Offshore Oceanography on the Aerosol Chlorides Formation during Typhoon Period

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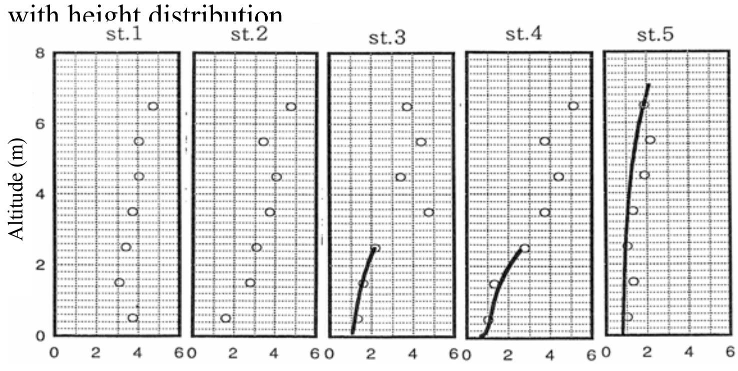
1. Introduction

The aerosol chlorides are formed by the mechanisms of wave breaking by bubble bursting and wind-induced wave tearing. These two mechanisms produce varieties of particle size distributions with heights. In general, three types of aerosol droplets are jet, film and spume droplets. The jet and film droplets are distribution in the size spectrum about 0.01~10μm, and spume droplets are in the range of 10~500μm. The mechanisms of those droplets are dissimilar depending on the size spectrum. The jet and film droplets are considered as the gas molecular motion referred as Brownian motion and molecular diffusion by Stokes-Einstein equation. The molecular diffusion is only the criteria for analyzing small aerosol motion. During typhoon, that causes cloudy condensation nuclei in the atmospheric boundary layer and remains floating in the atmosphere. The spume droplets are the larger size spectrum which flux is much larger than other droplets but the sedimentation is fast as well. Comparing the volume flux of all droplets, a 100μm spume droplet has volume equivalent to the 1million particles of 1μm film droplet. In the simulation of the chlorides attack on concrete structures near seashore, only spume droplets are significant to take into account [1,2]. In this paper, the model is mentioned on the aerosol formation by wave breaking during typhoon which is considered all aerosols as the spume droplets. The amount of aerosol chlorides produced by typhoon is much larger than the numbers in common environment.

2. Literatures reviews

The aerosol chlorides were produced by the wave breaking mechanism which was proposed in many empirical formulas by (wind speed)^3. Some expressions were discussed in the literature [3]. However, the expression is fit by a set of experiment of each literature, so it is difficult to obtain an expression to explain globally. The further research is to develop the aerosol chloride formation with the height distribution. The investigation for height distribution was done by Toba 1996 [4] (*See **Fig.1***) & Kazama et al 2004 [5]. The observed data by Toba 1996 is 8m height aerosol chloride profile which is consistent along this height averaged as 4 μg/hr at mean wind speed = 5m/s. The investigation was done during typhoon by Toba in 1999 (*See **Fig.2***) [6]. The apparent values of chlorides distribution were known with doubtful movement mechanism. Recently, the simulation of aerosol chloride movement was proposed by Kazama et al 2004; however, the amount of aerosol chlorides produced from wave breaking is still unknown. In analysis, the aerosol chlorides formation and transportation should be independently simulated. The most important is the prediction of aerosol chlorides distribution at the seashore prior to consider their transport. The study in this paper is concentrated on the estimation model for aerosol chlorides formed at the seashore with height distribution.



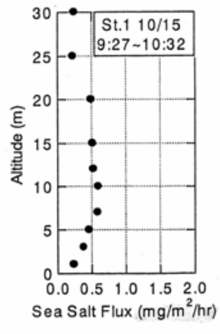


Fig.1: Sea-salt Measurement (μg/m^2/hr) at 0m, 7m, 12m, 17m, 29m from seashore [4] **Fig.2**: Sea Salt Flux at 20m from seashore [6]

3. Aerosol Chlorides Formation (Model & Experimental Results)

The aerosol formation by wave breaking mechanism at the seashore was studied, which the spume droplets were generated mostly flux rather than the film droplets. The local wind speed and the height of breaking wave are main parameters for analyzing the aerosol chlorides formation. In order to obtain the breaking wave height, the wave transformation along a sea-slope could be calculated by applying an infinitesimal distance and assuming an average water depth in that interval [7].

The model is established for aerosol chlorides formation at seashore, which is presented in a height distribution according to four main parameters of breaking wave, wind speed, wind directions and breakwater. The amount of airborne chlorides generated at a low level is large and decreases in a high level. Many references presented the airborne chlorides distribution in term of exponential function; however the highest upward transport could not be defined. In a better way, the airborne chlorides distribution in the air was proposed in the power function as shown;

$$W_{air,H_b} = \gamma[ah_{air}^{\alpha_1} + b].r_{wind} \tag{1}$$

$$a = -\alpha_2 . \frac{b}{3.5} \tag{2}$$

$$b = \alpha_3 \times (\frac{U^3}{10}) \times H_b^2 \times [1 + 4\cos\phi \sin\phi] \tag{3}$$

$$\gamma = \frac{C_{NaCl}}{C_{NaCl=3\%}} = \frac{C_{NaCl}}{3} \tag{4}$$

where, h_{air} is the reflected height from ground (m). *a* is particles dispersion factor. *b* is amount of ground-droplets; $f(U^3, H_b^2)$. H_b is breaking wave height (m) calculated by the wave propagation. With breakwater, ϕ is horizontal inclined angel of breakwater, otherwise; null. $h_{air,max}$ is maximum reflected height (m). γ is normalized salt concentration with 3% salt concentration. C_{Nacl} is the sea salt concentration neighboring the seashore (%). For the breaking wave by breakwater, the airborne chlorides are formed by the reflection mechanism. Thus, the declined angel of breakwater is a main parameter for explaining the difference of their formation. α_1 is the functional height coefficient. α_2 is the maximum height multiplication factor due to breakwater (= 0.8), and it is 1.0 in none of breakwater. α_3 is the seashore characterized factor (=3.0). The α_1-α_3 are the coefficient concerning with the scenery of seashore. r_{wind} is 1.0 if a wind direction could transport the airborne particles from seaside, otherwise; null.

The experimental results were observed during the typhoon No.10, 11 and 16. The apparatus for gathering the aerosol chlorides is the plastic plate with size 15x15 cm. The measuring duration is shortened as 30 minutes in the storm period, because the large amount of aerosol chlorides could be gathered within a short time. The investigate results were dramatically larger than the value investigated in the mild condition. The results, in the H_b=0.5m and U=5m/s; distributed in 1-5m height shows the same tendency with the experimental result in the literature in **Fig.1**. Overall experiments at Maehama Beach, Kochi in 2004 and calculations are illustrated in **Fig.3**.

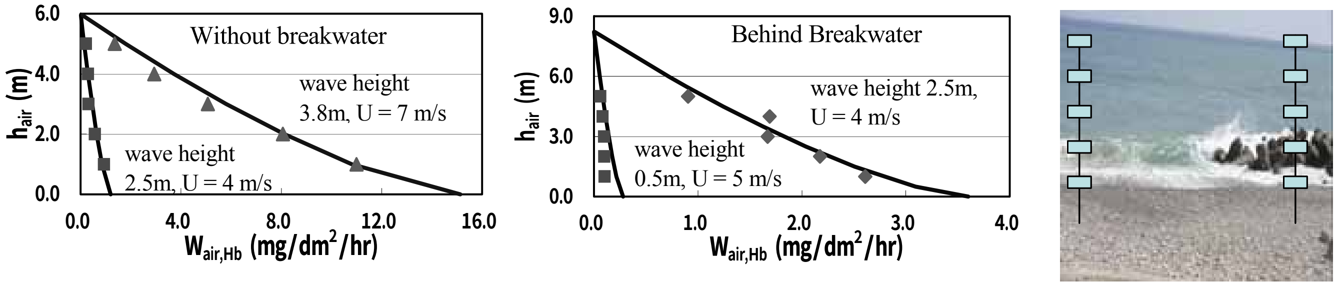


Fig.3: Experimental results and calculation in both with and without breakwater at Maehama Beach, Kochi, 2004

4. Conclusions

The prediction of the spume aerosol chlorides generated into the atmosphere has to consider the integrated impact of wave height, wind speed, wind direction, breakwater and sea salt concentration in the function of the reflected height. These parameters affect the amount of aerosol, but the maximum heights of spume aerosol particles formation seem to be independent. The breakwater is constructed for reducing the huge wave force and protecting shoreline structures during typhoon. In opposite, the aerosol chlorides generated behind breakwater are much larger than those generated on the plane beach issued the acceleration on chloride attack to RC structures.

5. References

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