

## Haze and Dengue: The Unanswered Questions

Annelies Wilder-Smith,<sup>1</sup>MD, Arul Earnest,<sup>1</sup>PhD, Stefan Ma,<sup>3</sup>PhD, Lee-Ching Ng,<sup>4</sup>PhD

Almost every year, Singapore experiences some deterioration of air quality due to trans-boundary haze, largely due to its geographical proximity to Indonesia where wildfires are being used to clear land. Like many haze episodes encountered in the past, severe haze engulfed the city state of Singapore in June 2013. The 24-hour Pollutant Standard Index (PSI) on 22 June 2013 hit the highest reading recorded ever in Singapore, in the 'very unhealthy' range of 246 and the 24-hour PM<sub>2.5</sub> concentration was highest at 314µg/m<sup>3</sup> on 20 June 2013.

With such high PSI and PM<sub>2.5</sub> values, the question arises whether haze has an impact on dengue transmission. Dengue, a mosquito-borne viral disease, is endemic in Singapore.<sup>1</sup> The extent of dengue activity depends on many factors, including mosquito population, herd immunity, travel and introduction of new virus serotypes or genotypes, epidemic potential of circulating virus, as well as climatic factors.<sup>2</sup> Meteorological factors affect fluctuations in mosquito population densities and extrinsic incubation of dengue virus in mosquitoes, hence also dengue activity.<sup>3</sup> Temperature, humidity, and rainfall are weather factors that have been described to influence the seasonal and inter-annual variation of dengue in tropical and subtropical countries.<sup>4,5</sup> But the effect of haze on dengue has not been studied in detail, as evidenced by a dearth on publications on haze in the context of vector-borne diseases.

However, one study has proposed that haze reduces dengue activity.<sup>6</sup> To study this hypothesis, we explored the impact of haze in Singapore on weekly notifications of dengue infections.<sup>7</sup> Using Autoregressive Integrated Moving Average (ARIMA) models, we investigated the relationship between weekly notifications of dengue fever and the pollution standard index between 2001 and 2008 in Singapore. ARIMA modeling is a robust method to forecast dengue activity.<sup>8</sup> Interestingly, the analyses showed no effect of the haze on dengue activity. However, ecological

time series models cannot tease out the direct effect of the haze on *Aedes* mosquitoes. Such models show a combined effect on dengue activity. For example, even if the toxic components of the haze do result in a higher mortality rate of *Aedes* mosquitoes, the haze may have changed both human and vector behaviour in a way that could have counteracted this effect. It is plausible that humans and possibly even mosquitoes were driven inside the houses because of the haze. Such behaviour of prolonged indoor stay would then even increase vector to human contact, biting activities and hence dengue infections. Another explanation for the lack of impact of haze on dengue infections in the period of 2001 to 2008 is that haze was not severe enough during the observation period. Indeed, the PSI values during that time period never reached the levels seen in June 2013. However, the lack of effect of haze on the number of dengue infections in Singapore 2001 to 2008 as shown by ARIMA is also supported by more historical evidence: In 1997 and 1998, there was a severe haze in Singapore, but the incidence of dengue in that time period was the highest in Singapore in the 1990s; in fact, it was the peak of a 6- to 7-yearly cycle of dengue epidemic observed in Singapore.<sup>9</sup>

However, the epidemiology of dengue is very complex and is influenced by many factors other than climatic factors. Hence, a role of haze in dengue cannot be excluded with certainty just based on epidemiological patterns. The question whether the toxic components of haze has any direct impact on mosquito survival remains unanswered. To address this question, entomological studies are necessary. However, to do ad-hoc entomological studies during an acute crisis of haze is logistically difficult. To create haze conditions under laboratory conditions may be even harder to do. Haze is not simply smoke from fire, but an effect of peat fires thousands of miles away.

Lastly, even if haze does have an effect on increasing the mortality rate of mosquitos, in most years the duration of

<sup>1</sup>Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

<sup>2</sup>Centre for Quantitative Medicine, Duke-NUS Graduate Medical School, Singapore

<sup>3</sup>Ministry of Health, Singapore

<sup>4</sup>National Environment Agency of Singapore, Singapore

Address for Correspondence: Prof Annelies Wilder-Smith, Lee Kong Chian School of Medicine, Novena Campus, 11 Mandalay Road, Singapore 308232.

Email: anneliesws@gmail.com

haze is (fortunately) too short to result in a major effect on dengue case numbers. The June 2013 haze in Singapore only lasted for a week, if PSI values beyond 100 are taken into account.

In summary, current epidemiological evidence does not lend support to the notion that haze in Singapore reduces or increases dengue activity. However, several questions remain unanswered. First, the direct effect of haze on mosquito survival or biting behaviour is unknown; entomological studies are required to address this question. Second, the effect of higher PSI values rather than averaged, on the national epidemiology of dengue is unknown. We suggest to extend the original study period (2001 to 2008)<sup>7</sup> to a longer time period including the current year that showed the highest ever recorded PSI values (2013). In addition, more detailed sub-analyses on the effect of extremely high PSI values (>200) or PM2.5 level on dengue activity will help provide more substantial insights into the relationship of haze and dengue. Lastly, data from surrounding regions such as Malaysia and Indonesia which experienced an equally bad or even worse haze may help shed more light on the potential impact of haze on dengue infections.

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