BUKTI KORESPONDENSI

Nama : Dr. Nia Yuniarti Hasan, SST., MT.

NIP : 197406081998032001

NIDN : 4008067401

Jabatan : Lektor

Unit Kerja : Politeknik Kesehatan Kementrian Kesehatan Bandung

Jurnal Internasional bereputasi (terindeks pada database internasional bereputasi dan berfaktor dampak). Penulis pertama: (60% x 40 = 24)	Chemical Composition And Sources Attribution Of Rainwater In Bandung Area, Indonesia.	Link Journal : https://geomatejournal.com/geomate Link Paper : https://geomatejournal.com/geomate/article/view/465 Link Dokumen : https://geomatejournal.com/geomate/article/view/465/1500 Link kebijakan similarity Jurnal : https://geomatejournal.com/geomate/ethics Link H-Indeks-SJR : https://www.scimagojr.com/journalsearch.php?q=21100327701&tip=sid URL Similarity : http://repo.poltekkesbandung.ac.id/7344/

1. Submited jurnal	: 21 Mei 2019
2. Review Results-: Int J of GEOMATE	: 4 Juni 2019
3. Sumbit revision	: 8 Juni 2019
4. Publication Fee Payment	: 12 Agustus 2019
5. Galley Proof for Issue 64--	: 15 Agustus 2019
6. Publication date	: 28 Desember 2019

Gmail **Nia Yuniarti Hasan <niayhasan@gmail.com>**

Fwd: Review Results-: Int J of GEOMATE-

Zakaria <zakaria@bio.mie-u.ac.jp> Wed, Jun 5, 2019 at 11:30 AM
To: Geomate Editor <editor@geomate.org>
Cc: driejana@tl.itb.ac.id, niayhasan@gmail.com, aminudin.sulaeman@gmail.com, herto@ftsl.itb.ac.id

Please use the attached one also.

Best Regards.

Zakaria

[Quoted text hidden]

2019-06-05 05-46AM - 87856.pdf
28K

Gmail **Nia Yuniarti Hasan <niayhasan@gmail.com>**

Fwd: Review Results-: Int J of GEOMATE-

Geomate Editor <editor@geomate.org> Tue, Jun 4, 2019 at 7:19 PM
To: driejana@tl.itb.ac.id, niayhasan@gmail.com, aminudin.sulaeman@gmail.com, herto@ftsl.itb.ac.id

Dear Authors,

Thanks for your kind contribution. We have reviewers' comments on your paper (attached). Please send the revised paper by maximum of 4 days upon receiving this email. Please send response to reviewers by authors in separate file. An example of “response to reviewers by authors” is attached. Please use the following link:

http://www.geomatejournal.com/revised

Best regards.

--

Dr. Zakaria Hossain (Ph.D. Kyoto Univ.)

Professor, Mie University, Japan
Editor-in-Chief, Int. J. of GEOMATE
Director, Sci. Eng. & Env. Int. Conf.
General Secretary, GEOMATE Int. Soc.
zakaria@bio.mie-u.ac.jp
society@geomate.org
conference@geomate.org
editor@geomatejournal.com
http://www.koku.bio.mie-u.ac.jp/
http://www.geomate.org/
http://www.confsee.com/
http://www.geomatejournal.com/

4 attachments

Example-Response to reviewer by Author.pdf
19K

87856 1.pdf
42K

2019-05-29 10-52PM - 87856.pdf
25K

87856 Dr Driejana.pdf
2970K

Wednesday, May 29, 2019

GEOMATE Journal Review and Evaluation

Paper ID number

87856

Paper Title

CHEMICAL COMPOSITION AND SOURCES ATTRIBUTION OF RAINWATER IN BANDUNG AREA INDONESIA

i. Originality

3

ii. Quality

3

iii. Relevance

5

iv. Presentation

3

v. Recommendation

4

Total (sum of i to v)

18

General comments

This is an interesting research on CHEMICAL COMPOSITION AND SOURCES ATTRIBUTION OF RAINWATER IN BANDUNG AREA INDONESIA . It is a good quality paper. It can be recommended for journal publication after a minor revision.

Mandatory changes

Please check the attachment to improve the manuscript.

Upload file (if any)

87856 Dr Driejana.pdf

GEOMATE Journal Review and Evaluation

Paper ID number
87856

Paper Title
CHEMICAL COMPOSITION AND SOURCES ATTRIBUTION OF RAINWATER IN BANDUNG AREA INDONESIA

i. Originality
3

ii. Quality
3

iii. Relevance
3

iv. Presentation
4

v. Recommendation
1

Total (sum of i to v)
14

General comments
1. The authors have very poor command on english language. This paper need to be completely re-written.
2. Test results should be compared with some standard or other sources.
3. The results should be validated.
4. Paper Title and the analysis do not march - abstract and conclusions are not clear
5. Revise abstract and conclusion
6. Itemize conclusion in simple english

Mandatory changes
Should be completely re-written

Suggested changes

The title should match with the analysis and findings. It appears that the authors are analyzing the rainwater chemical composition data and relating its contribution from various sources- vehicle emission... etc.

Due to poor english, the paper is not clear to readers what the authors have done.

Suggested Title: Statistical/???analysis of chemical composition and their attributing sources of rainwater in Bandung, Indonesia.

International Journal of GEOMATE, Month, Year, Vol (Issue), pp. 000-000
Geotec., Const. Mat. & Env., ISSN:2186-2990, Japan, DOI: https://doi.org/10.21660/YourID

CHEMICAL COMPOSITION AND SOURCES ATTRIBUTION OF RAINWATER IN BANDUNG AREA INDONESIA

Nia Yuniarti Hasan[1], *Driejana[2], Aminudin Sulaeman[3] and Herto Dwi Ariesyady[4],

[1]Environmental Engineering Doctoral Program, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, [2,4]Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, and [3]Faculty of Mathematics and Natural Science, Institut Teknologi Bandung, Indonesia,

*Corresponding Author, Received: 00 00. 2019, Revised: 00 00. 2019, Accepted: 00 00. 2019

ABSTRACT : Chemical composition and sources attribution of rainwater in Bandung area, Indonesia was conducted at 4 (four) locations during February to September 2016. The pH of the rainwater ranged from 4.74 to 6.20 (average of 5.45) with Precipitation Weighted Mean (PWM) pH of 4.80 to 4.91. The acidic ions of SO_4^{2-} and NO_3^- were significantly correlated (r = 0.870), so were Ca^{2+} and Mg^{2+} (r = 0.929) indicating similar sources. Principal component analysis applied to the studied variables extracted three main components accounted for 80.25% of the total variance of the pooled data. Sea-salt SO_4^{2-}, ss-Cl^-, Na^+, ss-K^+, nss-Ca^{2+}, ss-K^+ , nss-K^+ and NH_4^+ showing a high influence of natural sources related to the contribution of sea salts and crustal sources, suggesting the influence of long-range atmospheric transport and anthropogenic activities (human and animal wastes, and biomass burning); the second group consist of SO_4^{2-}, NO_3^-, H^+ and nss-Mg^{2+} likely from vehicular emissions and fossil fuels combustion and the third group contained nss-Cl^+ presumably from other acid reaction. It is concluded that rainwater quality in Bandung is influenced by air pollution from man-made activities.

Four or five keywords (First characters of each key are in capital/ uppercase letters), Italic

Keywords: acid rain, wet deposition, PCA, rainwater chemistry

1. INTRODUCTION

Chemical composition of rainwater was studied in many urban area worldwide e.g. for evaluating the impact of air pollution. Source analysis and contribution from both anthropogenic and natural sources to rainwater contamination are important in the context of air quality management [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18].

The pH of rainwater could be used as an indicator of atmospheric pollutant because normally pH of rainwater is 5.6, as the value that is expected on the equilibrium of pure water and atmospheric CO_2 [19]. Acidity variability occurs because of atmospheric chemistry processes involving various sources of air pollutants that are being absorbed and washout by rain droplets.

were influenced by

Alkaline pH in rainwater in Pune region India mainly originated from the abundance of Ca^{2+} caused by vehicle driven roadside dust [2]. While acidic rainwater in Shihwa Basin Korea were influence the dominant ions of SO_4^{2-} and NH_4^+ and neutralized by NH_4^+ and Ca^{2+} [17].

Elevation differences and local anthropogenic activities might account for the variation in the chemical composition of rainwater [13], causing e.g. monthly variations of rainwater chemistry in the Mountain region of Yulong in Southwestern China. Bandung area is located in mountainous region of West Java Indonesia at elevation of 768 meter above sea level. Bandung is the third most populous city in Indonesia after Jakarta and Surabaya. It is the capital of the West Java Province located about 140 km from Jakarta as national capital. Its urban activities and various accesses from different cities potentially affect the air quality and hence rainwater to some extended.

Bandung area has a tropical wet and dry climate with average ranges temperature of 18.1 to 31.9°C during 2015 and rainfall average of 184.75 mm with the ranges 0.3 mm/month (in July during the dry season) to 322.4 mm/month (in November in the wet season).

Due the its characteristics, rainwater quality in Bandung area is suggested to be influenced by air pollution. The purposes of the study is to characterize the chemical composition of rainwater. Samples were collected during rainy event in February to September 2016 and analyzed for sources attribution.

2. METODOLOGY

2.1 Sampling Area

Rainwater samples were collected at four locations, representing different elevation and landuse within Bandung area as are shown in Figure 1 as follow :

1) Lembang (06°49'35,01"S 107°37'04,54"E) with altitude about 1.272 m asl lies on the hillside of the mountain area. The site is located approximately 12 km away from the centre of

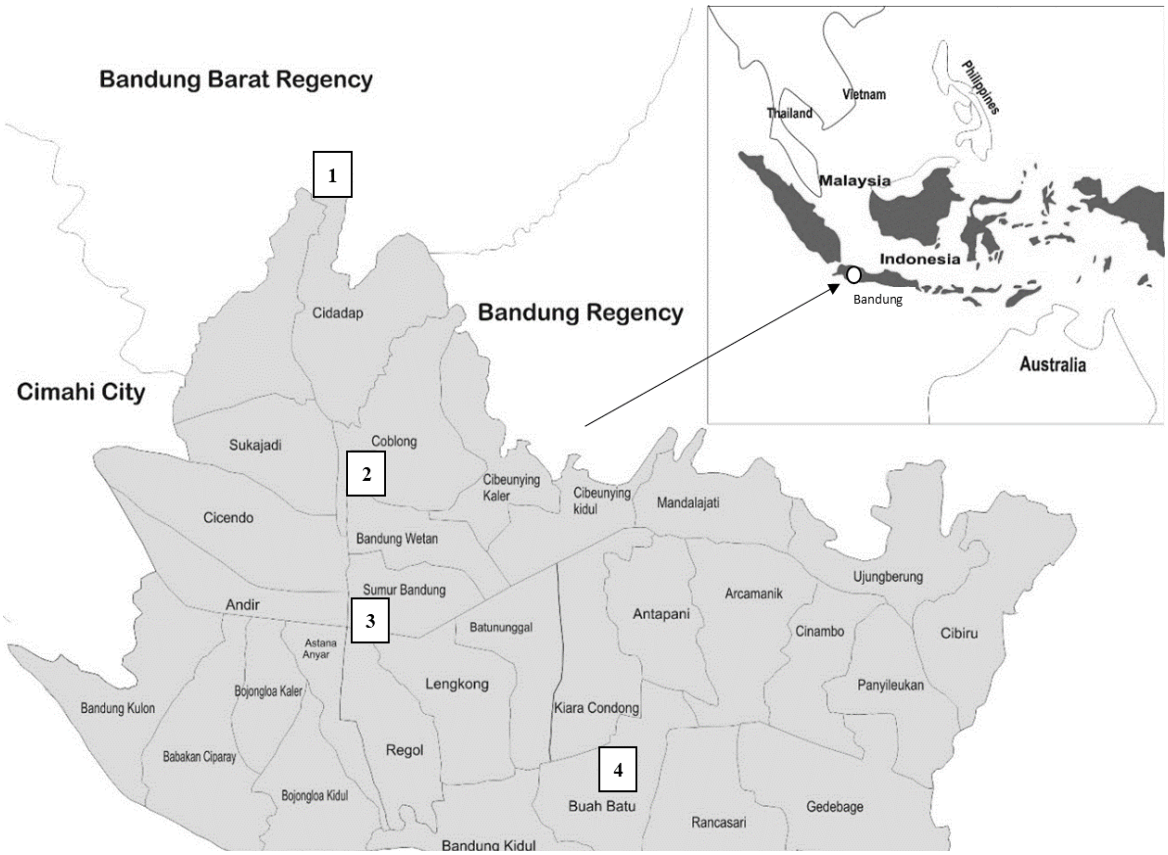


Fig. 1. Sampling Site

Bandung City, with landuse dominated by agricultural, livestock and tourism activity.

2) Coblong (06^{0}55'11,07"S 107^{o}36'04,54"E) with altitude about 803 m asl. It is an urban area with high traffic activity .
3) Sumur Bandung (06^{o}55'11,07"S 107^{o}36'39,34"E) with altitude about 742 m asl. It is the center of major urban activity such as offices complex, trading and traffic area.
4) Buah Batu (06^{o}53'26,69"S 107^{o}36'43,73"U) with altitude about 642 m asl is a sampling site in urban settlement area with high population density and their associated activities.

2.2 Sample Collection and Analysis

Rainwater samples were taken on a weekly basis from February to September 2016. The rainwater samples was collected using a polyethylene bottle (1.000 mL) with a polyethylene funnel (12 mm in diameter) equipped with a 1 mm filter plug and was put inside a stainless steel cylinder. The sampler bottles, funnels and filters sampler were cleaned and rinsed with deionized water before use. Rainwater samples was then transferred to 100 mL PE bottle for ions analysis.

The pH values and conductivity for the rainwater samples were analyzed with a pH meter (Sartorius Professional Meter PP-20) and a conductivity meter (Agilent Technologies 3200 C). Major ions in rainwater of sulphate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), pottasium (K^+) and ammonium (NH_4^+) were determined using Ion Chromatography (DIONEX ICS 500 DP).

Statistical characteristics of rainfall, pH, conductivity and Precipitation Weighted Mean (PWM) of ion concentration were analyzed. Spatial variation between sampling site was analyzed using *One-way* ANOVA. Sources attribution was analyzed using correlation and Principal Component Analysis (PCA).

2.1 Quality Control

The quality control of the samples was checked by ionic balance defined as : Ion Percent Difference = $[(C - A) / (C + A)] \times 100$, where C and A represents anion and cation equivalents ($\mu eq\ L^{-1}$), respectively [20].

Precipitation weighted mean (PWM) was carried out by summing the product of ion concentration and the precipitation amount, obtained from rainwater sampler, for each data pair and dividing the result by the sum of precipitation amount for a certain period [21].

3. RESULT AND DISCUSSION

3.1 Rainfall Amount, pH and Conductivity of Rainwater

Rainfall amount at 4 (four) sampling sites ware largely varied, ranging between 40.69 – 347.66 mm/month. High rainfall events during 2016 suggested as due La Nina impact in this year (Fig.2), with the highest events recorded in March, April and May.

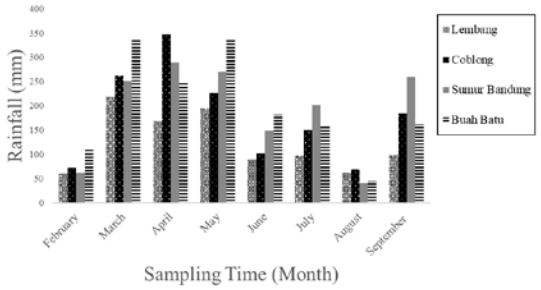


Fig.2 Rainfall Distribution at Four Sampling Site

The pH of the rainwater ranged from 4.74 to 6.20 (average 5.45), lower than the pH of typical natural rainwater (5.6), indicating influence of acidic substances in the rainwater [19].

Buah Batu showed tendency of having more acidic rainfall compared to other sites, particularly Lembang site which is located in rural area at the highest altitude. This is contrary to the acidic orographic enhancement found in the Northeren England [23], suggesting local urban emission sources might have larger influence in the chemistry of rainfall.

Nearly sixty percent of acid precipitation pH were between 5.0 to < 5.6, while 42% had pH < 5.0 (which would have significant effects on environmental acidification). Within this 42%, 11% were strongly acidic with pH < 4.5 (Fig. 3).

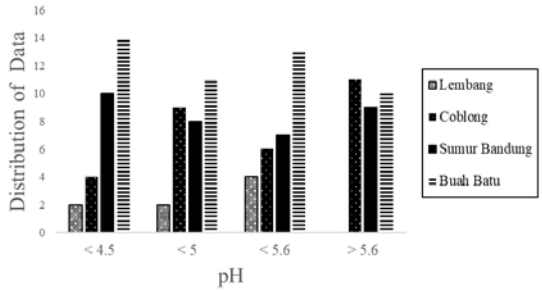


Fig.3 Rainwater pH Distribution

The major precursors of acidity in rainwater were SO_2 and NO_x as found in sources attribution analysis. Soil particles and sea spray origin species might play an important role in neutralizing SO_2 and NO_x.

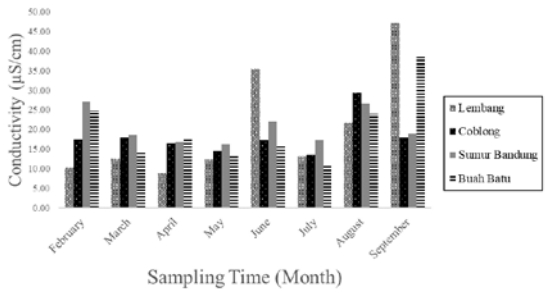
Rainwater conductivity is mainly contributed by water-soluble ions, the value being related to the total sum of anions and cations. The range of electric conductivity for rainwater was from < 0.5 to 100 µS/cm (Fig. 4). There is no clear pattern whether conductivity was related to the rainwater amount as the temporal variation of conductivity did not resemble the pattern of rainfall amount in Fig. 1.

Fig.4 Temporal Variation of Conductivity (µS/cm)

3.2 Temporal Variation of Precipitation Weighted Mean (PWM) Concentration

Precipitation Weighted Mean (PWM) concentrations was calculated to eliminated the dilution effect of rainwater quantity during high rainfall. Temporal variation of PWM concentration of major ions that reflect the variation due to acid chemistry processes in rainwater were shown in Figure 5.

The SO_4^{2-} and NO_3^- PWM concentrations showed irregular pattern where their high PWM



concentration were detected in low and high rainfall, might be due to the strength of acid precursor emissions from local and regional sources. Ammonium (NH_4^+) PWM concentration and Cl^-, Na^+, Ca^{2+}, Mg^{2+} and K^+ ions showed the increasing trend with decreasing rainfall amount suggesting the dilution of these ions that originated from natural sources.

The strong temporal variation showed by anion SO_4^{2-} and cation NH_4^+ presumably caused by the neutralization reaction in rainout and washout deposition processes.

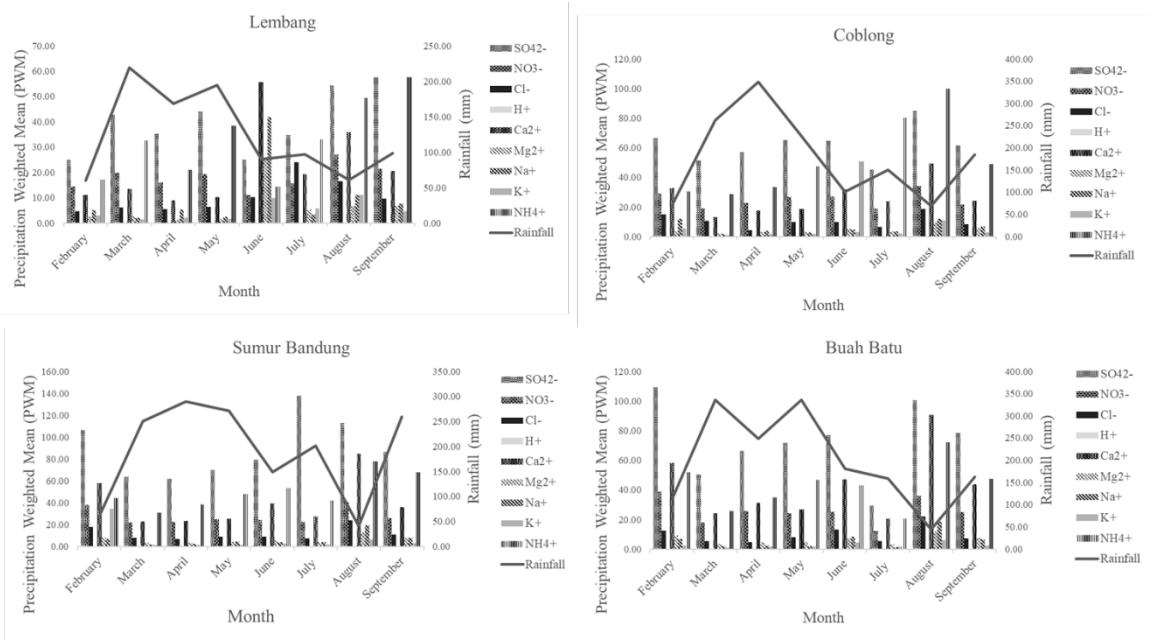


Fig.5 Temporal Variation of Precipitation Weight Mean (PWM) Concentration Ions

3.3 Neutralizing Factors

Neutralizing factor (NF) were used to evaluate the neutralization of major ions by crustal components (Ca^{2+} and Mg^{2+}) and NH_4^+. The neutralization of acids by base cations were evaluated by calculating the neutralization factors using the formula: NF (x) = $((X^+) /(SO_4^{2-} + NO_3^-)$ where X is the Ca^{2+}, Mg^{2+} and NH_4^+.

The NF observed for Ca^{2+}, Mg^{2+} and NH_4^+ were 0.31, 0.09, 0.56 (Lembang); 0.26, 0.05, 0.56 (Coblong); 0.32, 0.05, 0.49 (Sumur Bandung) and 0.38, 0.06, 0.43 (Buah Batu). The NF shows NH_4^+ was dominant neutralizing ion in Bandung area.

3.4 Sea salt and Non-Sea Salt Contribution

PWM concentration of sea-salt and non-sea salt contribution were described in Figure 6. Non-Sea salt SO_4^{2-} and non-sea salt Ca^{2+} were the dominant ions for all sampling site.

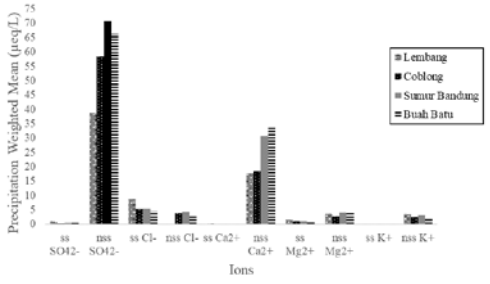


Fig.6 PWM Concentration Sea Salt and Non-Sea Salt Contribution

Non-sea salt sulfate was the highest anion PWM concentration in Bandung area for more than ten years monitoring by EANET (Acid Deposition Monitoring Network in East Asia). The trend of SO_2 emission 2000 – 2014 in Indonesia increased by 50% (+ 0.12 ppb $year^{-1}$ [23]. The observation at the in this study was in line EANET finding.

3.5 Sources Attribution Analysis

Statistical analysis were done using log-normal transformed data because the raw data of rainwater amount and ions concentration had positive skewweness distribution.

3.5.1 One-Way ANOVA

One-way analysis of variance (ANOVA) was used to analyzed spatial variability of the ions in rainwater chemistry as is shown in Table 1.

The F-test statistic was applied to test the null hypothesis that there is no variance of ions concentration and rainfall amount between different sampling site ($\alpha = 0.05$).

It was found that concentration of ions nss-SO_4^{2-}, NO_3^{2-}, nss-Cl^-, nss-Ca^{2+}, nss-Mg^{2+} and NH_4^+ were significantly different between the 4 (four) sampling sites indicating small-scale spatial variability.

Table 1 ANOVA of Ion Concentration in Rainfall and Rainfall Amount

	F	Sig.
Rainfall (mm)	1.289	0.281
$ssSO_4^{2-}$	0.252	0.860
$nssSO_4^{2-}$	**11.353**	**0.000**
NO_3^-	**3.258**	**0.024**
$ssCl^-$	0.076	0.973
$nssCl^-$	1.104	0.351
H^+	0.479	0.698
Na^+	0.252	0.859
$ssCa^{2+}$	0.252	0.860
$nssCa^{2+}$	**7.991**	**0.000**
$ssMg^{2+}$	0.088	0.967
$nssMg^{2+}$	**2.931**	**0.037**
ssK^+	0.253	0.859
$nssK^+$	0.517	0.671
NH_4^+	**2.932**	**0.037**

3.5.2 Ion Correlation

Correlation between ions is used to determine the sources of different anions and cations in the rainwater and their potential linkages. Ions concentration in rainwater was affected by rainfall amount and that might cause a multicollinearity problem. Partial correlation analysis of the strength and direction of a linear relationship between ions whilst controlling for rainwater amount were calculated and presented in Table 2.

The acidic ions of non-sea salt SO_4^{2-} and NO_3^- that significantly correlated (r = 0.901) might indicated similar sources. Natural rainwater becomes more acidic because sulfuric and nitric acids are formed from acidic gases of SO_2 and NO_3 from anthropogenic activities.

Significant correlation between SO_4^{2-} and NH_4^+ (r = 0.431) also NO_3^- and NH_4^+(r = 0.481) explained that ammonium compound in the atmosphere generally occurs as $(NH_4)_2SO_4$ and NH_4NO_3 [19].

On the other hand, significant correlation between Ca^{2+} and Mg^{2+} (r = 0.801) showed their occurrence from crustal origin.

3.5.3 Principal Component Analysis (PCA)

Principal components analysis (PCA) was used to identify and associate possible sources attribution of the species in rainwater chemistry .

As a cut off, factors with an eigenvalue >1 were retained. PCA explained 82.291% of the data variance. Factors are extracted to be interpretated as a common source for the components in the same factor.

Factor 1 explained about 60.75 % of the total variance, with strong positive loadings for sea salt SO_4^{2-}, sea salt Cl^-, sea salt Ca^{2+}, sea salt Mg^{2+}, Na^+, sea salt K^+, and non-sea salt K^+ showing a high influence of natural sources (sea and soil)

Table 2. Partial Correlation Coefficients Major Ions in Rainwater

	$nssSO_4^{2-}$	NO_3^-	$ssCl^-$	$nssCl^-$	H^+	Na^{2+}	$ssCa^{2+}$	$nssCa^{2+}$	$ssMg^{2+}$	$nssMg^{2+}$	ssK^+	$nssK^+$	NH_4^+
$ssSO_4^{2-}$	.563	.530	1.000	-.197	.109	1.000	1.000	.619	1.000	.449	1.000	.617	.430
	.000	.000	.000	.055	.291	.000	.000	.000	.000	.000	.000	.000	.000
$nssSO_4^{2-}$		.901	.563	.079	.178	.563	.563	.780	.563	.611	.562	.389	.431
		.000	.000	.446	.084	.000	.000	.000	.000	.000	.000	.000	.000
NO_3^-			.530	.009	.226	.530	.530	.627	.530	.438	.530	.366	.481
			.000	.929	.027	.000	.000	.000	.000	.000	.000	.000	.000
$ssCl^-$				-.198	.109	1.000	1.000	.619	1.000	.449	1.000	.616	.430
				.053	.290	.000	.000	.000	.000	.000	.000	.000	.000
$nssCl^-$					-.009	-.197	-.196	.048	-.197	.124	-.197	.107	-.095
					.930	.055	.055	.646	.055	.227	.054	.300	.358
H^+						.109	.110	.062	.109	.041	.109	.075	-.154
						.291	.288	.549	.290	.691	.292	.470	.134
Na^{2+}							1.000	.619	1.000	.449	1.000	.617	.430
							.000	.000	.000	.000	.000	.000	.000
$ssCa^{2+}$								.619	1.000	.450	1.000	.617	.430
								.000	.000	.000	.000	.000	.000
$nssCa^{2+}$									.619	.801	.618	.440	.282
									.000	.000	.000	.000	.005
$ssMg^{2+}$										.449	1.000	.617	.430
										.000	.000	.000	.000
$nssMg^{2+}$											.449	.379	.292
											.000	.000	.004
ssK^+												.616	.430
												.000	.000
$nssK^+$													.204
													.046

contribution to Bandung area rainwater. Non-sea salt K^+ in rainwater probably comes from biomass burning [1]. NH_4^+ sources from human and animal wastes, also originated from manmade activities (possibly fertilizers, agriculture wastes and urban activities).

Table 3. Component Matrix of the Sources Attribution Analysis using Principal Component Analysis (PCA).

	Component		
	1	2	3
ss-SO_4^{2-}	**0.955**	0.272	0.015
nss-SO_4^{2-}	0.304	**0.900**	0.080
NO_3^-	0.355	**0.853**	-0.008
ss-Cl^-	**0.955**	0.272	0.015
nss-Cl^-	-0.179	0.151	**0.822**
H^+	-0.365	**0.402**	-0.518
Na^+	**0.955**	0.272	0.015
ss-Ca^{2+}	**0.955**	0.272	0.015
nss-Ca^{2+}	**0.639**	0.548	0.341
ss-Mg^{2+}	**0.955**	0.272	0.015
nss-Mg^{2+}	0.479	**0.522**	0.427
ss-K^+	**0.955**	0.271	0.14
nss-K^+	**0.760**	0.168	0.326
NH_4^+	**0.430**	0.376	-0.008
Total Variance (%)	**62.750**	**10.780**	**8.761**

Factor 2 explained about 10.78% of total variance, with strong positive loading for non-sea salt SO_4^{2-}, NO_3^-, H^+ and non-sea salt Mg^{2+} were indicating the anthropogenic sources from vehicular emission, most notably fosil fuels combustion. With hydrogen ion being in the same factor, also acidification as a result. In Bandung area there were ± 1.6 million units of motor vehicle in 2015 which very likely significantly increase emission of SO_2 and NO_3 [24].

Factor 3 explained about 8.76 % of total variance for non-sea Cl^- probably as a result of reaction of the acid HCl with alkaline compound (Ca^{2+}, Mg^{2+} and K^+).

4. CONCLUSION

A study of the chemical characteristics of rainwater in Bandung area, Indonesia was conducted in 2016. The rainwater was acidic with an average pH of 4.81 and average conductivity of 20.01 µS/cm. The major anion component was SO_4^{2-} (36.2% of the total anion mass), while NH_4^+ was the main cation component (47.7% of total cation mass). The temporal variation of anion SO_4^{2-} and cation NH_4^+ PWM concentration showed these two ions as the highest in almost every month at all sampling sites, compared to other ions. Ammonium (NH_4^+) was the dominant neutralizing ion in rainwater chemistry in Bandung area.

Sources attribution analysis demonstrated that rainwater in Bandung area were also affected by natural sources with the contribution of sea salts and crustal sources as well as biomass burning and local anthropogenic activities (vehicular emission, fosil fuels combustion, human and animal wastes and manmade activities (fertiliz[illegible] wastes). Further studies shou[illegible] determining the sources and control of air pollution and implication of the rainwater quality towards its potentials as one of the water resources in urban area.

AKNOWLEDGEMENTS

5. KNOWLEDGEMENTS

This paper is part of the work of Riset KK dan Inovasi ITB 2017 entitled "*Prediksi Dampak Kesehatan Lingkungan Deposisi Basah Logam Berat di Wilayah Perkotaan Bandung*" funded by Institut Teknologi Bandung.

6. REFERENCES

[1] Sillapapiromsuk S. and Chantara S. Chemical Composition and Seasonal Variation of Acid Deposition in Chiang Mai, Thailand. Journal Environmental Engineering Resources, Vol. 15 (2), 2010, pp. 093-098

[2] Budhavant K.B., Rao P.S.P., Safai P.D., and Ali, K. Chemistry of Monsoon and Post-Monsoon Rains at a High Altitude Location, Sinhagad, India. Journal Aerosol and Air Quality Research, Vol. 9(1), 2009, pp. 65 –79.

[3] Wang H., and Han G. Chemical composition of rainwater and anthropogenic influences in Chengdu, Southwest China. Journal Atmospheric Research, Vol. 99, 2011, pp. 190-196.

[4] Salve P.R., Gobre T., Lohkare H., Krupadam R.J., Bansiwal A., Ramteke D.S., and Wate S.R. Source identification and variation in the chemical composition of rainwater at coastal and industrial areas of India. Journal Atmosppheric Chemistry, Vol. 68, 2011, pp. 183-198.

[5] Tiwari S., Chate D.M., Bisht D.S., Srivastava M.K., and Padmanabhamurty B. Rainwater chemistry in the North Western Himalayan Region, India. Journal Atmospheric Research

Vol. 104-105, 2012, pp. 128–138.

[6] Zhang X., Jiang H., Zhang Q., and Zhang X. Chemical characteristics of rainwater in northeast China, a case study of Dalian. Atmospheric Research, Vol.116, 2012, pp.151-160.

[7] Cerón R.M., Cerón J.G., Carballo C.G., Aguilar C.A., Montalvo C., Benítez J.A., Y. J. Villareal Y.J. and Gómez M.M. Chemical Composition, Fluxes and Seasonal Variation of Acid Deposition in Carmen Island, Campeche, Mexico. Journal of Environmental Protection, Vol. 4, 2013, pp. 50-56.

[8] Shrestha S., Pandey V.P., Yoneyama Y., Shrestha S. and Kazama F. An evaluation of rainwater quality in Kathmandu Valley, Nepal. Journal Sustainable Environment Resources, Vol. 23 (5), 2013, pp. 341-350.

[9] Zhao M., Li L., Liu Z., Chen B., Huang J., Cai J., and Deng S. Chemical Composition and Sources of Rainwater Collected at a Semi-Rural Site in Ya'an, Southwestern China. Atmospheric and Climate Sciences, Vol. 3, 2013, pp. 486-496.

[10] Gioda A., Olga L., Bracero M., Scatena F.N., Kathleen C., Weathers,Mateus V.L, and McDowell W.H. Chemical constituents in clouds and rainwater in the Puerto Rican rainforest : Potential sources and seasonal drivers. Journal Atmospheric Environment, Vol. 68, 2013, 208-220.

[11] Cerqqueira, F.R.F., Pinto M.F., Derossi, I.N., Esteves W.T., Santos M.D.R.S., and Matos R.C., Chemical characteristics of rainwater at a southeastern site of Brazil. Atmospheric Pollution Research, Vol. 5, 2014, pp. 253-261.

[12] Cui J., Zhou J., Peng Y., He Y., Yang H., and Mao J, Zhang M., Wang Y. and Wang S. Atmospheric wet deposition of nitrogen and sulfur in the agro ecosystem in developing and developed areas of Southeastern China. Atmospheric Environment, Vol. 89, 2014, pp. 102-108.

[13] Niu H., He Y., Luc X.X, Shen J., Du J., Zhang T., Pu T., Xin H., and Chang L. Chemical composition of rainwater in the Yulong Snow Mountain region, Southwestern China. Journal Atmospheric Research, Vo. 144, 2014, pp. 195-206.

[14] Pasha G.S.M., Shivashankara G.P., and Tiwari S. Chemical Composition and Ionic Variability of Wet and Bulk Precipitation in Urban Environment of Karnataka State, India, International Journal Current Research and Academic Review, Vol. 2(5), 2014, pp. 66 – 84.

[15] Rai P. Wet Deposition of Gaseous Pollutan in Dhanbad India for Rain Water Quality. International Journal of Current Engineering and Technology, Vol. 4(2), 2014, pp. 673-679.

[16] Zhang N., Cao J., He Y., and Xiao S. Chemical composition of rainwater at Lijiang on the Southeast Tibetan Plateau: influences from various air mass sources. Journal Atmospheric Chemistry, Vo. 51, 2014, pp.157-174.

[17] Park S.M., Seo B.K., Lee G., Kahng S.H., and Jang Y.W. Chemical composition of water soluble inorganic species in precipitation at Shinwa Basin, Korea, Journal Atmosphere, Vol. 6, 2015, pp. 732 – 75.

[18] Tiwari S., Hopke P.K., Thimmaiah D., Dumka U.C., Srivastava A.K., Bisht D.S., Rao P.S.P., Chate D.M., Srivastava M.K., Tripathi S.N. Nature and Sources of Ionic Species in Precipitation across the Indo-Gangetic Plains, India. Journal Aerosol and Air Quality Research, Vol. 16, 2016, pp. 943–957.

[19] Seinfeld, John, H., dan Pandis, S.N. Atmospheric Chemistry and Physics from Air Pollution to Climate Change, Second Edition, John Wiley and Son, Inc., New York. 2006.

[20] Acid Deposition Monitoring Network (EANET), Techical Manual for Wet Deposition Monitoring in East Asia, Network Center for EANET, 2015.

[21] Driejana, Raper, D.W., and Gee, I.L. Spatial Variation and Sources Attribution of the Chemical Composition in Acid Deposition in the Peak District, Northeren England. Prociding of The 95th Air & Waste Management Association Annual Conference & Exhibition, Salt Lake City, UT., 2000.

[22] Driejana, Lee, D. S., Kingdon R. D., Raper, D. W. and Gee, I.L. (2001) : Modelling acid deposition in the UK at a scale of 5km by 5km, Water, Air and Soil Pollution 130, 319 – 324

[23] Acid Deposition Monitoring Network (EANET). Third Periodic Report on the state of acid deposition in East Asia. Part I regional assessment, 2016.

[24] BPS-Statistic of Bandung Municipality, 2016.

[25] Cheng, Y., Liu, Y., Huo, M., Sun, Q., Wang, H., Chen, Z., and Bai. Chemical characteristics of precipitation at Nanping Mangdang Mountain in eastern China during

spring. Journal of Environmental Sciences, Vol. 23(8), 2011, pp. 1350-1358.

[26] Duan L., Yu Q., Zhang Q., Wang Z., Pan Y., Larssen T., Tang J. and Mulder J. Acid deposition in Asia: Emissions, deposition, and ecosystem effects. Journal Atmospheric Environment, Vol. 146, 2016, pp. 55-69.

[27] World Meteorogy Organization, Manual For The GAW Precipitation Chemistry Programme Guilines, Data Quality Objectives and Standard Operating Procedures, GAW Precipitation Chemistry Science Advisory Group, 2004 Amanded 2015.

[28] Giannoni S.M., Rollenbeck R., Trachte K., and Bendix J. Natural or anthropogenic? On the origin of atmospheric sulfate deposition in the Andes of southeastern Ecuador. Journal Atmospheric Chemistry and Physics, Vol. 14, 2014, pp. 11297–11312.

[29] Ianniello A., Spataro F., Esposito G., Allegrini I., Hu M., and Zhu T. Chemical characteristics of inorganic ammonium salts in $PM_{2.5}$ in the atmosphere of Beijing (China). Journal Atmospheric Chemistry and Physic, Vol. 11, 2011, pp. 10803–10822.

[30] Xu Z., Wu Y., Liu W.J., Liang C.H., Ji, J., Zhao T., and Zhang X. Chemical composition of rainwater and the acid neutralizing effect at Beijing and Chizhou City. Atmospheric Research, Vol. 164-165, 2015, pp. 278-285.

[31] Vet R., Artz R.S., Carou S., Shaw M., Ro C.U., Aas W., A., Baker, Bowersox V.C., Dentener F., Lacaux C.G., Hou A., Pienaar J.J., Gillett R., Forti C.M ., Gromov S., Hara H., Khodzherm T., Mahowald N.M., Nickovic S., Rao P.S.P., and Reid N.W. A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Journal Atmospheric Environment, Vo. 93, 2014, pp. 3-100.

[32] Xiao H.W., Xiao H.Y., Long A.M., Wang Y.L., and Liu C.Q. Chemical composition and source apportionment of rainwater at Guiyang, SW China. Journal Atmospheric Chemistry, Vol. 70, 2013, pp. 269-281.

[33] Zhao, M., Li, L., Chen, B., Huang, J., Cai, J., and Deng, S. Chemical composition and sources of rainwater collected at a semi-rural site in Ya'an, Southwestern China, Journal Atmospheric and Climate Sciences, Vol. 3, 013, pp. 486 – 496.

Please try to adjust the blank space by two columns.

Response by Authors to Reviewer's Remarks/Comments

Chemical Composition and Sources Attribution of Rainwater in Bandung Area Indonesia

Authors: Yuniarti Hasan, Driejana, Aminudin Sulaeman, and Herto Dwi Ariesyady

The authors have summarized their replies to the Reviewers' comments in this response letter in a two column format. A revised manuscript is submitted addressing all the comments to the Journal of GEOMATE for possible publication.

	Reviewer_A's Comments	***Authors Response***
	Rewrite the Abstract to reflect : Brief Introduction, Brief Justification, Brief Methodology, Brief Result (s) and Brief Conclusion	The authors appreciate the comment from the reviewer A : the abstract has been revised in manuscript
	Reviewer_B's Comments	***Authors Response***
	Please check the attachment to improve the manuscript	The authors appreciate the reviewer B : the sentences has been revised in the manuscript
	Reviewer_C's Comments	***Authors Response***
	The authors have very poor command on english language. This paper need to be completely re-written	The authors appreciate the reviewer C : the manuscript has been revised
	Test results should be compared with some standard or other sources.	The result revised as the reviewer's comment
	The results should be validated.	The results have been validated using Ion Balance (IB)
	Paper Title and the analysis do not march - abstract and conclusions are not clear.	The abstract has revised in manuscript
	Revise abstract and conclusion	The abstract and conclusion have been revised in manuscript
	Itemize conclusion in simple english.	The conclusion revised as the reviewer's comment

The authors appreciate the valuable comments from the Reviewers.

Gmail Nia Yuniarti Hasan <niayhasan@gmail.com>

Fwd: Galley Proof for Issue 64--

Geomate Editor <editor@geomate.org> Thu, Aug 15, 2019 at 6:44 PM
To: driejana@tl.itb.ac.id, niayhasan@gmail.com, aminudin.sulaeman@gmail.com, herto@ftsl.itb.ac.id

Dear Authors,

Attached herewith, please see the galley proof paper for final checking. Please note that this is the final correction and after this checking, you will not be able to change anything later on. As many grammatical errors found, we have done the following corrections:

1. Grammar corrected by Zakaria
2. Formatting correction is done by Zakaria
3. Figures and space including the title of figures and sections corrected by Zakaria
4. Please upload the galley proof file (both WORD and PDF) even no correction

Please do not change the format if any correction. We accept minor correction only (no major corrections). If any correction is needed, please do it on WORD file and then convert it to PDF file. Please send PDF version (Publishable Format including all journal information such as page numbers, vol, and issue number, date of received, revised and accepted etc.) of your galley proof paper by 4 days from the date of this email using the following link.

http://www.geomatejournal.com/galley

We accept online submission only. Please make sure that your copyright must be signed by all authors (samples attached).

Best regards.

Prof. Dr. Zakaria Hossain
Editor-in-Chief
International Journal of GEOMATE

3 attachments

sample-signed by all authors.pdf
668K

131-138-87856-Nia-Dec-2019-64.docx
614K

131-138-87856-Nia-Dec-2019-64.pdf
406K

International Journal of GEOMATE

A Scientific International Journal on Geotechnique, Construction Materials and Environment

PUBLISHING AGREEMENT

Dear Sir,

I am required to obtain copyright of papers from authors for the term of copyright and I would be grateful if you would confirm your acceptance by signing and returning the agreement below. I will not withhold permission for any reasonable request from you to publish any part of this paper in connection with any other work by you, provided the usual acknowledgments are given regarding copyright notice and reference to the original publication.

If it is appropriate, the author's employer may sign this agreement and, in any event, the employer may reserve the right to use the paper internally or for promotional purposes only by indicating to this agreement.

The author warrants that the manuscript is the author's original work and has not been published before (if excerpts from copyrighted works are included, the author will obtain written permission from the copyright owners and show credit to the sources in the manuscript). The author also warrants that the article contains no libelous or unlawful statements and does not infringe on the rights of others.

If the work was prepared jointly the author agrees to inform co-authors of the terms of the agreement and to sign on their behalf.

Editors-in-Chief

---

1. Authors' Confirmation (Please answer the followings)

- Q1. Have you filled in the gap in all pages (no blank space at all)? Answer (Yes):
- Q2. Are the references inside text according to the template? Answer (Yes):
- Q3. Are all the figures drawn according to the template? Answer (Yes):
- Q4. Are all figures with the same font size 10 and symbol etc? (Yes or No)? Answer (Yes):
- Q5. Does the paper length at least 6 to 8 pages or more? Answer (Yes):
- Q6. Are the legends and values of figures 10 font size? Answer (Yes):
- Q7. Does the list of references according to the template? Answer (Yes):
- Q8. Does the copyright signed by all authors? Answer (Yes):
- Q9. Are all equations clear and font size 10? Answer (Yes):
- Q10. Does your paper contain at least 10 recent references? Answer (Yes):
- Q11. Have you proofread English grammar by a native? Answer (Yes):
- Q12. Do you know the following free version of grammar correction? Answer (Yes):
  https://www.grammarly.com/office-addin/windows
- Q13. Does your paper contain at least 4 tables and/or figures? Answer (Yes):
- Q14. Have you understood guidelines given on web page? Answer (Yes):

2. Authors' Biography (Please write all authors' full name and biodata here)

a) Nia Yuniarti Hasan is a doctoral student in the Environmental Engineering Doctoral Program in of the Faculty of Civil and Engineering Institut Teknologi Bandung. Her research interest in air quality. Her contact email is niayhasan@gmail.com.

b) Driejana is an Associate Professor in the Faculty of Civil and Environmental Engineering Institut Teknologi Bandung. She obtained her Ph.D from the Manchester Metropolitan University, Manchester, UK. Her research interests include air quality and environmental health. Her contact e-mail is driejana@tl.itb.ac.id.

c) Aminudin Suleman is an Assistant Professor of the Faculty of Mathematics and Natural Sciences. He obtained his Ph.D from Intitut Teknologi Bandung. His research interest include analytical chemistry. His contact e-mail is aminudin.sulaeman@gmail.com

d) Herto Dwi Ariesyady is an Associate Professor of Civil and Environmental Engineering. He hold Ph.D degree in Urban Environmental Engineering at Hokkaido University Japan. His research interest include environmental management technology. His contact email is herto@ftsl.itb.ac.id.

3. Authors' Contributions (Please write all authors' contribution here)

Please state the contribution made by each author in the preparation, development, and publication of this manuscript.

a) **Nia Yuniarti Hasan**: conception, design, acquisition, analysis, and interpretation of data and drafting the article.

b) **Driejana**: general concept, some result interpretation, and refining the article.

c) **Aminudin Sulaeman**: critical reviewing and final approval of the version to be submitted.

d) **Herto Dwi Ariesyady**: critical reviewing and final approval of the version to be submitted.

4. Ethics (Please provide ethical issues that may arise after the publication of your paper)

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

Name of the Journal:

International Journal of GEOMATE

A Scientific International Journal on Geotechnique, Construction Materials and Environment

I hereby assign the copyright to my paper entitled,

Chemical Composition and Sources Attribution of Rainwater in Bandung Area Indonesia

+note -
if the paper is rejected, this assignment is null and void

Name of author:

1. Nia Yuniarti Hasan 2. Driejana 3. Aminudin Sulaeman 4. Herto Dwi Ariesyady

Signature: 1. 2. 3.

Date: 16 Agustus 2019

Please send this form duly filled and signed together with your manuscript to:

Dr. Zakaria Hossain, Editor-in-Chief
Professor, Division of Environmental Science and Technology
Graduate School of Bioresources, Mie University
1577 Kurima Machiya-cho
Tsu-city, Mie 514-8507, Japan
E-mail: zakaria@bio.mie-u.ac.jp
Tel: +81-59-231-9578
Fax: +81-59-231-9578

Zimbra **driejana@tl.itb.ac.id**

Re: Fwd: Publication Fee Payment

From : Zakaria <zakaria@bio.mie-u.ac.jp> Wed, Aug 14, 2019 11:11 AM
Subject : Re: Fwd: Publication Fee Payment
To : driejana@tl.itb.ac.id

Noted with thanks.

Best Regards.

Zakaria

On Wed, Aug 14, 2019 at 1:08 PM <driejana@tl.itb.ac.id> wrote:

> Dear Prof. Hossain,
>
> The publication fee has been sent by western union as attached.
>
> Best regards,
> Driejana
>
> ---------- Forwarded message ---------
> From: **Nia Yuniarti Hasan**<niayhasan@gmail.com>
> Date: Mon, Aug 12, 2019 at 12:08 PM
> Subject: Publication Fee Payment
> To: <zakaria@bio.mie-u.ac.jp>
>
> Dear Mr. Zakaria Hossain,
>
> We sent our publication fees payment for paper ID 87856 Dr Drejana. Chemical Composition and Sources Attribution of Rainwater in Bandung Area, Indonesia.
>
> Thank You
> Nia Yuniarti Hasan

International Journal of GEOMATE, Dec., 2019 Vol.17, Issue 64, pp. 131 - 138
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.64.87856
Geotechnique, Construction Materials and Environment

CHEMICAL COMPOSITION AND SOURCES ATTRIBUTION OF RAINWATER IN BANDUNG AREA, INDONESIA

Nia Yuniarti Hasan[1], *Driejana[2], Aminudin Sulaeman[3], and Herto Dwi Ariesyady[4]

[1]Environmental Engineering Doctoral Program, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, [2,4]Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia, and [3]Faculty of Mathematics and Natural Science, Institut Teknologi Bandung, Indonesia,

*Corresponding Author, Received: 20 May 2019, Revised: 13 Aug. 2019, Accepted: 28 Aug. 2019

ABSTRACT: Data of international and national monitoring stations have showed evidences of rainwater acidification in Indonesia. This research aimed to investigate the small-scale variations and the influence of urban activities to rainwater chemical composition in Bandung, Indonesia, as well as to determine the contributing sources to its chemical variation. Rainwater bulk samples had been collected weekly at 4 (four) locations representing differences in altitude and local land use, from February to September 2016. Samples were analyzed for pH, conductivity, and major ions (SO_4^{2-}, NO_3^-, Cl^-, Na^+, Ca^{2+}, Mg^{2+}, K^+, and NH_4^+). The results showed that the pH of rainwater were in the range of acidic to normal (average 5.42 ± 0.72), where ammonium acted as the major neutralizing factor (NF). Small-scale spatial variability of nss-SO_4^{2-}, NO_3^{2-}, nss-Cl^-, nss-Ca^{2+}, nss-Mg^{2+}, and NH_4^+ within 4 (four) locations were observed. Sulphate and NO_3^- as well as Ca^{2+} and Mg^{2+} were significantly correlated, with r = 0.870 and r = 0.929, respectively. Principal Component Analysis (PCA) indicated three main sources of rainwater chemistry. Firstly, a mix of natural sources (e.g., sea-salt aerosols, crustal elements and waste decomposition) which consisted of sea-salt SO_4^{2-}, ss-Cl^-, Na^+, ss-Ca^{2+}, nss-Ca^{2+}, ss-K^+, nss-K^+ and NH_4^+. Secondly, fossil fuel combustion/vehicular emissions, which consisted of nss-SO_4^{2-}, NO_3^-, H^+, and nss-Mg^{2+}; and thirdly, nss-Cl^+ presumably from other acid reaction. These three components accounted for 80.25% of the total variance. The results suggested that local and long-range transported emissions of natural and anthropogenic sources contributed to the rainwater chemistry in the Bandung area.

Keywords: Acid Rain, Wet Deposition, PCA, Rainwater Chemistry

1. INTRODUCTION

Chemical compositions of rainwater have been studied in many urban areas worldwide, such as to evaluate the impact of air pollution. Source analysis and contribution of anthropogenic and natural sources to rainwater contamination are important in the context of air quality management [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18].

The pH of rainwater could be used as an indicator of atmospheric pollution because in normal conditions, based on the value in the equilibrium of pure water and atmospheric CO_2, pH of rainwater is 5.6[19]. Acidity variability occurs due to atmospheric chemistry processes involving air pollutants absorbed from various sources and being wash out by rain droplets. For examples, the alkaline pH in rainwater in the Pune Region of India mainly caused by the abundance of Ca^{2+} originated from vehicle driven roadside dust [2]. Acidic rainwater in Shihwa Basin Korea was influenced by the dominant ions of SO_4^{2-} and NO_3^- which were neutralized by NH_4^+ and Ca^{2+} [17].

Elevation differences and local anthropogenic activities might account for the variation in the rainwater chemical composition [13], causing, e.g. monthly variations of rainwater chemistry in the Yulong Mountain Region in Southwestern China.

Bandung area is located in a mountainous region of West Java Indonesia where the lowest level is at an elevation of 768 meters above sea level (asl). Bandung is the third most populous city in Indonesia after Jakarta and Surabaya. It is the capital of the West Java Province, located about 140 km from Jakarta as the national capital. Its urban activities potentially affect its air quality, and hence rainwater, to some extent. Bandung has a tropical, wet, and dry climate with average temperature ranges from 18.1°C to 31.9°C during 2015 and an average rainfall of 184.75 mm with the ranges of 0.3 mm/month (in July during the dry season) to 322.4 mm/month (in November in the wet season).

Due to its characteristics, rainwater quality in the Bandung area might be influenced by air pollution. This paper explores rainwater characteristics in Bandung and identifies the likely sources that determine its chemical composition. Samples were collected during the rainy events from February to September 2016.

2. METHODOLOGY

2.1 Sampling Area

Rainwater samples were collected at 4 (four) locations, representing different elevation and land use within the Bandung area, as shown in Figure 1 as follow :

1) Lembang (06º49’35,01”S 107º37'04,54"E) with an altitude of approximately 1.272 m asl lies on the hillside of the mountain area. The site is located approximately 12 km away from the center of Bandung City, with the land use predominantly being agricultural, livestock, and tourism activity.
2) Coblong (06º55’11,07”S 107º36’04,54” E) with an altitude of approximately 803 m asl. It is an urban area with high traffic activity.
3) Sumur Bandung (06º55’11,07”S 107º36’39,34”E) with an altitude of approximately 742 m asl. It is the center of major urban activity such as offices complex, trading, and traffic area.
4) Buah Batu (06º53’26,69”S 107º36’43,73”U) with an altitude of approximately 642 m asl is a sampling site in urban settlement area with high population density and their associated activities.

Fig. 1. Sampling Site

2.2 Samples Collection and Analysis

Rainwater samples were taken on a weekly basis from February to September 2016. The rainwater samples were collected using a polyethylene bottle (1.000 mL). Rainwater passed through a polyethylene funnel (12 mm in diameter) equipped with a 1 mm filter plug that was put inside a stainless steel cylinder. The sampler bottles, funnels and filters were cleaned and rinsed with deionized water before each use. Rainwater samples were then transferred to 100 mL PE bottles for ion analysis.

The pH values and conductivity for the rainwater samples were analyzed with a pH meter (Sartorius Professional Meter PP-20), and a conductivity meter (Agilent Technologies 3200 C). Major ions in rainwater of sulphate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), and ammonium (NH_4^+) were determined using Ion Chromatography (DIONEX ICS 500 DP).

Statistical characteristics of rainfall, pH, conductivity, and Precipitation-Weighted Mean (PWM) of ion concentration were analyzed. The spatial variation between the sampling sites was analyzed using One-way ANOVA. Source attribution was analyzed using correlation and Principal Component Analysis (PCA).

2.1 Quality Control of Samples Analysis

The quality control of the samples was checked by Ion Balance (IB) defined as Ion Percent Difference (IPD), as IPD = [(C − A) / (C + A)] × 100, where, C and A represents anion and cation equivalents (μeq L^{-1}), respectively [20]. Precipitation weighted mean (PWM) was carried out by calculating the sum of the product of ion concentration and the precipitation amount, obtained from rainwater sample, for each data pair, and dividing the result by the sum of precipitation amount for a certain period [21].

3. RESULT AND DISCUSSION

3.1 Rainfall Amount, pH and Conductivity of Rainwater

Rainfall amount at 4 (four) sampling sites was largely varied, ranging between 40.69 – 347.66 mm/month. High rainfall events during 2016 were suggested to be impacted by the La Nina event (Fig.2), with the highest events recorded in March, April, and May.

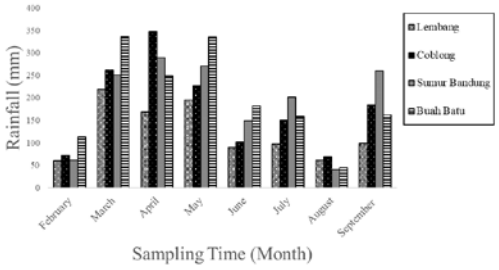


Fig.2 Rainfall Distribution at Four Sampling Sites

The pH of the rainwater ranged from 4.74 to 6.20 (average 5.45), lower than the pH of typical natural rainwater (5.6), indicating the influence of acidic substances in the rainwater [19].

Rainwater from Buah Batu showed a tendency of more acidic compared to other sites, particularly the Lembang site which is located in the rural area at the highest altitude. This condition is contrary to the acidic orographic enhancement found in Northern England [23], suggesting local urban emission sources might have a more significant influence in the chemistry of rainfall.

Nearly 60% of acid precipitation pH was between 5.0 to less than 5.6, while 42% had pH less than 5.0 (which would have significant effects on environmental acidification). Within this 42%, 11% were strongly acidic with pH < 4.5 (Fig. 3).

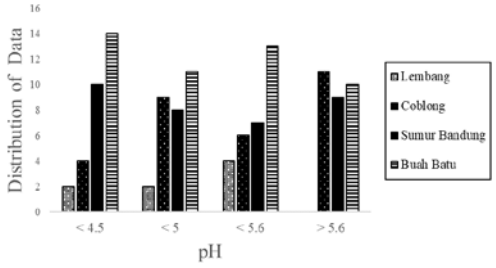


Fig.3 Rainwater pH Distribution

The major precursors of acidity in rainwater were SO_2 and NO_x as were found in the sources attribution analysis (See Section 3.5). Soil particles and sea spray origin species might play an essential role in neutralizing SO_2 and NO_x.

The abundance of acid precursors is seen in the rainwater conductivity, the value being related to the total sum of anions and cations. Rainwater conductivity is mainly contributed by water-soluble ions. The rainwater electric conductivity ranged from <0.5 to 100 µS/cm (Fig. 4). There is no clear pattern as to whether conductivity was related to the rainwater amount, as the temporal variation of conductivity did not resemble the pattern of rainfall amount as seen in Fig. 2.

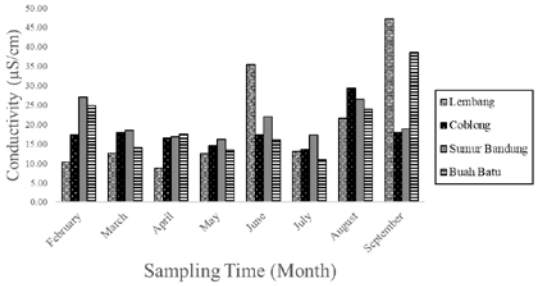


Fig.4 Temporal Variation of Conductivity (µS/cm)

3.2 Temporal Variation of Precipitation-Weighted Mean (PWM) Concentration

Precipitation-Weighted Mean (PWM) concentrations were calculated to eliminate the dillution effect of rainwater quantity during high rainfall. The temporal variations of PWM concentration of major ions that reflected the variation due to acid chemistry processes in rainwater are shown in Figure 5.

While rainfall monthly variation showed clear pattern of seasonal influence of lowest amount during June – August at all sites, SO_4^{2-} and NO_3^- PWM concentrations showed irregular patterns. Particularly for SO_4^{2-} and NO_3^-, the PWM concentrations were detected during low and high rainfall, suggesting that rainfall was not the sole factor affecting the concentration. Instead, the variation might be due to the strength of acid precursor emissions from local and regional sources. On the other hand, increasing ammonium (NH_4^+) as well as Cl^-, Na^+, Ca^{2+}, Mg^{2+}, and K^+ ions showed in the PWM concentration on lower rainfall suggested the dilution effect of these natural-origin ions. In addition, the strong temporal variation of anion SO_4^{2-} and cation NH_4^+ were presumably caused by the neutralization reaction in the rainout and washout deposition processes.

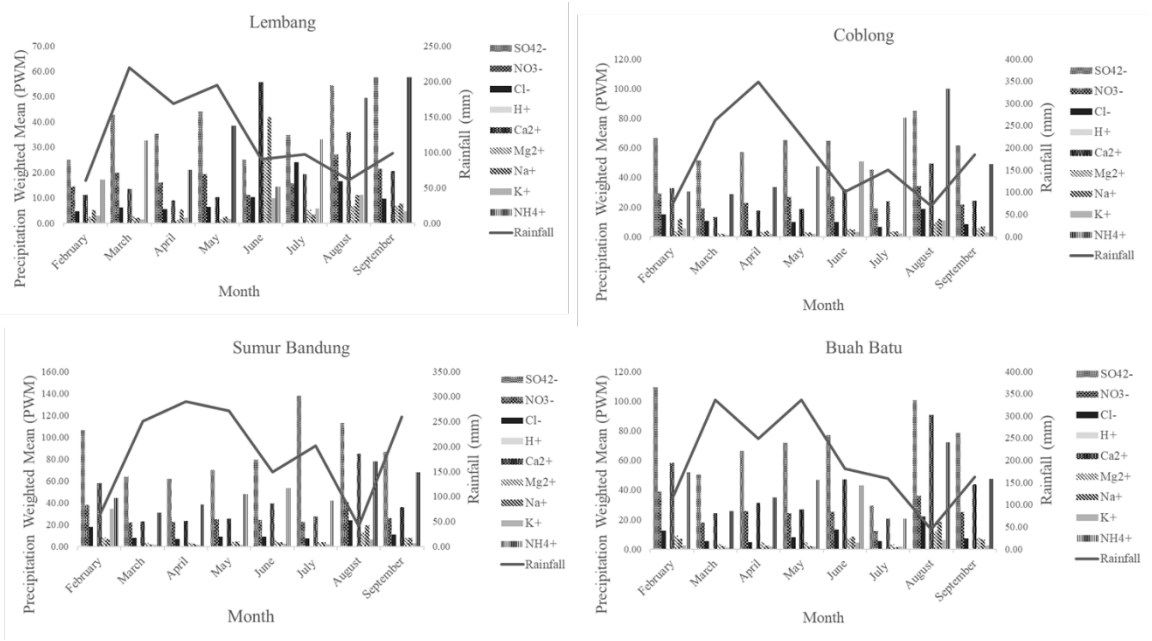


Fig.5 Temporal Variation of Precipitation Weight Mean (PWM) Concentration Ions

3.3 Neutralizing Factors

Neutralizing factor (NF) was used to evaluate the neutralization of major anions by crustal components (Ca^{2+} and Mg^{2+}) and NH_4^+. The neutralization of acids by base cations were evaluated by calculating the neutralization factors using the formula: NF (x) = $((X^+) /(SO_4^{2-} + NO_3^-)$ where X is the Ca^{2+}, Mg^{2+} and NH_4^+.

The NF observed for Ca^{2+}, Mg^{2+} and NH_4^+ were 0.31, 0.09, 0.56 (Lembang); 0.26, 0.05, 0.56 (Coblong); 0.32, 0.05, 0.49 (Sumur Bandung) and 0.38, 0.06, 0.43 (Buah Batu). Hence, NF showed that NH_4^+ was the dominant neutralizing ion in the Bandung area.

This result was similar to what was found in Chiang May Thailand [1], Dalian China [6], Ya'an, Southwestern China [9], and Nanpin Mangdang Mountain China [25].

3.4 Sea salt and Non-Sea Salt Contribution

PWM concentration of sea salt (ss) and non-sea salt (nss) contributions were described in Figure 6. Data used for analyzing ss-ions and nss-ions were the long-term monitoring by EANET (Acid Deposition Monitoring Network in East Asia). Non-sea salt SO_4^{2-} and nss-Ca^{2+} were the dominant ions for all sampling sites. Non-sea salt sulfate was the highest anion PWM concentration in the Bandung area for more than ten years of EANET monitoring. The trend of SO_2 emission during the 2000 – 2014 period in Indonesia increased by 50% (+ 0.12 ppb $year^{-1}$) [23]. The observation found in this study was in line with the EANET finding.

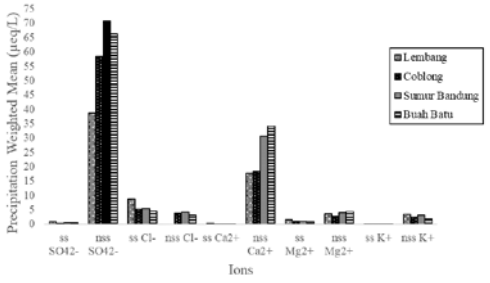


Fig.6 PWM Concentration of Sea Salt and Non-Sea Salt Contribution

3.5 Sources Attribution Analysis

3.5.1 One-Way ANOVA

One-way analysis of variance (ANOVA) was used to analyze the spatial variability of the ions in rainwater chemistry, as shown in Table 1. Statistical analysis was applied to log-normal transformed data because the raw data of rainwater amount and ion concentrations had positive skewness distribution.

The F-test statistic was applied to test the null hypothesis; that there is no variance of ions concentration and rainfall amount between different sampling sites ($\alpha = 0.05$).

It was found that the concentration of nss-SO_4^{2-}, NO_3^{2-}, nss-Ca^{2+}, nss-Mg^{2+}, and NH_4^+ ions were significantly different between the 4 (four) sampling sites indicating small-scale spatial

variability.

Table 1 ANOVA of Ion Concentration in Rainfall and Rainfall Amount

	F	Sig.
Rainfall (mm)	1.289	0.281
ss-SO_4^{2-}	0.252	0.860
nss-SO_4^{2-}	**11.353**	**0.000**
NO_3^-	**3.258**	**0.024**
ss-Cl^-	0.076	0.973
nss-Cl^-	1.104	0.351
H^+	0.479	0.698
Na^+	0.252	0.859
ss-Ca^{2+}	0.252	0.860
nss-Ca^{2+}	**7.991**	**0.000**
ss-Mg^{2+}	0.088	0.967
nss-Mg^{2+}	**2.931**	**0.037**
ss-K^+	0.253	0.859
nss-K^+	0.517	0.671
NH_4^+	**2.932**	**0.037**

3.5.2 Ion Correlation

Correlation between ions was used to determine the different sources of anions and cations in the rainwater and their potential linkages. Ions concentration in rainwater was affected by rainfall amount, possibly causing a multicollinearity problem. Partial correlation analysis of the strength and direction of a linear relationship between ions whilst controlling for rainwater amount were calculated and presented in Table 2.

The acidic ions of non-sea salt SO_4^{2-} and NO_3^- that significantly correlated (r = 0.901) possibly indicate similar sources. Natural rainwater becomes more acidic from the sulfuric and nitric acids that are formed by acidic gases of SO_2 and NO_3 from anthropogenic activities.

Significant correlation between SO_4^{2-} and NH_4^+ (r = 0.431) also NO_3^- and NH_4^+(r = 0.481) indicated that ammonium exists in the atmosphere as $(NH_4)_2SO_4$ and NH_4NO_3 [19]. On the other hand, a significant correlation between Ca^{2+} and Mg^{2+} (r = 0.801) showed their occurrence from the crustal origin.

3.5.3 Principal Component Analysis (PCA)

Principal components analysis (PCA) was used to identify and associate potential sources attribution of the species in rainwater chemistry. PCA was applied to explore data relationships and source types for rainwater composition in many studies [1, 2, 5, 9, 10, 11, 13, 16, 18]. As a cut-off, factors with an eigenvalue >1 were retained. Factors are extracted to be interpreted as a common source for the components in the same factor. In this study, PCA explained 82.291% of the data variance.

Table 2. Partial Correlation Coefficients of Major Ions in Rainwater

	nssSO_4^{2-}	NO_3^-	ssCl^-	nssCl^-	H^+	Na^{2+}	ssCa^{2+}	nssCa^{2+}	ssMg^{2+}	nssMg^{2+}	ssK^+	nssK^+	NH_4^+
ssSO_4^{2-}	.563	.530	1.000	-.197	.109	1.000	1.000	.619	1.000	.449	1.000	.617	.430
	.000	.000	.000	.055	.291	.000	.000	.000	.000	.000	.000	.000	.000
nssSO_4^{2-}		.901	.563	.079	.178	.563	.563	.780	.563	.611	.562	.389	.431
		.000	.000	.446	.084	.000	.000	.000	.000	.000	.000	.000	.000
NO_3^-			.530	.009	.226	.530	.530	.627	.530	.438	.530	.366	.481
			.000	.929	.027	.000	.000	.000	.000	.000	.000	.000	.000
ssCl^-				-.198	.109	1.000	1.000	.619	1.000	.449	1.000	.616	.430
				.053	.290	.000	.000	.000	.000	.000	.000	.000	.000
nssCl^-					-.009	-.197	-.196	.048	-.197	.124	-.197	.107	-.095
					.930	.055	.055	.646	.055	.227	.054	.300	.358
H^+						.109	.110	.062	.109	.041	.109	.075	-.154
						.291	.288	.549	.290	.691	.292	.470	.134
Na^{2+}							1.000	.619	1.000	.449	1.000	.617	.430
							.000	.000	.000	.000	.000	.000	.000
ssCa^{2+}								.619	1.000	.450	1.000	.617	.430
								.000	.000	.000	.000	.000	.000
nssCa^{2+}									.619	.801	.618	.440	.282
									.000	.000	.000	.000	.005
ssMg^{2+}										.449	1.000	.617	.430
										.000	.000	.000	.000
nssMg^{2+}											.449	.379	.292
											.000	.000	.004
ssK^+												.616	.430
												.000	.000
nssK^+													.204
													.046

Table 3. Component Matrix of the Sources Attribution Analysis using Principal Component Analysis (PCA).

	Component		
	1	2	3
ss-SO_4^{2-}	**0.955**	0.272	0.015
nss-SO_4^{2-}	0.304	**0.900**	0.080
NO_3^-	0.355	**0.853**	-0.008
ss-Cl^-	**0.955**	0.272	0.015
nss-Cl^-	-0.179	0.151	**0.822**
H^+	-0.365	**0.402**	-0.518
Na^+	**0.955**	0.272	0.015
ss-Ca^{2+}	**0.955**	0.272	0.015
nss-Ca^{2+}	**0.639**	0.548	0.341
ss-Mg^{2+}	**0.955**	0.272	0.015
nss-Mg^{2+}	**0.479**	**0.522**	0.427
ss-K^+	**0.955**	0.271	0.14
nss-K^+	**0.760**	0.168	0.326
NH_4^+	**0.430**	0.376	-0.008
Total Variance (%)	**62.750**	**10.780**	**8.761**

Factor 1 explained approximately 60.75 % of the total variance, with strong positive loadings for sea salt SO_4^{2-}, sea salt Cl^-, sea salt Ca^{2+}, sea salt and non-sea salt Mg^{2+}, Na^+, sea salt and non-sea salt K^+ indicating the natural source (sea and soil) contributions to rainwater. In addition, non-sea salt K^+ in rainwater presumably comes from biomass burning [1]. NH_4^+ sources might come from human and animal wastes and other human-made activities (possibly fertilizers, agriculture wastes, and urban activities).

Factor 2 explained approximately 10.78% of the total variance, with strong positive loading for non-sea salt SO_4^{2-}, NO_3^-, H^+, and non-sea salt Mg^{2+} suggesting anthropogenic sources from vehicular emission, most notably fossil fuels combustion. With hydrogen ion being in the same factor, this also points to acidification as a result. In Bandung, there were ± 1.6 million units of a motor vehicle registered in 2015, which likely contributed significantly to SO_2 and NO_3 emissions [24].

Factor 3 explained approximately 8.76 % of the total variance with non-sea salt Cl^- as the sole component, possibly as the result of the acid HCl with alkaline compound (Ca^{2+}, Mg^{2+}, and K^+).

4. CONCLUSIONS

The analysis of rainwater in Bandung in this study found that:

1. The pH of rainwater tends to be acidic with the values ranged between 3.4 to 7.71 (average 5.42 ± 0.72), with the average conductivity of 19.60 µS/cm.
2. The major anion component was SO_4^{2-} (36.2% of the total anion mass), while NH_4^+ was the main cation component (47.7% of total cation mass). The major components found that, SO_4^{2-} and NH_4^+ PWM concentrations were the highest at all sampling sites in almost every month, compared to other ions.
3. Ammonium (NH_4^+) was found to be the dominant neutralizing ion.
4. Small-scale spatial variability found for nss-SO_4^{2-}, NO_3^{2-}, nss-Cl^-, nss-Ca^{2+}, nss-Mg^{2+}, and NH_4^+, indicate the influence of local emission sources.
5. Principal Component Analysis (PCA) demonstrated that rainwater was also affected by natural sources of sea salts and crustal sources as well as biomass burning and local anthropogenic activities (vehicular emission, fossil fuels combustion, human and animal wastes and human made activities (fertilizers and agriculture wastes).

5. ACKNOWLEDGMENTS

This paper is part of the work of the Riset KK dan Inovasi ITB 2017 entitled "*Prediksi Dampak Kesehatan Lingkungan Deposisi Basah Logam Berat di Wilayah Perkotaan Bandung*" funded by Institut Teknologi Bandung.

6. REFERENCES

[1] Sillapapiromsuk S. and Chantara S. Chemical Composition and Seasonal Variation of Acid Deposition in Chiang Mai, Thailand. Journal Environmental Engineering Resources, Vol. 15 (2), 2010, pp. 093-098

[2] Budhavant K.B., Rao P.S.P., Safai P.D., and Ali, K. Chemistry of Monsoon and Post-Monsoon Rains at a High Altitude Location, Sinhagad, India. Journal Aerosol and Air Quality Research, Vol. 9(1), 2009, pp. 65 –79.

[3] Wang H., and Han G. Chemical composition of rainwater and anthropogenic influences in Chengdu, Southwest China. Journal Atmospheric Research, Vol. 99, 2011, pp. 190-196.

[4] Salve P.R., Gobre T., Lohkare H., Krupadam R.J., Bansiwal A., Ramteke D.S., and Wate S.R. Source identification and variation in the chemical composition of rainwater at coastal and industrial areas of India. Journal Atmospheric Chemistry, Vol. 68, 2011, pp. 183-198.

[5] Tiwari S., Chate D.M., Bisht D.S., Srivastava M.K., and Padmanabhamurty B. Rainwater chemistry in the North Western Himalayan Region, India. Journal Atmospheric Research Vol. 104-105, 2012, pp. 128–138.

[6] Zhang X., Jiang H., Zhang Q., and Zhang X. Chemical characteristics of rainwater in northeast China, a case study of Dalian. Atmospheric Research, Vol.116, 2012, pp.151-160.

[7] Cerón R.M., Cerón J.G., Carballo C.G., Aguilar C.A., Montalvo C., Benítez J.A., Y. J. Villareal Y.J. and Gómez M.M. Chemical Composition, Fluxes and Seasonal Variation of Acid Deposition in Carmen Island, Campeche, Mexico. Journal of Environmental Protection, Vol. 4, 2013, pp. 50-56.

[8] Shrestha S., Pandey V.P., Yoneyama Y., Shrestha S. and Kazama F. An evaluation of rainwater quality in Kathmandu Valley, Nepal. Journal Sustainable Environment Resources, Vol. 23 (5), 2013, pp. 341-350.

[9] Zhao M., Li L., Liu Z., Chen B., Huang J., Cai J., and Deng S. Chemical Composition and Sources of Rainwater Collected at a Semi-Rural Site in Ya'an, Southwestern China. Atmospheric and Climate Sciences, Vol. 3, 2013, pp. 486-496.

[10] Gioda A., Olga L., Bracero M., Scatena F.N., Kathleen C., Weathers, Mateus V.L, and McDowell W.H. Chemical constituents in clouds and rainwater in the Puerto Rican rainforest: Potential sources and seasonal drivers. Journal Atmospheric Environment, Vol. 68, 2013, 208-220.

[11] Cerqqueira, F.R.F., Pinto M.F., Derossi, I.N., Esteves W.T., Santos M.D.R.S., and Matos R.C., Chemical characteristics of rainwater at a southeastern site of Brazil. Atmospheric Pollution Research, Vol. 5, 2014, pp. 253-261.

[12] Cui J., Zhou J., Peng Y., He Y., Yang H., and Mao J, Zhang M., Wang Y. and Wang S. Atmospheric wet deposition of nitrogen and sulfur in the agroecosystem in developing and developed areas of Southeastern China. Atmospheric Environment, Vol. 89, 2014, pp. 102-108.

[13] Niu H., He Y., Luc X.X, Shen J., Du J., Zhang T., Pu T., Xin H., and Chang L. Chemical composition of rainwater in the Yulong Snow Mountain region, Southwestern China. Journal Atmospheric Research, Vo. 144, 2014, pp. 195-206.

[14] Pasha G.S.M., Shivashankara G.P., and Tiwari S. Chemical Composition and Ionic Variability of Wet and Bulk Precipitation in Urban Environment of Karnataka State, India, International Journal Current Research and Academic Review, Vol. 2(5), 2014, pp. 66 – 84.

[15] Rai P. Wet Deposition of Gaseous Pollutant in Dhanbad India for Rain Water Quality. International Journal of Current Engineering and Technology, Vol. 4(2), 2014, pp. 673-679.

[16] Zhang N., Cao J., He Y., and Xiao S. Chemical composition of rainwater at Lijiang on the Southeast Tibetan Plateau: influences from various air mass sources. Journal Atmospheric Chemistry, Vo. 51, 2014, pp.157-174.

[17] Park S.M., Seo B.K., Lee G., Kahng S.H., and Jang Y.W. Chemical composition of water-soluble inorganic species in precipitation at Shinwa Basin, Korea, Journal Atmosphere, Vol. 6, 2015, pp. 732 – 75.

[18] Tiwari S., Hopke P.K., Thimmaiah D., Dumka U.C., Srivastava A.K., Bisht D.S., Rao P.S.P., Chate D.M., Srivastava M.K., Tripathi S.N. Nature and Sources of Ionic Species in Precipitation across the Indo-Gangetic Plains, India. Journal Aerosol and Air Quality Research, Vol. 16, 2016, pp. 943–957.

[19] Seinfeld, John, H., dan Pandis, S.N. Atmospheric Chemistry and Physics from Air Pollution to Climate Change, Second Edition, John Wiley and Son, Inc., New York. 2006.

[20] Acid Deposition Monitoring Network (EANET), Technical Manual for Wet Deposition Monitoring in East Asia, Network Center for EANET, 2015.

[21] Driejana, Raper, D.W., and Gee, I.L. Spatial Variation and Sources Attribution of the Chemical Composition in Acid Deposition in the Peak District, Northern England. Proceedings of The 95th Air & Waste Management Association Annual Conference & Exhibition, Salt Lake City, UT., 2000.

[22] Driejana, Lee, D. S., Kingdon R. D., Raper, D. W. and Gee, I.L. (2001) : Modelling acid deposition in the UK at a scale of 5km by 5km, Water, Air and Soil Pollution 130, 319 – 324

[23] Acid Deposition Monitoring Network (EANET). Third Periodic Report on the state of acid deposition in East Asia. Part I regional assessment, 2016.

[24] BPS-Statistic of Bandung Municipality, 2016.

[25] Cheng, Y., Liu, Y., Huo, M., Sun, Q., Wang, H., Chen, Z., and Bai. Chemical characteristics of precipitation at Nanping Mangdang Mountain in eastern China during spring. Journal of Environmental Sciences, Vol. 23(8), 2011, pp. 1350-1358.

[26] Duan L., Yu Q., Zhang Q., Wang Z., Pan Y., Larssen T., Tang J. and Mulder J. Acid deposition in Asia: Emissions, deposition, and ecosystem effects. Journal Atmospheric Environment, Vol. 146, 2016, pp. 55-69.

[27] World Meteorology Organization, Manual For The GAW Precipitation Chemistry Programme Guidelines, Data Quality Objectives and Standard Operating Procedures, GAW Precipitation Chemistry Science Advisory Group, 2004 Amended 2015.

[28] Giannoni S.M., Rollenbeck R., Trachte K., and Bendix J. Natural or anthropogenic? On the origin of atmospheric sulfate deposition in the Andes of southeastern Ecuador. Journal Atmospheric Chemistry and Physics, Vol. 14, 2014, pp. 11297–11312.

[29] Ianniello A., Spataro F., Esposito G., Allegrini I., Hu M., and Zhu T. Chemical characteristics of inorganic ammonium salts in $PM_{2.5}$ in the atmosphere of Beijing (China). Journal Atmospheric Chemistry and Physic, Vol. 11, 2011, pp. 10803–10822.

[30] Xu Z., Wu Y., Liu W.J., Liang C.H., Ji, J., Zhao T., and Zhang X. Chemical composition of rainwater and the acid neutralizing effect at Beijing and Chizhou City. Atmospheric Research, Vol. 164-165, 2015, pp. 278-285.

[31] Vet R., Artz R.S., Carou S., Shaw M., Ro C.U., Aas W., A., Baker, Bowersox V.C., Dentener F., Lacaux C.G., Hou A., Pienaar J.J., Gillett R., Forti C.M ., Gromov S., Hara H., Khodzherm T., Mahowald N.M., Nickovic S., Rao P.S.P., and Reid N.W. A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Journal Atmospheric Environment, Vo. 93, 2014, pp. 3-100.

[32] Xiao H.W., Xiao H.Y., Long A.M., Wang Y.L., and Liu C.Q. Chemical composition and source apportionment of rainwater at Guiyang, SW China. Journal Atmospheric Chemistry, Vol. 70, 2013, pp. 269-281.