Potential impact of climate variability on respiratory diseases in infant and children in Semarang

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Abstract. Temperature, humidity, and rainfall may influence respiratory disease, including acute respiratory infection (ARI) and pneumonia. In Semarang, the temperature and humidity has increased 0.1°C and 1.6% respectively during 2002-2011. ARI and pneumonia in children under 5 years had increased during 2012-2014. This study aimed to analyze the relationship of climate variability and ARI and pneumonia incidence. It was an ecological study. Subject consisted of patients visited primary health care of Bandarharjo from 2011 to 2015. Pneumonia was related to infants (<1-year-old) and children (1-4 years old), while ARI was related to children (≥5 years old). Data of climate was obtained from Agency for Meteorology, Climatology and Geophysics (BMKG) Semarang. Pearson correlation (α=0.05) was used to analyse the correlation of the 60 samples. Mean of temperature was 27.96°C, relative humidity was 74.73%, and rainfall was 179.98 mm/month. The total of ARI was 38523 cases and pneumonia was 1558 cases. Temperature, humidity, and rainfall had no correlation to pneumonia. Humidity had a significant correlation to ARI on female children and total ARI (r=0.3 and r=0.26; p-value=0.02 and 0.04 respectively). Rainfall and temperature had no correlation to total ARI. This study concluded humidity has potential impact to ARI.

Keywords: climate variability, acute respiratory disease, pneumonia, infant, children

1. Introduction

Climate change refers to any change in climate over time due to natural variability or as a result of human activity [1]. The change of climate influences regional weather change, such as heat wave, extreme weather, temperature and precipitation [2]. Average temperature of earth surface rises to exceed the safe threshold of 2°C above preindustrial average temperature during the 21st century [3].

Climate change harms human health, both directly and indirectly. Direct effects include changes of earth system, such as rising temperatures, increasing climate variability, rainfall or snowfall in some areas, and drought. Indirectly, climate-related ecosystem changes increases the range, seasonality, and infectivity of some vector-borne diseases [4]. Drought conditions produce pollution that creates multiple health challenges such as more dust and particulates [5].

Some studies showed the relationship between climate and respiratory diseases. The proportion of primary care visits due to respiratory diseases varied according to seasonal changes [6], [7]. Ambient temperature and absolute humidity correlate to the occurrence of upper respiratory tract infection (URTI) [8].
Acute respiratory disease caused of death among children aged <5 years and it was contributed 15% globally and 17% in South-East Asia Region in 2015 [9]. Pneumonia and diarrheal are among the leading causes of child mortality in the world [10]. One of the populations most at risk for pneumonia is children under five years [11].

The mean minimum temperature, rainfall and the incidence of respiratory syncytial virus (RSV) and pneumonia infections was the significant correlation [12]–[14]. The number of hospitalizations due to pneumonia on children, infants, and adults, was in accordance with the increase or decrease in temperature, humidity, precipitation, wind speed, and thermal comfort index [15]. Temperature, sunshine duration, relative humidity, and concentration of pollutants were significantly correlated to severe acute respiratory infection [16]. Climate change directly threaten respiratory health by promoting or aggravating respiratory diseases or indirectly by increasing exposure of risk factors for respiratory diseases [17].

The epidemiological outcome of climate change on disease patterns worldwide will intense, especially in developing countries [3]. Temperature is related to the prevalence of upper and lower respiratory tracts infection in developing country [18]. Climate change will affect the health of urban populations [19]. Higher temperatures occur in urban areas than in rural area [20], and have a different effect on hospitalizations for respiratory disease [21].

The evidence of climate change in Semarang is monthly increase of surface temperatures over the last 100 years [22]. Over the next 100 years, the temperature may rise up to 1°C [23]. According to Minanda et al, during 2002-2011, the mean temperature was 27.7°C and relative humidity 76%. The climate, however, has changed during 2002-2011, the mean temperature has increased 0.1°C and the mean of relative humidity has increased 1.6% [24].

Based on primary health care reports in 2013 and 2014, acute respiratory infection (ARI) in the upper tract system on children was the main health problem in Semarang. The cases were 85125 (in 2013) and 56376 (in 2014). According to the hospital report in Semarang, cases of ARI were 2290 cases in 2013 and 1696 cases in 2014. Pneumonia in infants have also increased during 2012-2014. The average of pneumonia cases in children under five years old was 3079 [25], [26]. The ARI and pneumonia in Semarang are potentially influenced by climate variability. Objective of this study was to analyse the climate variability and respiratory disease in infant and children who visited in PHC Bandarharjo-Semarang.

2. Methodology
The research was an ecological study [27]–[29] and carried out in coverage area of the primary health care (PHC) Bandarharjo, Semarang. The coverage area consists of 4 villages, i.e. Bandarharjo, Tanjung Mas, Kuningan, and Dadapsari. The population of children under-five years from January 2011 to December 2015 estimated 7530 to 7841. The total study subject were 38993 cases of acute respiratory infection (ARI) in children ≥ 5 years old and 1588 cases of pneumonia in children aged <1 year and 1-4 years old who visited the PHC of Bandarharjo during January 2011 to December 2015.

Acute respiratory diseases included acute respiratory infection (ARI) in the upper tract system (“ISPA”) and pneumonia. ARI and pneumonia were diagnosed by the medical doctor and paramedic used standard diagnostic (guideline) for ARI and pneumonia [30]. ARI located above the epiglottis were considered as upper airway diseases, while those at the epiglottis and below were considered as diseases of the lower respiratory tract. Symptoms related to the respiratory tract (such as coughing), but without diagnosis, were defined as a non-specific respiratory disease [6]. It was excluded from the samples. Pneumonia is a form of acute respiratory tract infection (ARTI) that affects the lungs. When an individual has pneumonia, the alveoli in the lungs are filled with pus and fluid, which makes breathing painful and limits oxygen intake [11].

Reliability and validity of data were ensured by cross check to registered diseases at PHC of the Bandarharjo. ARI and pneumonia were old and new cases.

Climate refers to the average state of the atmosphere for a given time scale (hour, day, month, season, year, the decade and so forth) and for a specified geographical region. The average-state of atmosphere involves temperature, precipitation, wind, cloudiness and sunshine, pressure, visibility, humidity and elements with noteworthy human impacts [31]. Monitored data of temperature, relative
humidity and rainfall at Semarang level and area of PHC Bandarharjo were obtained from Agency for Meteorology, Climatology and Geophysics (BMKG) of Semarang. Semarang has 9 climate monitoring stations and distributed in Ngaliyan, Tanjung Mas, Siliwangi, Genuk, Tlogosari, Candi, Klipang, Mijen, Gunungpati. The Tanjung Mas station is the one to monitor the variability of temperature, relative humidity and rainfall at surrounding area included area PHC of Bandarharjo.

The climate variability used mean of temperature (°C), mean of relative humidity (%) and mean of rainfall (mm) per month both at Semarang level and area PHC of Bandarharjo. The temperature measured by wet and dry bulb thermometer. Relative humidity measured by the wet and dry hygrometer. Rainfall measured by rainfall instrument type Hillman with an auto record. The BMKG maintained the climate equipment at least a week to ensure sensitivity of equipment and it was calibrated every 5 years or when replaced by new equipment. Monitoring of climate (temperature, relative humidity) conducted every day on 07.00, 13.00, and 18.00 at local time and recorded in form, it is called Fklm71. The rainfall is measured on 07.00 at local time and recorded in rainfall card. The climate data at Semarang level and area PHC of Bandarharjo reported to BMKG of Semarang every month [32]. Rainfall is classified into four levels: 0-50 mm/month (low), >50-150 mm/month (medium), >150-300 mm/month (high), and > 300 mm/month (very high) [33]. The climate data at Semarang level for picturing and comparing the temperature, relative humidity and rainfall to climate at area PHC of Bandarharjo.

The data of climate at area PHC of Bandarharjo as independent variables were obtained from daily monitoring at the Tanjung Mas station, and it was transformed to mean of temperature, relative humidity and rainfall per month. As dependent variables were ARI and pneumonia cases per month. Total of samples were 60 climate, 60 ARI and 60 pneumonia cases. It was calculated from average climate data and diseases (ARI and Pneumonia) per month during 2011-2015. Spearman correlation was used to analyze the correlation between climate and ARI and pneumonia cases with α=5% [34].

3. Result and Discussion

3.1. City of Semarang

Semarang is located between the 6°50’- 7°10’ south latitude and 109°35’- 110°50’ east longitude [35]. Restricted to the west with Kendal, at East with Demak, at Semarang regency in the south and the north is limited by the length of the Java Sea coastline which covers 13.6 km [36]. Altitude of Semarang lies between 0.75 to 348 m above the sea level [35]. The total area of Semarang is 373.7 km², composed of 16 districts and 177 villages [37]. The population of the Semarang amounted to 1575068 people, consisting of 787705 men and 797167 women [38]. The population density of Semarang was 4172 per km² [39].

The climate condition at Semarang level during 2011-2015 consisted of temperature 27.97°C±0.83°C, relative humidity 74.83%±7.88%, and rainfall 180.75 mm±194.34mm per month. Rainfall was classified as very high [33]. Mean of temperature during five years has increased 0.58°C, but mean of relative humidity and mean of rainfall had fluctuated. Mean of temperature in 2011 was 27.72°C, in 2012 and 2013 were 27.95°C, and in 2014 was 27.98°C. The highest mean temperature was in 2015 (28.30°C). Relative humidity during five years ranged 58-90% per month, while rainfall ranged 0-736 mm per month.

3.2. Area of primary health care of the Bandarharjo

PHC Bandarharjo covers an area that lies 0.75 meters above sea level. The area is located at shore line and most of it is covered by tidal inundation (local term: rob) [35]. Total area PHC of Bandarharjo is 761.1 km² and it consists of Bandarharjo village (342.7 hectare), Tanjung Mas village (330 hectare), Kuningan village (46.9 hectare), and Dadapsari village (41.5 hectare). The total population of four villages in 2014 was 78394 [37]. The distribution of population: Bandarharjo village (20967 people), Tanjung Mas village (30678), Kuningan village (15427 people), and Dadapsari village (11322 people).

Temperature in area of PHC Bandarharjo during 2011-2015 (table 1) was 28.15°C±0.72°C, relative humidity was 76.13%±6.45%, and rainfall was 180.27 mm/month±167.34mm (very high).
Mean of temperature for the last four years (2012-2015) has increased 0.23°C. Mean of temperature in 2011 was 28.13°C, in 2012 was 28.05°C, in 2013 was 28.12°C, in 2014 was 28.15°C and in 2015 was 28.28°C. The highest mean of temperature was in 2015. The mean of relative humidity and rainfall per year fluctuated. Relative humidity ranged 63-86%/month and rainfall ranged 0-992 mm/month.

Based on mean rainfall per month, type of month in PHC Bandarharjo can classify as wet month (rainfall>100 mm), humid month (60-100 mm), dry month (<60 mm) [40]. The wet month is more frequent than the dry month and humid month. Cases of pneumonia and ARI in PHC Bandarharjo were higher in the wet month than in the dry and humid months (data not showed). It was clarified that during the dry season there were 21% fewer visits for respiratory disease in health facility [6].

Climate change influences the regional weather changes in accordance with temperature, sea level, precipitation, and extreme weather events. Those will cause downstream effects on the environment that lead to adverse health effects [3]. Coastal communities, in low-income countries, are vulnerable to a range of health effects due to climate variability and long-term climate change [41]. Geographically, the area of PHC Bandarharjo lies in coastal area and the most of the population are categorized as low income.

During rainfall or wet month the temperature will decrease [42]. The pattern of peak of the pneumonia cases was in January-February-March and November-December. The patterns of pneumonia cases was similar to rainfall and humidity, particularly in high rainfall (figure 1), and the correlation was not significant (p=0.08). High transmission of pneumonia occurs during high rainfall (June-October) and regular surface wetness [43]. Pneumonia is affected by colder temperature. A temperature decrease from one day to the next had an adverse impact on childhood pneumonia [44]. The increased incidence of respiratory disease (pneumonia) during the colder periods of the year is due to the low temperatures [15]. Associated with cold days in Central Australia climate zone, there was an increased in acute respiratory admissions for children [21]. The conceptual mechanism of infection may illustrate that a decrease in air temperature causes a decrease in the temperature of the nasal airway. Cooling of the nasal airway compromises respiratory defend against infection by slowing mucociliary clearance and inhibiting leukocyte phagocytosis. The sign of warming of the body and airway associated with fever and nasal congestion that are natural way to defend against infection [45]. The most common pathogens that caused pneumonia are *Streptococcus pneumoniae*, *Haemophilus influenza* type b (Hib), and respiratory syncytial virus (RSV) [11], [46]. Contradictive with Kim’s finding that the risk of pneumonia was higher in the dry season than in the rainy season. There was variability in the relationship between climate factors and pneumonia [14].

Mean of temperature (0.17°C) and mean of relative humidity (1.3%) were higher in area PHC of Bandarharjo than Semarang in general, but mean of rainfall in area PHC of Bandarharjo was lower (-0.48 mm/month). According to the statistical test, there were significant different between mean temperature, relative humidity, and rainfall in Semarang and in area PHC of Bandarharjo (p-value=0.0001) (data not showed). Bandarharjo had higher temperature because it lies in the coastal area. It was confirmed that global mean sea surface temperatures (SST) have risen, with associated warming temperature in the coastal area [47].

Total patients visited (old and new visits) to PHC of Bandarharjo was 63222. Total pneumonia (table 1) in Bandarharjo village was 1072 (68%), Tanjung Mas 363 (22%), Kuningan was 107 (7%) and Dadapsari village was 50 (3%) out of 1592 cases. The average of pneumonia cases was higher in children aged 1-4 years than in infant (<1 year). In Kuningan village, Pneumonia cases in children under five years both in male and female in 2012 to 2015 tended to increase. It had the same trend with the temperature, although the causal mechanisms were not well understood.
Table 1. The number of Pneumonia cases on infants and children under five years and climate during 2011-2015 in area PHC of Bandarharjo.

| Year | Bandarharjo village | Tanjung Mas village | Kuningan village | Dadapsari village | Mean temperature | Mean relative humidity | Mean rainfall |
|------|---------------------|---------------------|------------------|-------------------|------------------|-----------------------|--------------|
|      | Male | Female | Male | Female | Male | Female | Male | Female |                 |                  |               |              |
| 2011 | 6    | 10     | 5    | 3      | 1    | 1      | 2    | 1      | 28.13            | 76.92            | 194.5         |
| 2012 | 50   | 30     | 14   | 13     | 2    | 3      | 0    | 0      | 28.05            | 75.42            | 177.17        |
| 2013 | 60   | 40     | 9    | 17     | 4    | 3      | 2    | 3      | 28.12            | 77.17            | 202.58        |
| 2014 | 26   | 31     | 11   | 11     | 3    | 3      | 2    | 0      | 28.15            | 76.33            | 199.42        |
| 2015 | 44   | 44     | 19   | 12     | 7    | 12     | 4    | 4      | 28.28            | 74.83            | 127.67        |
| Mean | 37.2 | 31     | 11.6 | 11.2   | 3.4  | 4.4    | 1.6  | 2      | 28.15            | 76.13            | 180.27        |

The highest cases of ARI in children ≥5 years (Table 2) were in Bandarharjo village (31.53%) and the lowest cases was in Dadapsari village (20.75%). Cases of ARI in Tanjung Mas and Kuningan were 8356 cases (21.24%) and 10243 cases (26.28%) respectively. ARI cases declined in all villages since 2011, but rose in 2015. Based on gender, ARI in children ≥5 years found higher proportion in female than male.

Table 2. The number of ARI cases on children ≥5 years and climate during 2011-2015 in area PHC of Bandarharjo.

| Year | Bandarharjo village | Tanjung Mas village | Kuningan village | Dadapsari village | Mean temperature | Mean relative humidity | Mean rainfall |
|------|---------------------|---------------------|------------------|-------------------|------------------|-----------------------|--------------|
|      | Male | Female | Male | Female | Male | Female | Male | Female |                 |                  |               |              |
| 2011 | 2189 | 2216   | 1022 | 1021   | 1649 | 2115   | 1286 | 1413   | 28.13            | 76.92            | 194.5         |
| 2012 | 1220 | 1906   | 930  | 1348   | 1333 | 1694   | 1053 | 1386   | 28.05            | 75.42            | 177.17        |
| 2013 | 731  | 1154   | 665  | 1051   | 608  | 855    | 539  | 719    | 28.12            | 77.17            | 202.58        |
| 2014 | 433  | 715    | 367  | 618    | 316  | 595    | 290  | 535    | 28.15            | 76.33            | 199.42        |
| 2015 | 603  | 1123   | 463  | 871    | 372  | 706    | 301  | 564    | 28.28            | 74.83            | 127.67        |
| Mean | 1035.2 | 1422.8 | 689.4 | 981.8 | 855.6 | 1193 | 693.8 | 923.4 | 28.15            | 76.13            | 180.27        |

The proportion of total pneumonia by sex was higher in male than female in three villages (Bandarharjo, Tanjung Mas, and Kuningan) (table 1). As many as 82.1% children with pneumonia were under five years of age, and almost half of children with pneumonia (46.4%) were infants. The boys were leading in all age groups [48].
Figure 1. The pattern of monthly average of the temperature (A), humidity (B), rainfall (C) and Pneumonia (infant and children <5 years old)
3.3. Correlation between climate and Pneumonia and ARI

Temperature, relative humidity, rainfall had no correlation to total pneumonia in infant and children. The average cases of Pneumonia per month tend to increase during 2011-2015, both of infant and children under five years old and also by gender. Relative humidity had a positive correlation to total ARI ($r=0.26$; $p$-value=0.04). Relative humidity had the positive correlation to ARI in female children ($r=0.3$; $p$-value=0.002), temperature and rainfall had no correlation to pneumonia ($p=0.35$, $r=-0.12$; $p=0.08$, $r=-0.22$ (table 3).
Table 3. The summary correlation between climate and pneumonia and ARI

| Climate       | Pneumonia <1 year | Pneumonia 1-4 years | Total Pneumonia (<1 year + 1-4 years) | ARI≥5 years | Total ARI≥5 years |
|---------------|------------------|--------------------|--------------------------------------|-------------|------------------|
|               | Male (n=60)      | Female (n=60)      | Male (n=60)                          | Female (n=60) | Male (n=60)      | Female (n=60) |                   |
| Mean          | \( p=0.72 \)     | \( p=0.26 \)      | \( p=0.66 \)                        | \( p=0.20 \) | \( p=0.35 \)     | \( p=0.17 \)     | \( p=0.12 \)     | \( p=0.1 \)     |
| temperature   | \( r=0.05 \)     | \( r=0.15 \)      | \( r=0.06 \)                        | \( r=0.17 \) | \( r=0.12 \)     | \( r=0.18 \)     | \( r=0.21 \)     | \( r=0.19 \)    |
| Mean          | \( p=0.17 \)     | \( p=0.87 \)      | \( p=0.62 \)                        | \( p=0.59 \) | \( p=0.53 \)     | \( p=0.10 \)     | \( p=0.02 \)     | \( p=0.04 \)    |
| relative      | \( r=-0.18 \)    | \( r=0.02 \)      | \( r=-0.07 \)                       | \( r=-0.07 \) | \( r=-0.08 \)    | \( r=0.21 \)     | \( r=0.30 \)     | \( r=0.26 \)    |
| humidity      | \( r=-0.23 \)    | \( r=0.09 \)      | \( r=-0.21 \)                       | \( r=-0.21 \) | \( r=-0.22 \)    | \( r=0.16 \)     | \( r=0.17 \)     | \( r=0.17 \)    |
| rainfall      | \( p=0.08 \)     | \( p=0.47 \)      | \( p=0.12 \)                        | \( p=0.10 \) | \( p=0.08 \)     | \( p=0.22 \)     | \( p=0.21 \)     | \( p=0.20 \)    |

Respiratory illness remains a major killer and cause of morbidity for children, causing almost 20% of all under-five deaths. Vulnerability of children to respiratory disease not all of which are directly affected by climate change [49]. Children more vulnerable than adults, because children of more rapid metabolism, the immaturity of the child’s respiratory system, were the development of the lungs and thorax is progressive and continues until ten years of age, as well as the capacity to adapt to climate issue [49]-[50].

Our result was quite similar to Falagas that relative humidity had correlation to upper and lower respiratory tract infection [51]. Relative humidity causes both direct and indirect health effect. Very low or high relative humidity may cause physical discomfort, as the relative humidity of the air directly affects to temperature perception. Relative humidity as a determinant of the incidence of infections will depend on the relative strength of the settling rate of aerosols and the survival of airborne pathogens [52]. The incidences of respiratory infection were found to be lower among people who live in environments with a relative humidity level between 40% - 70% [53]. The recovery of the airborne pathogen (virus) was higher at a higher relative humidity and the stability of the aerosol was at the relative humidity of 60%. Humidity performs and important role and can affect the transmission of the virus [50]. When relative humidity moved from 1% to 6% there was a 39% increase in the cases of respiratory syncytial virus (RSV) [7]. Seasonality of certain ARI pathogens can be explained by meteorological influences, for example Rhinovirus correlated to relative humidity [54].

Rainfall had no correlation to total ARI, but had the same pattern with the total of ARI, whereas temperature and relative humidity had no same pattern with total ARI. Primary care visits for respiratory disease, especially those due to upper airway diseases, are related to the rainy season [6].

Children’s vulnerability to respiratory disease may related to their proximity to traffic, the level of crowding in their homes, and the cooking or heating fuel burned within their homes. But it can also be related to ambient outdoor air quality [49]. Indoor aspect due to indoor air pollution resulted from fuel for cooking. The quality of housing contributed to respiratory disease of home’s inhabitant. The tighter of the building made by brick will easy to spread indoor air pollution and influence the home’s inhabitant [55]. The coverage of healthy housing proportion in coverage area PHC Bandharharjo in 2012-2014 tended to decline, i.e. 508 out of 582 inspected houses (87.29%), 510 out of 600 (85%), 277 out of 400 (69.25%) respectively. Lack of housing quality and the overcrowding found in temporary housing for the homeless contribute to morbidity from respiratory infections and activation of tuberculosis [56].

Respiratory infections are also influenced by outdoor air pollution. The outdoor air pollution affected by climate change. Change in climate globally will affect to regional weather and potential to produce air pollution through anthropogenic, natural emission and atmospheric process [2], [57]. If the
climate becomes warmer and more variable, air quality is likely to be affected [57]. Climate change also affected ozone concentration [58] and particulate matter (PM) concentration in polluted environments by 0.1–1 mg/m³ over the coming decades [59].

Air pollutants (PM, Ozone, sulfur dioxide) are environmental risk factors of respiratory diseases [60]. Ground-level ozone can exacerbate chronic respiratory diseases and cause short-term reductions in lung function. Exposure of PM can aggravate chronic respiratory [57]. Ozone inhalation induces epithelial damage and consequent inflammatory responses in the upper and lower airways [60]. Short-term exposure to PM2.5 increases the risk for hospital admission for cardiovascular and respiratory diseases [61]. The weekly number of RSV positive cases was also correlated to the mean PM₁₀ concentration [12]. Exposures to carbon monoxide, sulfur dioxide, and nitrogen dioxide can affect respiratory illnesses, lung irritation, and alterations in the lung’s defense systems [57]. Particulate matter significant associated with emergency department visits due to asthma, wheezing, bronchitis, and lower respiratory tract symptoms. High ozone levels seem to be linked to asthma and asthma-like symptoms [60].

4. Conclusion

Pneumonia cases in children under five years both in male and female in 2012 to 2015 tended to increase and had same trend with temperature. Relative humidity had potential impact on total ARI incidence and female children. The effect of relative humidity on ARI varies between sexes. Rainfall had the same pattern with the total ARI and it has potential to respiratory infection. Cases of pneumonia and ARI in PHC Bandarharjo were higher in the wet month than in the dry and humid months. It is advisable to consider other factors that may contribute to the incidence of respiratory tract infections, such as indoor and outdoor air pollution, housing condition.

5. Acknowledgment

The authors would like to thank Agency for Meteorology, Climatology and Geophysics (BMKG) Semarang - Indonesia for serving climate data at Semarang level and area of PHC Bandarharjo, and to District Health Office of Semarang and Primary Health Care of Bandarharjo, Semarang for providing data of diseases and health profile.

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