Estimation of Chlorine Release in Tsunami

In a devastating tsunami event, the wave height is taken as the water depth at Tathong Channel. It is assumed that the integrity of the chlorine store would be compromised and any chlorine leak would lead to direct release to atmosphere.

It is anticipated that chlorine drums in storage area would not be affected while drums in the chlorine store sink because of the weight of content and the drum itself. However, the connection piping between on-duty drums and draw-off units may be potentially damaged due to stress imposed on the connection point in the water current. In the worst scenario, the valve on a drum connecting to the draw-off unit would be completely broken leading a full bore rupture.

While on-duty chlorine drums would be submerged in seawater, chlorine discharging from the damaged drums would be in form of liquid. It expands and passes through the subsea dispersion process before it reaches the seawater surface and releases to atmosphere. Since chlorine dissolves in water, the amount of chlorine releasing to atmosphere would be less than the discharge quantity. The amount of chlorine releasing to atmosphere is estimated in the following sections.

<u>Discharge rate</u>

The discharge rate 1.3 kg/s is obtained from the Phast discharge model for 1 drum. The total discharge rate for 2 on-duty drums are 2.6 kg/s. The discharge rate of chlorine from a drum under water is slower than in atmosphere because of the water pressure.

<u>Water Depth</u>

The water depth is taken as the vertical distance between discharge point and water surface and is calculated from the formula, wave height (10m) – evaluation of ground floor level of chlorine store from mean sea level (3m) – vertical distance of valve from ground level (1m) = 6m.

<u>Amount of chlorine dissolving in seawater</u>

Referring to various documents and literatures, hydrolysis reaction of chlorine in water takes place instantaneously [1]. Because the volume of seawater is ample, concentrations of products at the right hand side of the chemical equation $Cl_2 + H_2O \rightarrow HOCl + HCl$, is nearly zero. Hence, the reaction is shifted to the right without or insignificant backward reaction taking place. Therefore, chlorine gas would not be discharged to atmosphere from the submerged drums.

The above discussion can be illustrated by calculations in the following sections. The reaction between chlorine and water proceeds with a first-order reaction rate constant of 20.9 +/- 1.2 sec^{-1} at 25°C (Spalding, 1961 [2]).

A first-order reaction has a rate, k, proportional to the concentration of one reactant, [A].

Rate = k[A]

where the first-order rate constant has unit of sec^{-1}.

The integrated rate law of a first-order reaction is the following:

$[A]_t = [A]_0 \, e^{-kt}$

where $[A]_0$ is initial concentration of A

$[A]_t$ is the concentration of A at time t,

k is the rate constant, and

t is the elapsed time.

A very short duration 0.5 seconds is considered for demonstration purpose. Hydrolysis reaction between chlorine and water is given as follow,

$Cl2(g) + H2O(l) \leftrightarrow HOCl(aq) + HCl(aq)$

Since the volume of water is ample, it is assumed that the concentration of the products is nearly zero such that the reaction is far shifted to the right i.e. no backward reaction can take place. Only forward reaction is considered.

According to the rate law,

$[A]_t = [A]_0 \, e^{-kt}$

$[Cl2]_{t=0.5}=[Cl2]_0 \, e^{-(20.9)(0.5)}$

$[Cl2]_{t=0.5} / [Cl2]_0 = 2.89 \times 10^{-5}$

Referring to the total discharge rate of 2.6 kg/s above, the total release rate of chlorine to atmosphere is estimated as 2.89×10^{-5} x 2.6 = 7.51×10^{-5} kg/s. At this release rate, the chlorine concentration in atmosphere is too low such that lethal dose contours are not obtained from the PHAST model. In conclusion, the probability of fatality due to chlorine release in tsunami is insignificant.

References:

[1] FILMTEC™ Reverse Osmosis Membranes Technical Manual, Dow Chemical Company.

[2] Charles W. Spalding (1961), The absorption of chlorine into aqueous media in light of the penetration theory.