concentrations. The nitrate concentrations also did not vary much and are very low.

The mean and range of the ionic ratios namely sodium/potassium, sulfate/sodium, sulfate/chlorine and chlorine/sodium ionic ratio in rain water given in table 3. Except the chlorine/sodium ionic ratio the remaining ionic ratios at different sampling points are greater than one. From this table it is observed that the value of sulfate/sodium ratio is high in industrial area when compare to the other areas. This is because; the value of sulfate is grater in industrial area than in other areas. The same trend is also observed for sulfate/potassium, sulfate/chlorine ionic ratios. The value of sodium/potassium, sulfate/ chlorine ionic ratio being greater than unity indicates that sodium concentration is greater than the corresponding potassium concentration. The chlorine/ sodium ionic ratios are less than unity and show a reveres trend that is greater over residential and commercial areas than industrial. Sulfate/chlorine ionic ratios at N.S.T.L, INS Virabahu and Andhra University is an attributed to the fact that low sulfate concentration and corresponding high sodium, potassium and chlorine concentrations respectively. It is assumed that all the sulfur dioxide in air was converted into sulfate for the present calculations for wash out factor. The wash-out factor values are indicated in table 5.Mulagada; Jagadamba and N.S.T.L are taken as the representatives of industrial, commercial and residential areas. The chemical compositions of rain water in industrial, commercial and residential are compared in figures. The mean and range of chemical composition of rain water in Visakhapatnam is compared with major Indian cities. These values are compiled in table 4. The P^H of the rain water samples collected over Visakhapatnam varied between 3.5 and 8.8 with an average of 6.24.The P^H of the samples collected in other Indian cities like Ahmadabad was found on the basic side 6.9 to 9.1 with an average of 7.89. One possible explanation is that the pollution in the Ahmadabad city is mainly owing to burning of coal. Even though the emission of sulfur dioxide from coal and oil burning are similar, the fly ash which is a producer of only coal burning basic in nature , neutral ions the acidity impacted by the emissions of sulfur dioxide.

SUMMARY AND CONCLUSIONS

Even though it is difficult to draw definite conclusions in view of the number of factors involved and the complexity of the problem, the following tentative conclusions can be drawn. Rain acts as a good scavenger for the ambient air pollution control and is a very important for the monsoonal country such as India, where the rainfall is concentrated in four months (July to October) during the year. This is confirmed in the case of sulfur dioxide by the wash out factor which depends upon the amount of concentration of sulfur dioxide in air, amount of rain fall and its period. The P^H of rain water samples collected in Visakhapatnam was acidic. It is relatively more acidic in industrial area. This might be due to burning of fuel, oil and also due to the presence of oil refinery. The sodium and chlorine ion concentrations are relatively higher at Jagadamba; Old post office, INS Virabahu and Andhra University these being in the vicinity of

the sea. The analysis of the rain water samples shows be an important parameter for all the monitoring survives, because the only the rain water composition can throw light on the different types of pollutions in the atmosphere and there by one can pinpoint which pollutant is more important to monitor and control in a particular area. From this rain water analysis one can find out how much pollution is washed down by rain.

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