Effect of Wind Speed on the Measurement of Rainfall

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ABSTRACT

The purpose of this study was to investigate the effect of wind speed on the measurement of rainfall. The study site was set up at meteorological station of National Pingtung University of Science and Technology, in which a five-opening directional raingauge and a standard raingauge were installed. The differences between rainfall measurements of both raingauges were compared and analyzed to verify the accuracy of rainfall measurements. Results were summarized as follows: 1. The rainfall loss rate increases when the wind speed increases and/or rainfall intensity decreases. 2. The analysis of every 10 minutes records can advise the relation between rainfall intensity and wind speed during a typhoon. 3. When rainfall intensity was above 10 mm hr⁻¹, and average wind speed reached 2 m s⁻¹, the rainfall loss rate was about 4%. The rainfall loss rate was about 17%, when the average wind speed reached 10 m s⁻¹. 4. During the typhoon, the rainfall loss rate was about 19 % when the average wind speed reached 10 m s⁻¹. The rainfall loss rate was about 43 % when the average wind speed reached 18 m s⁻¹.

Keywords: Rainfall measurement, Five-opening directional raingauge, Standard raingauge, Wind speed, Rainfall loss rate.

INTRODUCTION

Taiwan is located in the subtropical zone, and more than 2/3 of the island is mountainous area. Most parts of the watershed in Taiwan lie in hillside area. Generally, the normal method of observing rainfall is utilizing the round cylinder raingauge that posted on the ground surface. The systemic error of estimated precipitation is between 3% to 30% decreases (Sevruk 1982). Due to the influence of wind factor the rainfall does not fall vertically down to the ground surface or to the raingauge, causing a minor or a major loss in the collection of rainfall. The meteorological data reveals that the larger the wind speed and
the smaller the rainfall intensity, the larger the rainfall deviation (Sevruk 1996). Especially, those records observed during typhoons or storms. The loss rate of rainfall measurement will directly influence the estimation of runoff in a watershed, planning of water resource, the occurrence condition of debris flow, and the prevention of catastrophic disaster.

The main purpose of this research was to study the effect of wind speed on rainfall measurement. A five-opening directional raingauge and a standard raingauge were installed at the meteorological station of the Department of Soil and Water Conservation of National Pintung University of Science and Technology (hereinafter referred to as “meteorological station”). The difference between both self-recorded raingauge’s records were compared and analyzed to verify the accuracy of the measurements of rainfalls at hillside.

**MATERIALS AND METHODS**

1. **INTRODUCTION OF THE EXPERIMENTAL SITE**

   The experimental site located inside the meteorological station of National Pingtung University of Science and Technology is with the north latitude 22° 39', east longitude 120° 39', EL 71m, and occupies 2,000 m² and equipped with a set of automatically meteorological system. The system includes meteorological inductors, central record system, computer, and peripheral equipment. According to the meteorological station statistics, average temperature in summer is 27.2°C and is 19.6°C in winter, with annual average temperature of 24°C. The area belongs to the subtropical climate and often there is thunder shower in afternoon of summer. The annual average rainfall is about 2,600 mm. The monsoon direction is north or northwest in winter and south or southwest in summer.

2. **INSTRUMENTS FOR EXPERIMENT**

   (1) Standard self-recorded raingauge

   It is the most common type of raingauge. The diameter of the opening is 20 cm and the area of the opening is 314 cm².

   (2) Five-opening directional raingauge

   In order to analyze the influence of wind factor in all directions to the raingauge, the standard raingauge is modified to have five openings, in north, east, west, south and top directions, to collect the rainfalls from all directions. The area of the five openings is 1,570 cm². The section area of individual directional opening is the same as a standard raingauge and each directional opening collects its own directional rainfall and stores and records on its independent device.

3. **CALCULATION FORMULA OF FIVE-OPENING DIRECTION RAINGAUGE**

   This study employs the law of vector to calculate the rainfall records from those five openings which are East (E) • South (S) • West (W) • North (N) and Top (H). The formula for above calculations is stated as follows:

   \[
   V = \sqrt{(N - S)^2 + (E - W)^2}
   \]

   where:
   - \(V\) : weighted rainfall in N, S, E, and W directions,
   - \(N\) : rainfall in the north direction,
   - \(S\) : rainfall in the south direction,
   - \(W\) : rainfall in the west direction, and
   - \(E\) : rainfall in the east direction.

   The total weighted rainfall of the five-opening directional raingauge is then calculated and added up according to the law of vector:

   \[
   R = \sqrt{V^2 + H^2}
   \]

   where:
   - \(R\) : total weighted rainfall of the five-opening directional raingauge,
   - \(V\) : weighted rainfall in N, S, E, and W directions,
   - \(H\) : rainfall in the top direction.

   The angle of the rainfall \(i\) to the ground surface must be calculated by the law of trigonometric function:

   \[
   \tan i = \frac{V}{H}
   \]

   where:
   - \(V\) : weighted rainfall in N, S, E, and W directions,
   - \(H\) : rainfall in the top direction.
4. FORMULA FOR CALCULATION OF RAINFALL LOSS RATE

Comparison is made between the records collected from standard rain gauge and the records collected from the five-opening directional rain gauge in the meteorological station. The rainfall loss rate (D, %) can be calculated as follows:

\[
D\% = (1 - \frac{\text{standard rain gauge}}{\text{five-opening directional rain gauge}}) \times 100\%
\]

RESULTS AND DISCUSSION

1. RESULTS OF RAINFALL LOSS RATE CALCULATION

The purpose of investigating the rainfall measurement of hillside field was in order to employ an optimal method of measuring and calculating rainfall. A five-opening directional rain gauge was installed at the meteorological station in August 2001. This study was conducted from Aug. 27, 2001 to Sep. 10, 2003 by way of comparing the records of the five-opening directional rain gauge and the standard rain gauge. In order to explore the influence of wind speed and the wind direction on the rainfall, the data collected from the meteorological station was utilized to investigate the relationship between wind speed and rainfall. The units of every 10 minutes period rainfall record have been collected from the computer record in the meteorological station. Coordinating with above saying rainfall records the wind speed and direction records of every 60 minutes period are downloaded at the same time. During the time of typhoon the wind speed records in every 10 minutes period were collected manually. After dividing the rainfall records into several groups according to different wind speed, a regression analysis was performed to examine the relation between wind speed and rainfall. Table 1 shows the record of standard rain gauge is 20.5 mm and the records of five-opening directional rain gauge are E : 7.0 mm, W : 5.5 mm, N : 1.0 mm, S : 24 mm and H : 22.5 mm at 2003/08/04/02:00. From mentioned data above, it reveals that the wind direction is mainly from South. While the wind speed reaches 16.2 m/s, the total weighted rainfall (V) is 32.2 mm for the five-opening directional rain gauge from the calculation of formulas (1) and (2) and the rainfall is 20.5 mm for the standard rain gauge. The rainfall loss rate is up to 30.1 %.

2. DISCUSSION OVER RELATIONSHIP BETWEEN THE RAINFALL LOSS RATE AND WIND SPEED

(1) Rainfall intensity above 10 mm hr⁻¹

For the records of rainfall intensity above 10 mm hr⁻¹ the average wind speed was mainly lower than 4 m s⁻¹ (Fig. 1). According to the relationship between average wind speed and rainfall loss rate, the rainfall loss rate was 4 % at the wind speed of 2 m s⁻¹. At the average wind speed of 10 m s⁻¹, the rainfall loss rate was 17 %.

(2) DUJUAN typhoon (No.13 of 2003)

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Time</th>
<th>Turn towards the east (mm)</th>
<th>Turn towards the west (mm)</th>
<th>Turn towards the south (mm)</th>
<th>Northwards (mm)</th>
<th>Top (mm)</th>
<th>Five opening rain gauge Rainfall (mm)</th>
<th>Standard rain gauge Rainfall (mm)</th>
<th>Average wind speed (ms⁻¹)</th>
<th>Loss rate of rainfall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Sep.20</td>
<td>18:00</td>
<td>1</td>
<td>4</td>
<td>1.5</td>
<td>11</td>
<td>30</td>
<td>31.6</td>
<td>29</td>
<td>3.8</td>
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</tr>
<tr>
<td>2001</td>
<td>Sep.28</td>
<td>24:00</td>
<td>0.5</td>
<td>0.5</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td>9.8</td>
<td>8.5</td>
<td>3.8</td>
<td>86</td>
</tr>
<tr>
<td>2003</td>
<td>Sep.2</td>
<td>02:00</td>
<td>6</td>
<td>8.5</td>
<td>9</td>
<td>95</td>
<td>355</td>
<td>356</td>
<td>35.5</td>
<td>4.5</td>
<td>03</td>
</tr>
<tr>
<td>2003</td>
<td>Aug.4</td>
<td>01:00</td>
<td>23.0</td>
<td>1.5</td>
<td>37</td>
<td>1</td>
<td>111.5</td>
<td>199.1</td>
<td>105.5</td>
<td>7.7</td>
<td>64</td>
</tr>
<tr>
<td>2003</td>
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<td>02:00</td>
<td>7.0</td>
<td>5.5</td>
<td>24</td>
<td>1</td>
<td>225</td>
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<td>30.5</td>
<td>16.2</td>
<td>301</td>
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<tr>
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<td>Aug.4</td>
<td>05:00</td>
<td>4.5</td>
<td>0.5</td>
<td>17</td>
<td>0</td>
<td>22</td>
<td>28.1</td>
<td>19.5</td>
<td>13.2</td>
<td>21.7</td>
</tr>
</tbody>
</table>
From the meteorological data (Fig. 2) of DUJUAN typhoon, before 01:10 the rainfall intensity was more stronger and the average wind speed was more smaller, thus the rainfall loss rate was small. But, after 01:10, the wind speed was getting stronger and the rainfall intensity was decreasing, thus the rainfall loss rate increased to 30 %. Despite the rainfall intensity, all records are analyzed and concluded in Fig. 3. The rainfall loss rate was 19 % when the average wind speed was 10 m s\(^{-1}\). The rainfall loss rate was 33 % when the average wind speed was 18 m s\(^{-1}\).

(3) MORAKOT typhoon (No. 9 of 2003)

From the meteorological data (Fig. 4) of MORAKOT typhoon, before 00:10 the rainfall intensity was more slower and the average wind speed was more stronger, thus the rainfall loss rate went up to 30 %. Same day after 00:10, wind speed lowered down and rainfall intensity moved up, thus the rainfall loss rate decreased. Despite the rainfall intensity, all records are analyzed and concluded in Fig. 5. The rainfall loss rate was 23 % when average wind speed was 10 m s\(^{-1}\). The rainfall loss rate is 47 % when the average wind speed was 18 m s\(^{-1}\).

(4) Synthetic discussion of two typhoons mentioned above

Pooled the 10-minute period records of rainfall and wind speed from two typhoons mentioned above, the results can be shown as Fig. 6. The rainfall loss rate was 23 % when the average wind speed is 10 m s\(^{-1}\). The rainfall loss rate was 43 % when the average wind speed was 18 m s\(^{-1}\).

CONCLUSIONS AND SUGGESTIONS

1. CONCLUSIONS
According to the results, the observed records of standard raingauge are influenced by wind speed and rainfall intensity. After comparing with the five-opening directional raingauge, the relationship of rainfall loss rate for standard raingauge can be analyzed and concluded as follows:

The rainfall loss rate increases as the wind speed increases and/or the rainfall intensity decreases. The analysis of 10 minutes period records can advise the relation between rainfall intensity and wind speed during a typhoon. When rainfall intensity was above 10 mm hr\(^{-1}\), and average wind speed reached 2 m s\(^{-1}\), the rainfall loss rate was about 4%. The rainfall loss rate is about 17%, when the average wind speed reached 10 m s\(^{-1}\). During the typhoon, the rainfall loss rate was about 19 % when the average wind speed reached 10 m s\(^{-1}\). The rainfall loss rate was about 43 % when the average wind speed reached 18 m s\(^{-1}\).

### 2. SUGGESTIONS

The function of standard raingauge is influenced by wind speed and rainfall intensity. These two factors cause rainfall losses in rainfall measurements. The rainfall loss can be modified by the given adjusting factors in Table 2.

### REFERENCES


### Table 2. Rainfall loss rate adjusting factor

<table>
<thead>
<tr>
<th>Average wind speed (m s(^{-1}))</th>
<th>Rainfall Status and its intensity (mm hr(^{-1}))</th>
<th>Normal rainfall</th>
<th>Typhoon hour*2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loss rate (%)</td>
<td>Correct the factor</td>
<td>Loss rate (%)</td>
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<td>0</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1.04</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>1.07</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
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</tr>
<tr>
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<td>19</td>
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<tr>
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</tr>
<tr>
<td>20</td>
<td>32</td>
<td>1.48</td>
<td>49</td>
</tr>
</tbody>
</table>

*1. Carry on the analysis with records of 60 minutes interval
*2. Carry on the analysis with records of 10 minutes interval during typhoon
