Evaluation of Salinity Environment using Gauze Method and Simulated Air Flow around the Gauze

Khaing Khaing Htun

***Abstract*—** Myanmar is the northwestern most country on the mainland of southeast Asia, the total area is 676,578 km^2 with 1930 km coastal line. Letkokkon, the selected location is one of the southwest point in Yangon Region in Myanmar. In this paper, salinity can be affected by both natural and human influences. Deposition rate is not only dependent on distance but also other weather and environmental factors. Even longer distance could be affected more salinity concentration and consequently specify as the salinity environment. The concentration of ABS is closely related to the wind velocity as wind with higher speed may carry more. Therefore, wind flow characteristic would be measured by using OpenFOAM software. All the show results were made for the simulation of the fluid flow round gauze in the computational domain. The main goals were to know the nature of air flow that may carry chloride to be salinity environment.

***Keywords*—** ABS, Ketkokkon, OpenFOAM, Salinity Environment, wind velocity

I. Introduction

The sea salt can significantly influence the quality of air. Sea salt can cause enhanced concentrations of particulate matter and change particle chemical composition, in particular in coastal area. Myanmar is the northwestern most country on the mainland of southeast Asia, the total area is 676,578 km^2 with 1930 km coastal line. In coastal regions, the atmosphere is enriched with marine aerosol particles that are naturally generated by the action of wind on the sea water surface. That sea salt is transported along the coastal area and rests on the surface of concrete structure [1]–[3]. Maintenance of deteriorated infrastructures subjected to chloride attack had become a challenging task. It is going to be more serious problem in near future in which budget and resource are decreasing. One of the critical issues is quantification of the airborne chloride amount coming to the structure [4]. The concentration of ABS is closely related to the wind velocity as wind with higher speed may carry more salt to a longer distance. There is a need to properly develop the application of Computational Fluid Dynamics 'CFD' methods in support of air quality studies. [5] Wind flow characteristic can be measured by using OpenFOAM Software which means Open Field Operation and Manipulation, is an CFD code. This provides a short step by step guide to calculating the flow around the gauze using. The important feature of using this software is getting the shortest possible space of time.

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II. The Case Study

The quantity of salt collected by the salinity measurement device on site depends on several factors (such as distance from the sea, prevailing wind direction, wind speed, air temperature and humidity, and topography and natural). Therefore, the installation of salinity sample collection should be made carefully.

A. Source of Salinity

Myanmar coastal line covers an area of around 1930 km on the Andaman sea and Bay of Bengal flowing to the Indian Ocean. Letkokkon, the selected location is one of the southwest point in Yangon Region in Myanmar. Salinity can be affected by both natural and human influences. Natural influences are freshwater flow, tidal stage, stratification of estuarine waters and rainfall. Human influences are dams and river diversions, land development, wastewater discharges and environment. The source of salinity in Letkokkon area is related with both natural and human influence. Sea level rise is one of the main reason behind the salinity in this area. The Satellite map showing the location of selected area is presented in Fig. 1.

Fig. 1 Selected Area in Location Map

B. *Installation of Salinity Measurement Devices*

In field observation, there have seven exposure sites at different distances (50 m, 295 m, 701m, 800m, 1694 m, 2958 m and 11379m) from the sea in the Letkokkon Village of the Kungyangone township in Myanmar. All sample house is the same level on the ground and one site at distance 800 m is on the roof slab of Technical High School are shown in Figure 3. The chloride concentration attached to the gauze is tested monthly and the deposition rate is calculated. The dry gauze method as specified in JIS Z 2382: 1998 is used as the captured devices [6]. The gauze, used in the hospital, is mounted on the wooden frame. The size of the gauze which is exposed to the atmosphere is 100 mm x 100 mm. The devices are placed at 1 m height above the ground level that are shown in Figure 2. They are placed under the sample house, which is oriented to the sea, in order to avoid the washing process due to the effect of rain and snow.

TABLE I
DIFFERENT DIRECTION OF AIRBORNE SEA SALT CAPTURED DEVICES

Sr. No.	Station No.	Distance from the Sea (m)	Facing Direction
1	L_1	50	163 SSE
2	L_2	295	154 SSE
3	L_3	701	165 SSE
4	L_4	1694	172 S
5	L_5	2958	204 SSW
6	L_6	11379	183 S

Fig. 2. Installation of Dry Gauze in the Sample House at Difference Distance

Fig. 3. Placing Sample House on the roof of Technical High School

The amount of airborne sea salt is measured by exposing the dry-gauze plates at the proposed locations for a duration of one month. After one month of exposure period, the installed devices are removed from each location and they are kept in the plastic bag until the chemical analysis. The chloride that attached to the gauze is measured by the silver nitrate titration at Environmental Laboratory in Yangon Technological University. The concentration of chloride is calculated by the formula of given in "Standard Method"; [9]

$$Cl^{-}\text{ (in mg/L)} = \frac{(\text{ml } AgNO_3 - \text{blank}) \times 0.5 \times 1000}{(\text{ml sample})} \quad (1)$$

C. *Calculation of the Deposition Rate of Chloride*

A method of dry-gauze plate is used to capture the chloride ion concentration in the atmosphere. The chloride concentration is measured by the silver nitrate titration of Standard method. When the values of chloride concentration are got, the deposition rate of chloride on the dry-gauze can be calculated by using the following formula;

$$R_{(NaCl)} = 0.0412 \times (C_1 - C_2) \times \frac{1}{t} \times 100 \quad (2)$$

Where,

$R_{(NaCl)}$ = deposition rate of Chloride [NaCl (mg/ m^2 . d)]

C_1 = Concentration of chloride ions in the exposed sample solution (mg/l)

C_2 = Concentration of chloride ions in the unexposed sample solution (mg/l)

t = exposure period (day)

$$0.0412 = \frac{\text{formula weight of NaCl}}{\text{atomic weight of Cl}} \times \frac{50 \text{ ml}}{1000 \text{ ml}} \times \frac{100 \text{ cm}^2}{200 \text{ cm}^2}$$

D. *Collection of the Meteorological Data*

The weather link station Model #6351 which is a kind of Vantage VUE system as shown in Fig. 4 is installed on the roof of Technical High School, Letkokkon Village. From this system, temperature (inside, outside, high and low), humidity (outside and inside), dew point, wind speed, wind direction, wind run, high speed, high direction, wind chill, heat index, barometer, rain rate and rain fall data can be got for every 30 minutes.

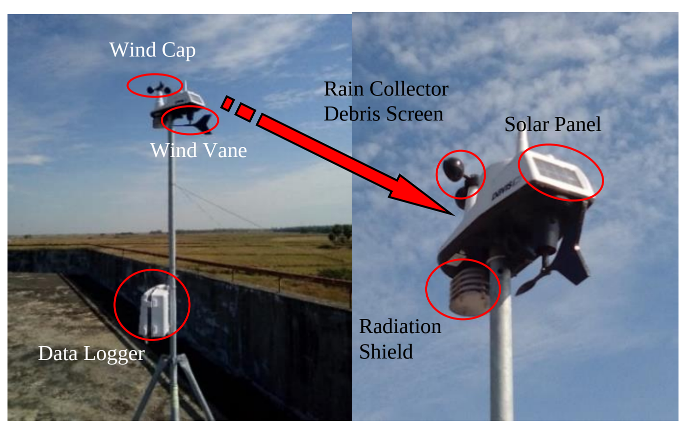

Fig. 4. Anemometer on the Roof Slab of Technical High School

III. ANALYSIS OF THE MEASUREMENT RESULTS

A method of dry-gauze plate is used to capture the chloride ion concentration in the atmosphere. The chloride concentration is measured by the silver nitrate titration of Standard method.

A. Chloride Deposition at Different Distances from the Sea

Chloride deposition rates for each site were monitored for a period of nineteen months from July, 2016 to January, 2018. Variations of chloride deposition in observation station are closely related to the season. The variation of chloride deposition in each month during the observation period is shown in Table 2.

TABLE III
DIFFERENT DIRECTION OF AIRBORNE SEA SALT CAPTURED DEVICES

Sr. No	Month	Distance from the Sea						
		50m	295 m	701 m	1694 m	2958 m	11379 m	800 m
1	July (2016)	4.81	6.87	9.06	7.55	18.13	Not start	
2	August (2016)	9.53	19.83	18.80	17.12	1.16	15.45	Not start
3	September (2016)	3.02	5.36	3.43	2.61	9.20	2.61	
4	October (2016)	2.53	1.59	4.78	4.65	5.32	2.79	1.33
5	November (2016)	4.97	2.98	2.98	3.13	3.41	2.98	5.11
6	December (2016)	5.15	4.64	2.45	12.23	3.73	2.70	4.38
7	January (2017)	7.00	5.08	4.67	13.05	4.94	3.98	8.24
8	February (2017)	9.06	8.51	7.83	32.41	8.10	7.83	10.16
9	March (2017)	14.15	12.22		28.84	19.09	14.28	20.33
10	April (2017)	17.07	20.16		42.67	22.66	33.11	28.40
11	May (2017)	12.13	4.23		19.23	13.85	11.79	20.49
12	June (2017)	19.91	5.84		19.57	33.07	14.88	31.59
13	July (2017)	10.76	10.53		12.47	22.20	9.5	14.65
14	August (2017)	8.90	15.15	Loss	8.77	14.49	7.04	6.11
15	September (2017)	7.30	3.30		3.06	7.53	1.29	2.00
16	October (2017)	5.97	1.96		1.65	6.80	2.16	2.88
17	November (2017)	3.79	3.63		1.81	2.47	3.96	1.98
18	December (2017)	6.99	4.66		1.79	3.92	2.51	7.88
19	January (2018)	4.85	4.39		6.22	5.22	3.51	7.67

B. Characteristics of the distribution of salinity

According to Table 2 and Figure 5, it can be seen that characteristic of chloride distribution in each station is not the same manner because some samples are placed in paddy field, other are in residential area and along road side. Therefore, environmental factors are one of the major influence of salinity distribution. The experimental results show that the variations of chloride deposition in each month not only depend on distance from the sea but also the meteorological parameters and environmental factors like fertilizers, chloride content in the soil and canal water.

As the above matter, deposition rate is not only dependent on distance but also other weather and environmental factors. Even longer distance could be affected more salinity concentration than near in some months and consequently specify as the salinity environment. This have been accordingly deduced and described the average chloride concentration over all points as presented in Figure 6.

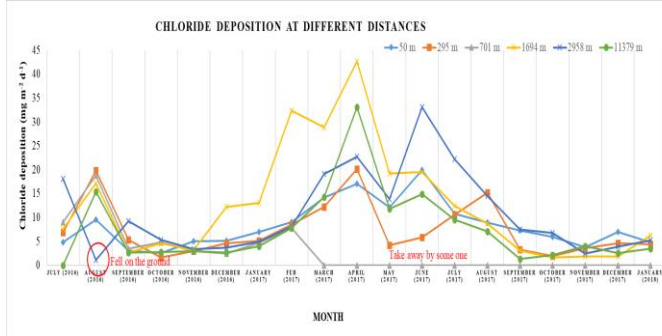

Fig. 5. Chloride Deposition at Different Distance

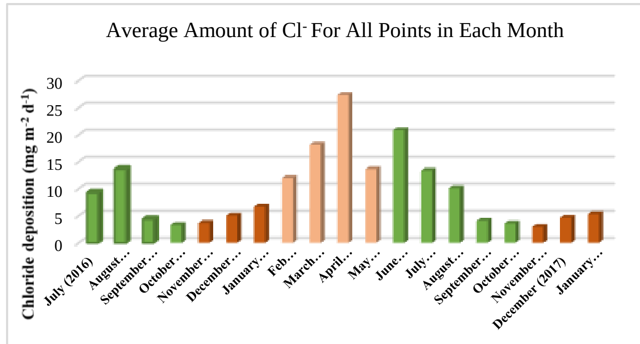

Fig. 6. Average Amount of Chloride for All Points

C. Wind Condition in Selected Area

Based on meteorological data, the magnitude of mean wind speed in that case, in rainy season is about 4.3 ms^{-1}. Furthermore, dominant wind direction for this season is southwest direction. Influenced wind direction in winter is almost north that normal to the coastal line and come from inland. During summer of rising temperatures, the magnitude of wind in both winter and summer are almost same as 2.2 ms^{-1}. The whole Bay of Bengal is almost clam and relax totally insignificant in storm formation. By April, important changes take place in the surface air movements over Myanmar [7].

As wind may influence not only wind speed but also frequency of wind, consider and draw the wind rose diagram according to getting meteorological data and showing in Figure 7 and Figure 8, maximum annual average wind speed is 3.25 ms^{-1}. Furthermore, the most frequent wind direction is from E and SE direction.

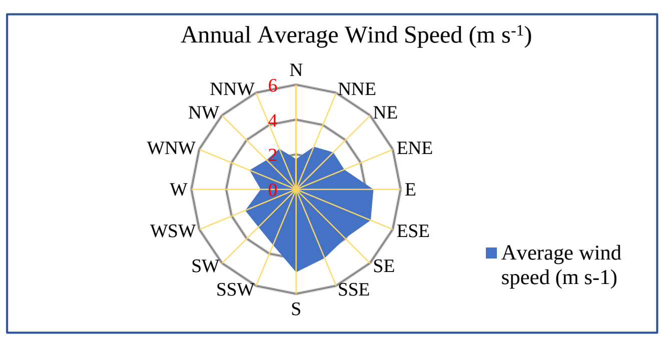

Fig. 7. Wind Rose Diagram with Annual Average Wind Speed

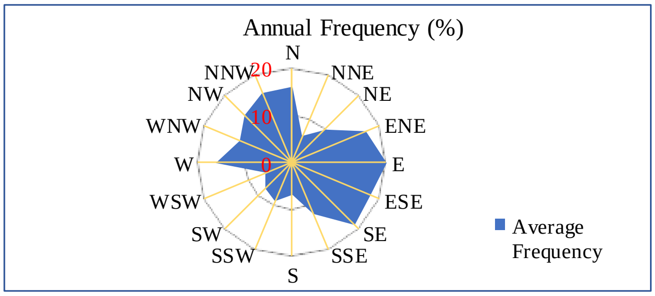

Fig. 8. Wind Rose Diagram with Annual Frequency

IIII. Simulation Details

Computational fluid dynamics (CFD) simulation is increasingly being used to guide the development of flow pattern and environment variable. This is partly attributable to a renewed interest in structural analysis, but also due to the availability of powerful affordable desk-top computers which are able to solve the complex nonlinear equations in CFD models within an acceptable time frame [8].

A. Boundary and Initial Conditions

OpenFOAM is essentially an open source software package that is primarily meant to be used as toolbox for applying the principles, method and modelling strategies conceived in the field of computational fluid dynamics. OpenFOAM software was used to simulate wind flow patterns around gauze. The software provides an efficient solution framework, including geometry handling, mesh generation, solution, post-processing and data analysis [9].

This is incompressible flow in two-dimensional rectangular domain. All the boundaries are walls, the bottom is slip form. A typical pre-processing (mesh generation) process for CFD computation is described in general. In this process description the domain geometry is taken as is from the design system [10] and shown in Figure. 9. The Reynolds number is defined as Re = UD/ν where U is the mean velocity of the imposed parabolic profile on the inflow boundary and D is the dimension of the sample.

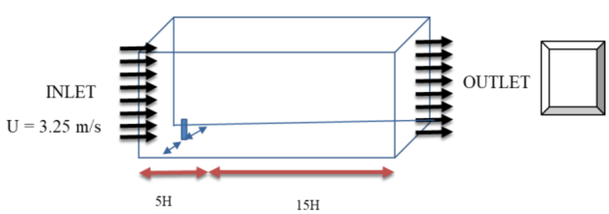

Fig. 9. Geometry of Computational Domain

B. K-epsilon Turbulence Model

K-epsilon (k-ε) turbulence model is the most common model used in Computational Fluid Dynamics (CFD) to simulate mean flow characteristics for turbulent flow conditions. It is a two equations model which gives a general description of turbulence by means of two transport equations (PDEs).

The first transported variable is the turbulence kinetic energy (k).

$$k = \frac{3}{2}\,(UI)^2 \qquad (3)$$

The second transported variable is the rate of dissipation of turbulence energy (ε).

$$\varepsilon = C_u^{0.75}\, k^{1.5} / \ell \qquad (4)$$

ℓ = 0.7L
I = the initial turbulence intensity [%]
U = the initial velocity magnitude
ℓ = the turbulence or eddy length scale
Cu = k epsilon model parameter [0.09]
L = characteristic length

C. Mesh Generation

Even though the actual data structure used to store the mesh in memory depends on the type of the dataset, some abstractions are common to all types. In general, a mesh consists of vertices (points) and cells (elements, zones). Cells are used to discretize a region and can have various types such as tetrahedra, hexahedra, etc. Each cell contains a set of vertices. The mapping from cells to vertices is called the connectivity.

The mesh generator included with OpenFOAM is named blockMesh that is shown in Figure 11. It generates meshes from an input dictionary blockMeshDict located in the constant/polyMesh directory in the case directory. The utility SnappyhexMesh was used for the generation of the different meshes. The shape of the plate was imported as a surface mesh from a shape created with a FreeCAD software that is described in Figure 10. It was then converted to a stereolithography (STL) file with a 0.15m element size varying according to the curvature of the shape. The STL file was then linked to snappyHexMesh for the creation of the volume of fluid. [11]

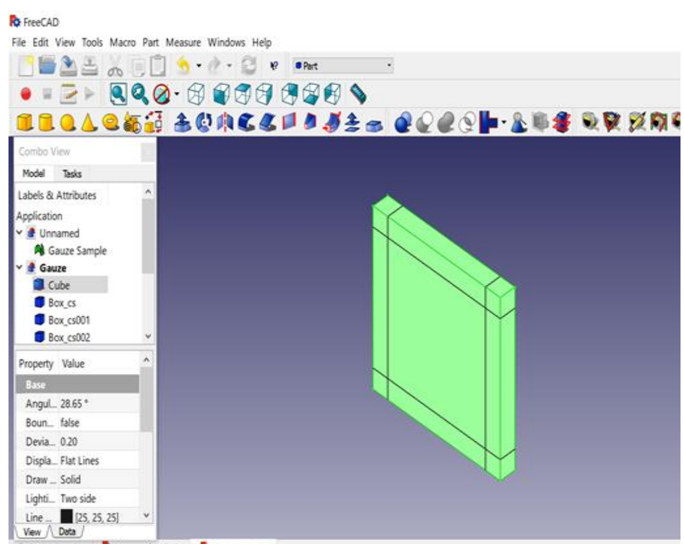

Fig. 10. Model of Plate in Free CAD Software

The meshing phase differs substantially depending on the mesh type. Unstructured tetrahedral mesh is usually generated automatically into the given geometry. The user needs to define meshing parameters like desired element size (mesh density) and optional local mesh adjustment parameters and mesh quality optimization attributes. The actual meshing is done by the routine. For structured mesh there are usually several manual process phases. The user defines the blocks for the mesh; typically, there has to be 12 block edges and six faces that topologically form a block shape. Creating a structured mesh for industrial geometry requires more time and may be a difficult task for complex geometries with many geometrical details. Especially for CFD this is often a decision and compromise between computational efficiency, accuracy and the time required for preprocessing. After the mesh has been successfully created the process continues with computation definition, including among others setting boundary conditions and initial conditions for the flow case. This phase is out of the scope of this report

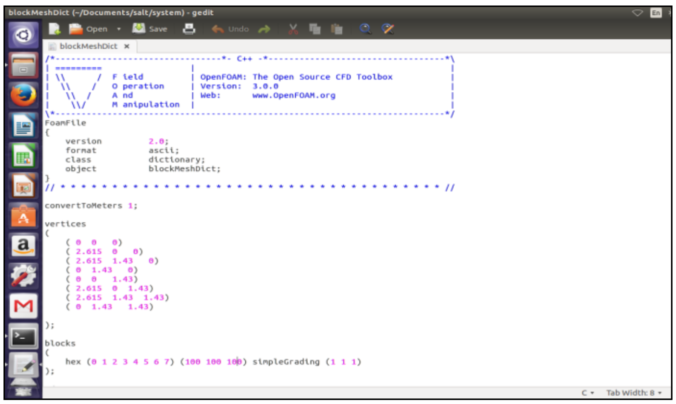

Fig. 11. BlockMesh in OpenFOAM Software

D. Run the Simulation

OpenFOAM applications can be run in two ways, as a foreground process, i.e. one in which the shell waits until the command has finished before giving a command prompt; as a background process, one which does not have to be completed before the shell accepts additional commands. To prepare paraFoam to display the data of interest, must first load the data at the required run time. If the case was run while ParaView was open, the output data in time directories will not be automatically loaded within ParaView. In this simulation the start time is 0s and the latest time is 2000s.

IIII. DISCUSSION AND RESULT ANALYSIS

In this simulation took turbulence into account with the k-epsilon model. This model was used for its proven reliability in simulation area and its ability to be a good freestream model with a good boundary layer model.

A. Post-processing

As soon as results are written to time directories, they can be viewed using paraFoam. Return to the paraFoam window and select the Properties panel for the cavity. OpenFOAM case module. If the correct window panels for the case module do not seem to be present at any time.

Even the control wind is 3.25ms^{-1}, buoyancy dominates and for the cases shown in figure is able to drive a flow out around the upper and lower edge of gauze plate is strong wind that is about 8% more than control wind. On the other hand, backward of the plate, downstream side can be clearly seen there is rare blow of air about 0.15m distance from the plate. The magnitude of wind has about 1.8 ms^{-1} when the distance reach 0.5m. Block mesh and slice to know the nature of flow are shown in Figure 12.

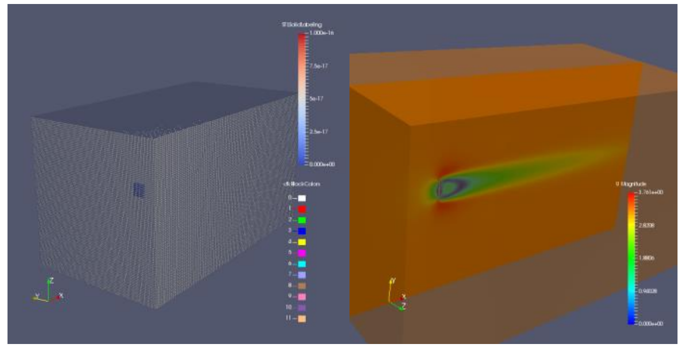

Fig. 12. BlockMesh and Slice to Show Air Flow

B. Stream Tracer

In order to displace the stream lines, it is being going to use the filter Stream Tracer but this filter cannot work on surface geometry so first extract the internal mesh. To do so, go to the filter menu in the paraView and select Extract Parts in the new panel open select only Internal Mesh and then Accept. Figure 13 show the air flow by stream tracer. It can be conclude, there is weak flow back of the plate according to the figure.

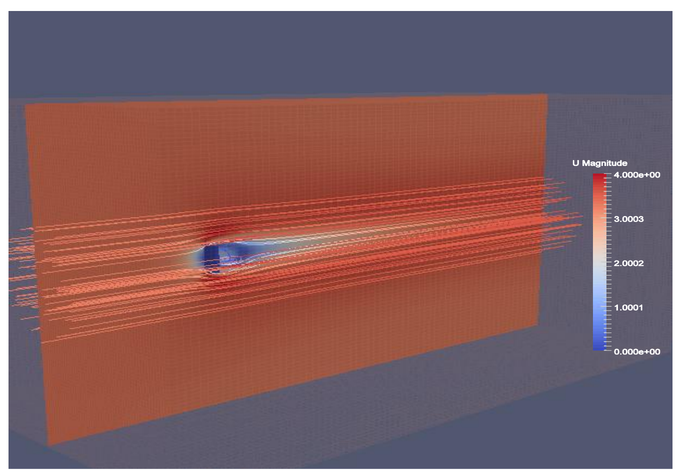

Fig. 13. Streamlines along the Gauze Frame

C. Discussion about Residual

Convergence was taken to be when the enthalpy residual (units of Watts) fell 10^{-4} of the U_x. Typically, this was after about 2000 iterations. A typical air flow pattern and typical pressure distributions are shown in Figure 14. The velocity vectors may slowly and steady stable when iteration reach around 10^{-3}.

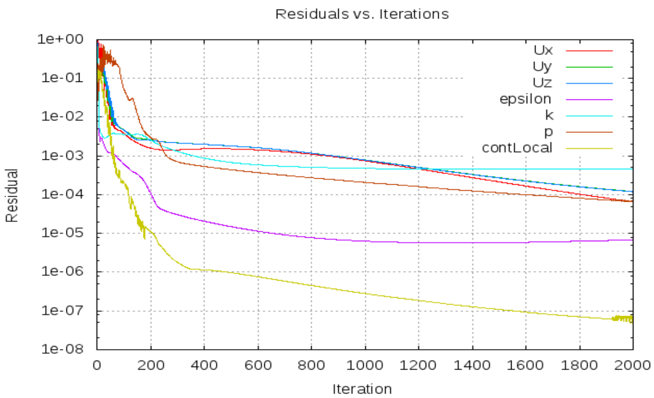

Fig. 14. Residual Plot with Logarithmic Scale

IV. Conclusion

The result of in-field airborne sea salt measurements that the trends of the distribution of seasonal air born sea salt are almost same for three number of stations (L_1, L_2 and L_3) in every month. But the content of airborne sea salt in (L_1) decreases in rainy season because of lacking fertilizer effect on it as it is located in open space. In winter and summer, (L_4) 1694 m from the coastal line is seriously high due to environment effects as placing near residential area. Even the control wind is $3.25ms^{-1}$, buoyancy dominates and for the cases shown in figure is able to drive a flow out around the upper and lower edge of gauze plate is strong wind that is about 8% more than control wind. On the other hand, backward of the plate, downstream side can be clearly seen there is rare blow of air about 0.15m distance from the plate. The magnitude of wind has about 1.8 ms^{-1} when the distance reach 0.5m. These flows are qualitatively similar to those obtained for the assisting flow simulations. In this paper we presented the CFD computations with OpenFOAM. All the shown results were made for the simulation of the fluid flow round gauze in the computational domain. The main goals were to know the nature of air flow that may carry chloride to be salinity environment. Further, we have shown one practical task, when we were interested about the pressure loss due to woven gauze that will be affect some percentage of chloride distribution over the salinity environment.

Acknowledgment

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[As Myanmar has the long coastal line, salinity environmental problem should be emphasized for the maintenance of deteriorated infrastructures have been subjected to chloride attack. It is going to be more serious problem in near future in which budget and resource are decreasing]