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Rainwater Chemistry and Biochemical Effects: Basis for Air Quality Assessment of Cagayan de Oro City, Philippines

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Abstract

This research attempted to characterize the air quality in the vicinity of what has been considered the densely polluted part of Cagayan de Oro City, Philippines - the Agora-Highway intersection—through the study of the rainwater chemistry and the rainwater biochemical effects. The parameters selected include the following: color, appearance, pH, conductivity, nitrate, suspended solids, chemical oxygen demand (COD), and pro-oxidant activity (in vitro). The bioassays used mongo and lettuce seeds for percent germination and root length. Ipomoea reptans (kangkong) was also used for effect on biomass loss and leaf length change. The same plant was then utilized for biochemical tests which included electrolyte leakage, lipid peroxidation, total phenolics, chlorophylls, and carotenoids. A control was run for each of the bioassays using distilled water (Wilkins Distilled Drinking Water).

In the whole, the results of the physico-chemical analyses showed that the rainwater during the period of the study was generally polluted only to a very minimal extent. The exception was the nitrate level which was somewhat high if considered for human consumption. Further, the bioassay and biochemical test results revealed that relative to the control, the rainwater did not acquire any general toxicity. While there are definitely limitations, on the basis of these data, the overall assessment is that the air during the period of this study was still quite safe from the harmful effects of pollutants.

Keywords: rainwater; rainwater chemistry; biochemical effects

1. Introduction

Because of the serious threat to human and ecological health, the Philippine Clean Air Act of 1999 (Republic Act 8749) has designated suspended particulate matter, sulfur dioxide, nitrogen oxide, carbon monoxide, and photochemical oxidants (such as ozone) as criteria pollutants. As such, there are National Ambient Air Quality Guideline Values for them. The Act has also established standards for other pollutants, namely, ammonia, carbon disulfide, chlorine/chlorine compounds, formaldehyde, hydrogen chloride, hydrogen sulfide, phenol, fluorine compounds, and various heavy metals (mercury, lead, cadmium, etc.). The standards are ambient source-specific and/or point-of-emission standards.

There are other substances for which there may be no specific standards such as those that belong to the class called hazardous air pollutants (HAPs) also known as toxic air pollutants (TAPs). About 200 substances are recognized as HAPs in the USA.

Rainwater has become increasingly dirty in the passage of time because of pollution. While it is initially a product of natural distillation, the formation of rainwater involves initially nucleation on aerosol particles. When the water is condensed, it interacts with various substances in the air dissolving some of them. As the rainwater falls, it collects more impurities. In effect, the first amounts of rainwater can be much polluted but the condition improves as the raining continues, i.e., the rainwater becomes cleaner. The entire process also cleans the air. Aerosols (ammonium, nitrate, and sulfate) get reduced by 30% to 73% after rainfall while the gases (ammonia, nitrogen dioxide, sulfur dioxide, and chlorine) can go down by 24% to 63% (Warburton, 2003).

The ability of rainwater to capture air pollutants makes it a good medium for studying the extent of pollution in a locality. Such a study was done in Singapore in 1997-1998 which showed, among others, that both formic acid and acetic acid are the major organic acids that contributed to the acidity of rainwater (Asian Aerosol Data Synthesis Project, 2003). A longer-term research based on rainwater was done in a semi-arid region of India wherein the chemistry of the rainwater was largely affected by the wind-carried dust and soil as indicated by the good correlation between calcium and nitrate ions, calcium and sulfate ions, and sulfate and nitrate ions (Kumar et al., 2002).

Since not everything that is deleterious to health, human or ecological, can be determined completely by way of chemical and physical testing and since there can be various forms of synergism arising from the complex make up of rainwater, it is a good complementary strategy to conduct bioassays. Bioassays make use of biological organisms to test for chemical toxicity. They provide an integrated picture of the overall danger to life forms of a sample of water. When a certain sample is toxic to some degree, it will affect some function or even the survival of the test organism. Measuring these effects can be related to the toxicity level of samples (Keddy *et al.,* 1995).

This study aimed to fill a knowledge gap by way of an indirect kind of study—determining the extent and trend of air pollution by studying the quality of the rainwater in Cagayan de Oro City. The city is a highly urbanized and rapidly growing commercial center in the Philippines. It is located on the north coast of Mindanao with an area close to 500 km^2 and with neighboring industrial sites to the east and west. With a population of over 600,000, it is the 10th most populous city of the Philippines. Along with this, vehicular traffic in the city has increased tremendously like never before.

In this study, monitoring was conducted for a relatively protracted period of time in order to see seasonal variations. Actual sampling took place from July, 2004 to March, 2005. This was done at the main campus of the Mindanao University of Science and Technology located adjacent to the Agora-Highway intersection which has been reported to be where air pollution is at its worst as far as the city is concerned.

The general objective of this study is to investigate the extent of air pollution in Cagayan de Oro City by studying the physical and chemical properties of the rainwater and testing its effects on living systems using suitable indicators. The specific objectives are to characterize the rainwater (1) in terms of selected physical properties, (2) in terms of some chosen chemical properties, and (3) by way of evaluating selected biological activities.

2. Methodology

2.1 Sampling

The water samples were collected using plastic basins mounted on high stools placed in the open field of the university campus when there were indications that rain would soon fall. Collection of a particular rainwater sample commenced upon the start of a rain. The water quantities collected in the different basins were mixed and homogenized thoroughly by stirring with a clean Teflon paddle then transferred to plastic narrow-mouth containers for analysis. On certain months (like in December, 2004 to February, 2005) no samples were collected because of the very infrequent rains or the insufficiency of rain volume. Actual sampling collection depended on rain occurrence.

2.2 Physico-Chemical Tests

The following parameters were included: color, appearance, pH, conductivity, nitrate, suspended solids, chemical oxygen demand (COD), and pro-oxidant activity (*in vitro*).

Color and appearance were simply assessed based on ocular inspection. The pH, conductivity, and nitrate were determined through the use of a pH meter (Cole-Parmer pH/mv/^{o}C meter), a conductivity meter (Hach SensIon 5), and a nitrate meter (Horiba ion meter), respectively. The suspended solids, on the other hand, were determined gravimetrically by filtration through a 47-mm glass fiber filter disc (Hach Company, 1989).

The COD was determined using a modified method designed by Sato et al. (2001). The method is intended for low levels of COD (0-30 ppm) and is based on the determination of absorbance at 350 nm. To determine the pro-oxidant activity of the water samples, an adoption of the antioxidant activity method modified from Osawa and Namiki was used (Anggadiredja *et al.*, 1997).

2.3 Bioassays and Biochemical Tests

The biochemical tests were carried out on the leaves of the upland kangkong (*Ipomoea reptans*) plantlets which were, on the average, 20 days old (+/- 5 days). These were grown inside the laboratory in a 50:50 mixture of seasoned coconut coir and composted coconut coir. The plantlets were harvested upon reaching the desired age and the roots were cleaned using tap water. Then the roots were cut to a length of about 4~5 cm and the excess water was removed using pieces of paper tissues (Kleenex). The prepared plantlets were distributed into 10 plastic cups wherein 5 cups would be for the test sample and another 5 for the control (Wilkins Distilled Drinking Water). Each cup had 15~20 plantlets.

For the biochemical testing, all parts of the test plants from that part where the first set of leaves emerged to the youngest leaves were separated and used. A strip of 1 cm leaf was taken from the youngest fully formed leaf of each of 5 plantlets in each cup for the determination of electrolyte leakage. The rest of the leaf materials from each cup were ground in a mortar and pestle in preparation for extraction and other biochemical testing. These biochemical tests were done according to accepted procedures (Hendry & Grime, 1993).

3. Results and Discussion

3.1 Physico-Chemical Test Results

The data obtained for color, appearance, pH, conductivity, nitrate, suspended solids, chemical oxygen demand (COD), and pro-oxidant activity are shown in the tables that follow. Some variations in the number of test trials for the different parameters were due to constraints in the rainwater sample volume available.

Table 1 summarizes the results for the color, appearance, and suspended solids contents of the rainwater samples. The results indicated that all the samples are generally clear and colorless. The suspended solids contents were rather variable but in the whole they were quite low so that they were not even visible by ocular inspection. These results are unlike what are usually observed with rain collected from the rooftops which are definitely heavily laden with dusts and other dirt that have accumulated on the rooftops.

Table 1. Color, appearance, and suspended solids of rainwater samples

Date	Color	Appearance	Suspended solids (ppm)
7/15/2004	colorless	clear	2
8/12/2004	colorless	clear	11
8/19/2004	colorless	clear	2
9/7/2004	colorless	clear	3
9/28/2004	colorless	clear	35
10/1/2004	colorless	clear	3
10/28/2004	colorless	clear	19
11/26/2004	colorless	clear	27
3/7/2005	colorless	clear	10
Average	colorless	clear	12

Table 2 presents the pH and conductivity of the rainwater samples both of which manifest the ionic characteristics of the water samples. On just the basis of pH, the rainwater in the area is normal—slightly acidic but none

Table 2. pH and conductivity of rainwater samples

Date	pH [mean (std dev/trials)]	Conductivity (micromho/cm) [mean (std dev/trials)]
7/15/2004	6.35 (0.07/2)	4.0 (0.0/2)
8/12/2004	6.55 (0.10/4)	56.0 (0.0/4)
8/19/2004	5.60 (0.26/4)	24.3 (1.3/4)
9/7/2004	6.60 (0.12/4)	21.8 (0.5/4)
9/28/2004	6.87 (0.05/4)	40.8 (1.7/4)
10/1/2004	6.48 (0.13/4)	8.8 (0.5/4)
10/28/2004	6.50 (0.14/4)	32.3 (1.5/4)
11/26/2004	5.64 (0.04/2)	30.5 (1.0/4)
3/7/2005	6.30 (0.08/4)	10.4 (0.7/4)
Average	6.32	25.4

below a pH of 5.6 which would be indicative of acid rain. There were just two occasions when the pH came close to 5.6 and these were during the months of August and November, 2004. The rest were above the pH of 6.

In terms of conductivity, the average during the period of the study was 25.4 micromho/cm. This, however, ranged from a low of 4.0 to a high of 56.0. They were relatively clean—free from a lot of dissolved ions. However, it can be said that the extent of the contamination of the rainwater with dissolved ions is somewhat variable. This could indicate the variable quantity and nature of the ionic pollutants in the air from time to time.

Table 3, shows the summary results for the nitrate, chemical oxygen demand (COD), and the pro-oxidant activity.

Table 3. Nitrate, COD, and pro-oxidant activity data of rainwater samples

Date	Nitrate (ppm) [mean (std dev/trials)]	COD (ppm) [mean (std dev/trials)]	Pro-oxidant Activity [mean (std dev/trials)]
7/15/2004	17.0 (1.4/4)	25.3 (2.4/3)	0.998 (0.028/5)
8/12/2004	38.5 (8.1/4)	36.0 (2.7/3)	1.049 (0.070/5)
8/19/2004	24.0 (4.6/4)	14.1 (3.3/3)	1.054 (0.020/5)*
9/7/2004	33.5 (3.7/4)	0.0 (3.0/3)	0.988 (0.038/5)
9/28/2004	26.0 (7.6/4)	48.9 (1.7/3)	1.001 (0.040/5)
10/1/2004	21.0 (3.6/4)	0.0 (1.6/3)	1.022 (0.033/5)
10/28/2004	21.8 (2.4/4)	31.9 (2.9/3)	1.009 (0.024/5)
11/26/2004	28.0 (2.0/4)	0.0 (5.0/3)	1.008 (0.040/5)
3/7/2005	25.2 (4.2/4)	0.0 (3.2/3)	1.005 (0.035/5)
Average	26.1	17.4	1.015

* Significant at alpha of 0.05

While the nitrates seemed to be near each other from sample to sample during the period with an overall average of 26.1 ppm, there are actually some statistically significant differences. The ANOVA did on the results showed an F value of 7.73 which is significant at an alpha of 0.05. No trend is manifested by the results. It is, however, still a major concern since it indicates substantial oxides of nitrogen in the air. In addition, it must be watched especially if rainwater is used for drinking or cooking. This is because the safe level of nitrate in water for human consumption is 10 ppm maximum.

On the other hand, the COD, averaging at 17.4 ppm during the entire study period, was more erratic ranging from 0.0 to almost 50.0 ppm. Like the nitrate level, no trend is manifested. The levels at almost zero ppm could have been the result of a cleansing of the air by an earlier rain which was not caught for sampling.

The pro-oxidant activity test results have been quite consistent at just about 1.00 indicating that there were no pollutants in the air carried by the rain that could be dangerous to living organisms. Individual one-sample t-test applied to each sample data against the hypothetical value of 1.000 yielded results not significant at alpha of 0.05. This is with the exception of the data for the August 19, 2004 sample. However, the magnitude of the difference from 1.000 is not of any practical significance. The whole information is comforting since living organisms possess tissues that are rather sensitive to oxidizing or pro-oxidizing species that can put them under stress. This in turn can lead to all sorts of aberrations or ailments.

3.2 Bioassay Results

The bioassays conducted involved the use of kangkong plantlets, mongo seeds, and lettuce seeds. Table 4 summarizes the germination and root length data for mongo seeds.

By means of the independent two-sample t-test, it is shown that the % germination in both sample and control may be considered equivalent in all the rainwater samples. On this basis, there is no evidence of toxicity in rainwater. As far as root length is concerned, all samples exhibited similar effects on root growth with the exception of the first and last samples during the period of the study. The one in July revealed that the rainwater was of better quality but the one in March, 2005 showed that the rainwater was

Table 4. Percent germination and root length of mongo seeds in sample and in control

Date	% Germination		Root Length (cm)	
	Sample	Control	Sample	Control
	[mean (std dev/trials)]		[mean (std dev/trials)]	
07-15-04	100 (0/5)	100 (0/5)	3.97 (1.08/10)	2.63 (0.88/10)*
08-12-04	100 (0/5)	98 (4.5/5)	4.45 (2.16/10)	5.80 (3.57/10)
08-19-04	100 (0/5)	98 (4.5/5)	6.34 (4.06/10)	5.80 (3.57/10)
09-07-04	100 (0/5)	100 (0/5)	5.47 (2.68/10)	5.94 (1.19/10)
09-28-04	100 (0/5)	98 (4.5/5)	6.99 (2.61/10)	6.80 (3.46/10)
10-01-04	100 (0/5)	98 (4.5/5)	9.41 (3.34/10)	6.80 (3.46/10)
10-28-04	98 (4.5/5)	100 (0/5)	5.29 (1.95/10)	7.21 (3.16/10)
11-26-04	100 (0/5)	100 (0/5)	7.62 (3.62/10)	6.10 (3.58/10)
03-07-05	100 (0/5)	100 (0/5)	5.13 (1.17/10)	9.69 (3.47/10)*
Average	99.8	99.1	6.07	6.31

*Significant at alpha of 0.05

inferior. This is indicative of some variability that greatly depends also on the variability of the air quality in the area. On the overall, however, it can be said that the rainwater in this part of Cagayan de Oro City had not acquired toxicity from air pollutants.

In Table 5, the results using lettuce seeds are presented. These are still in terms of % germination and root length.

Table 5. Percent germination and root length of lettuce seeds in sample and in control

Date	% Germination		Root Length (cm)	
	Sample	Control	Sample	Control
	[mean (std dev/trials)]		[mean (std dev/trials)]	
7/15/2004	98 (4.5/5)	94 (6.0/5)	1.88 (1.06/10)	1.81(0.59/10)
8/12/2004	72 (11.0/5)	82 (14.8/5)	1.19 (0.53/10)	1.45(0.70/10)
8/19/2004	86 (20.7/5)	82 (14.8/5)	2.08 (1.12/10)	1.45(0.70/10)
9/7/2004	76 (18.2/5)	80 (7.1/5)	1.66 (0.84/10)	1.84(0.93/10)
9/28/2004	80 (7.1/5)	94 (8.9/5)*	2.44 (1.34/10)	1.98(0.84/10)
10/1/2004	80 (7.1/5)	94 (8.9/5)*	1.76 (0.92/10)	1.98(0.84/10)
10/28/2004	98 (4.5/5)	90 (14.1/5)	1.48 (0.67/10)	1.65(0.91/10)
11/26/2004	88 (17.9/5)	92 (8.4/5)	1.99 (0.96/10)	1.30(0.61/10)
3/7/2005	84 (11.4/5)	96 (5.5/5)	1.72 (0.71/10)	2.29(1.40/10)
Average	99.8	99.1	6.07	6.31

*Significant at alpha of 0.05.

The above results using lettuce seeds convey something else compared to the mongo seed results. In the % germination, the September and October, 2004 results indicate the rainwater samples to be inferior in quality. The root length data, on the other hand, show they are comparable.

Taking the overall picture from the results for mongo seeds and lettuce seeds, it may be inferred that the rainwater, on the average, is not polluted. This indicates further that the air through which it passed is not laden with pollutants that have potential to cause harm.

Additional data were obtained based on the kangkong plantlets soaked in the rainwater samples and in the control which was Wilkins Distilled Drinking Water. These data are summarized in Table 6.

Table 6. Kangkong plantlets: loss in weight and leaf length after incubation with sample and with control

Date	Weight Loss (g)		Leaf Length Increase (cm)	
	Sample	Control	Sample	Control
	[mean (std dev/trials)]		[mean (std dev/trials)]	
7/15/2004	0.69(0.26/5)	1.04(0.13/5)*	no data	
8/12/2004	2.65(0.83/5)	2.43(0.50/5)	no data	
8/19/2004	0.26(0.31/5)	0.60(0.24/5)	-0.02(0.23/10)	0.01(0.10/10)
9/7/2004	0.36(0.13/5)	2.07(0.24/5)*	0.22(0.15/10)	0.19(0.19/10)
9/28/2004	0.18(0.17/5)	0.03(0.06/5)	0.34(0.22/10)	0.70(0.51/10)
10/1/2004	0.26(0.35/5)	0.09(0.08/5)	0.35(0.49/10)	0.36(0.28/10)
10/28/2004	0.29(0.04/5)	0.26(0.19/5)	0.28(0.24/10)	0.41(0.50/10)
11/26/2004	3.32(1.79/5)	2.07(0.90/5)	0.01(0.37/10)	0.06(0.18/10)
3/7/2005	0.05(0.09/5)	0.07(0.05/5)	0.27(0.19/10)	0.32(0.19/10)
Average	0.90	0.96	0.21	0.29

*Statistically significant at alpha of 0.05

The only comparison that came out significant among all the data in the table are the weight loss of the kangkong plantlets during the sampling on July 15 and September 7, 2004. The first one is consistent with the data on root length for mongo seeds while the second significant difference is something new—not detected earlier. But here again the rainwater sample is better than the control. In the end, the weight loss and root length tell the same story, namely, of rainwater devoid of toxicity and, subsequently, of air quality that was still quite acceptable in the overall.

So, at the macroscopic level, while there were isolated cases of differences between sample and control, the monitoring of bulk properties could not reveal what can be considered as consistent pattern of departure from quality. Or, it is possible that a general difference existed but the tests were not sensitive enough.

3.3 Biochemical Test Results

As part of the scheme to detect any toxicity that the rain might have brought down as it washed through layers of air in the part of Cagayan de Oro covered by this study, the following selected biochemical tests were applied: electrolyte leakage, lipid peroxidation, total phenolics, chlorophylls, and carotenoids. (For the last two, the ratio of chlorophylls to carotenoids was calculated). These were all employed on the kangkong plantlets that have been subjected to testing (48-hour incubation) with the sample and the control.

Electrolyte leakage and lipid peroxidation are quite related. The electrolyte leakage, also called the cell membrane stability test, can demonstrate any damage to the cell membrane. Any damage would lead to the leakage of cellular material into the distilled water increasing its conductivity. On the other hand, the lipid peroxidation indicates initial oxidative damage to the cell membranes. Oxidants can oxidize the multiple bonds in the hydrocarbon chains of the lipid bilayer. This is measured in terms of the production of malondialdehyde (MDA) upon testing.

Table 7 shows the averages for electrolyte leakage percentages and MDA contents (representing lipid peroxidation) for the sample and the control.

Looking at once at the overall averages, it appears that the rainwater samples were less damaging than the control considering the lower mean values. Examining the results of the individual samples and comparing sample to control, it can be seen that no consistent trend exists.

Under these tests, there is an isolated case of significant difference in terms of the lipid peroxidation in that sample showing higher level of peroxidation compared to the control. Unfortunately, this finding was not supported by the % electrolyte leakage. Excluding this lone result, it can be said that there is again no evidence that the rainwater quality had deteriorated at all due to any decline in air quality. The indication is that there was no substantial damage to the cell membranes which are mainly made up of lipids. The lipid material had not become oxidized and this is

Table 7. Kangkong plantlets: percent electrolyte leakage and MDA after incubation with sample and with control

Date	% Electrolyte Leakage		MDA (nmol/mg)	
	Sample	Control	Sample	Control
			(x 10^{-5})	
	[mean (std dev/trials)]		[mean (std dev/trials)]	
8/12/2004	11.57(3.58/5)	10.71(1.45/5)	11.1(3.14/5)	11.5(3.20/5)
8/19/2004	38.42(26.3/5)	40.45(20.3/5)	18.8(2.52/5)	18.7(3.69/5)
9/7/2004	15.94(2.01/5)	27.21(11.6/5)	9.03(1.17/5)	1.15(4.70/5)*
9/28/2004	17.37(5.44/5)	16.82(4.42/5)	no data	
10/1/2004	17.60(3.62/5)	27.23(19.9/5)	2.71(4.64/5)	6.72(7.07/5)
10/28/2004	25.49(10.4/5)	22.49(2.97/5)	5.94(5.80/5)	9.68(8.27/5)
11/26/2004	43.64(20.1/5)	58.99(22.7/5)	4.52(1.99/5)	4.64(2.86/5)
3/7/2005	no data		9.84(5.37/5)	13.8(7.79/5)
Average	22.73	27.18	8.85	9.46

*Statistically significant at alpha of 0.05

consistent with the results of the pro-oxidant activity evaluation under the physico-chemical tests.

Table 8 shows the summarized results of the last two (or three) biochemical tests used to evaluate the rainwater quality, namely, total phenolics and chlorophylls/carotenoids.

As shown, the total phenolics test detects significant differences between sample and control during the months of August, September, and November of 2004. Surprisingly, in two out of the three cases, the greater phenolics were observed in the control. This formation of phenolics is an indication of stress experienced by the plantlets. At any rate, these are favorable results for the rainwater. Looking at the chlorophylls-carotenoids ratios exhibiting statistically significant differences, these are also favorable to the rainwater samples.

To summarize, aside from the great majority of the comparisons which did not come out statistically significant, the few statistically significant ones are tabulated in Table 9 as to whether they were favorable to the rainwater or not.

It is clear above that the total favorable outweighs the total unfavorable to rainwater. Considering, too, that the overwhelming majority of the results indicate no difference from control, then, the rainwater in this part of the city is relatively very safe. As a consequence, the air hovering over the area is still not that dirty with pollutants to become a problem.

Table 8. Kangkong plantlets: total phenolics and chlorophyll-carotenoid ratio after incubation with sample and with control

Date	Total phenolics (ppm) Sample [mean (std dev/trials)]	Total phenolics (ppm) Control [mean (std dev/trials)]	Chlorophylls-carotenoids ratio Sample [mean (std dev/trials)]	Chlorophylls-carotenoids ratio Control [mean (std dev/trials)]
7/15/2004	54.68(4.29/5)	58.13(4.07/5)	3.85(0.12/5)	3.69(0.13/5)
8/12/2004	50.99(8.87/5)	50.31(5.62/5)	2.66(0.20/5)	2.61(0.20/5)
8/19/2004	16.53(2.68/5)	21.60(1.71/5)*	3.22(0.17/5)	3.11(0.44/5)
9/7/2004	14.50(1.36/5)	19.47(4.14/5)*	4.15(1.04/5)	2.77(0.33/5)*
9/28/2004	12.81(0.86/5)	12.92(0.60/5)	3.38(0.25/5)	3.40(0.21/5)
10/1/2004	13.23(0.76/5)	13.38(0.93/5)	3.93(0.22/5)	4.01(0.50/5)
10/28/2004	9.34(0.50/5)	9.76(1.02/5)	4.98(0.48/5)	3.63(0.29/5)*
11/26/2004	14.61(1.20/5)	10.42(1.59/5)*	2.68(0.31/5)	3.05(0.60/5)
3/7/2005	9.24(1.02/5)	10.35(1.46/5)	4.94(1.22/5)	4.54(0.25/5)
Average	21.77	22.93	3.75	3.42

* Statistically significant at alpha of 0.05

Table 9. Classification of statistically significant results in bioassay and biochemical tests

Test	Favorable to rainwater	Not favorable to rainwater
Root Length (mongo)	*	*
% Germination (lettuce)		**
Weight Loss (kangkong)	**	
Lipid Peroxidation		*
Total Phenolics	**	*
Chlorophylls-Carotenoids Ratio	**	
Total	7	5

4. Conclusion and Recommendation

As far as the physico-chemical parameters studied are concerned, in general, the rainwater is clean. The high level of nitrate is initially a concern but considering the dilution that comes about as the rain continues, it is likely that the nitrate drops to a much safer level.

The bioassay results and the biochemical tests which have all been made against control, in the overall, also indicate that the rainwater under study is devoid of potential harm. Extrapolating from this, the same can be more or less said of the air in the vicinity.

This study can be expanded to achieve a more thorough understanding of rainwater and air quality. In the future, a wider area can be covered for monitoring instead of just in the vicinity of the Agora-Highway intersection. Perhaps, more key areas in the city can be studied and the results correlated with other data like air quality monitoring that may be available in sufficient quantity later or with other factors like vehicular density.

It can also be widened to include a few more critical test parameters like sulfur dioxide and heavy metals which have not been included in this study due to limitations in instrumentation available to the researchers. Finally, some more sensitive bioassays can be employed, such as the Allium test, to further validate non-toxicity results. This Allium test can include not only root growth inhibition in terms of Effective Concentrations, e.g., EC_{50} and EC_{30}, but also an examination of chromosomal aberrations in the root tips. These more sensitive tests can most likely reveal subtle effects which in the long run can lead into more serious problems.

5. References

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