Development of A Consequence Analysis Computer Code, HYRISK

Seokwoo Sohn, Jihyun Kim and Moosung Jae*
Department of Nuclear Engineering, Hanyang University, Seoul, 04763, Republic of Korea
Corresponding author: jae@hanyang.ac.kr

1. Introduction

After the Fukushima accident in 2011, safety analysis of multiple accidents in Korea has been required, and research is actively underway. Despite a major accident, Japan maintains its existing power plant, and China's number of new plants are exploding. Most of China's major power plants are located near the West Sea, which is very close to Korea. Due to the concentration of nuclear power plants in adjacent areas, citizens are curious and anxious about the accidents of neighboring countries. Currently WinMACCS, developed by Sandia National Laboratory (SNL) in the United States, is widely used to evaluate the consequence of an NPP accident. However, this code is easy to evaluate up to 80km from the accident point, but it is difficult to evaluate at a further distance. Therefore, MURRG developed HYRISK, a code for evaluating long-distance consequences which is based on HYSPLIT, a code that is easy to predict the long-term spread of pollutants to evaluate the dose and risk of long-range accidents.

2. Methods

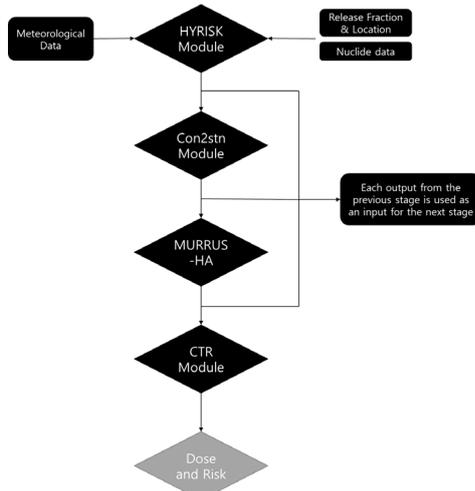### 2.1 HYRISK calculation process

Fig. 1. HYRISK Code Calculation Process

The HYRISK code is a bundle of modules in one package. There are 4 main modules for the calculation process. The HYRISK module, con2stn, MURRUS-HA, and the CTR(Convert to Risk). Each of the modules uses the output from the precious stage as an input for the next stage. After the 4 stages of the calculation process we can obtain the results which are the dose and risk from a specific NPP accident.

2.1 HYRISK Module

The first process of the code is the HYRISK module. This module is based on the HYSPLIT code which is the main code that calculates the concentration of the nuclides that are released from the accident simulation. The HYRISK module has a user-friendly GUI which is compatible with existing WinMACCS inputs. By automatically making the control file, which is the input used for HYSPLIT, it cyclically runs the HYSPLIT module reducing the time one needs to spend on making the inputs and running the process manually.
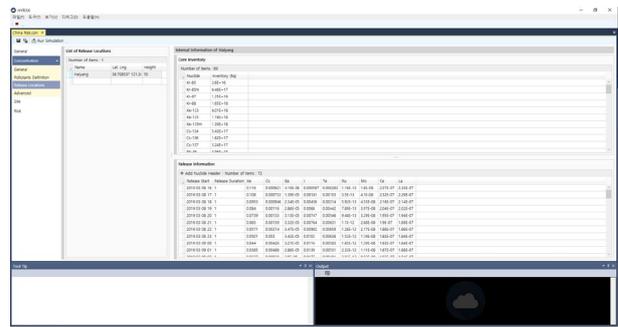

Fig. 2. HYRISK Module GUI

2.2 Con2stn module

The con2stn module is a module included in the original HYSPLIT code. The module is used to extract the concentration values within the HYRISK output. The output format of HYSPLIT is in a grid shape. On each grid point, there is a concentration value calculated from HYSPLIT and a latitude, longitude value with it. Con2stn allows the user to extract the values from a specific point in the grid. To overcome the limit of handling only one output file at a time, we used a system batch file to cyclically run 'con2stn.exe' for all the output files made from the HYRISK module.

2.3 MURRUS-HA

After running the con2stn model and collecting the concentration for the investigation points, another module is needed to organize the outputs. Since the con2stn module is originated from the HYSPLIT code, the output is not organized as desired. The output from the con2stn module must be modified for the final dose and risk calculation. MURRUS-HA is a tool used originally for extracting the outputs from the

WinMACCS code. The original tool was modified to suit the purpose.

Fig. 2. MURRUS-HA output specifics 1

Fig. 3. MURRUS-HA output specifics 2

In if you run the MURRUS-HA code, two excel files are created by default. Each of the files are names as 'STA01_L1' and 'STA01_L2'. STA01 represents the station number 1 which is the first station the user selected for calculation. L1 and L2 represents the levels to analyze concentration. There were two levels of interest in the sample figure, so there are two files for each level denominated as L1 and L2. If you look at Figure 2, there are up to three locations, so you can see that two excel files for each location are generated depending on the concentration you want to observe. Figure 3 shows the contents of the excel file. In each excel file, the concentration values obtained by HYRISK are entered at intervals of one hour depending on the period of data collection. Area 1, highlighted in red, is arranged according to the nuclide order the user entered in the HYRISK code. Area 2, highlighted in green, shows the date and time at the hourly interval from the day when data was collected. Area 3, highlighted in blue, shows the concentration values for each nuclide inspected for each time interval.

2.4 CTR Module

The final step of the HYRISK process is the CTR (Concentration to Risk) module. The CTR module calculates the dose and risk using the output concentration organized with MURRUS-HA. Figure 4 is an example of the CTR module interface. The user can calculate both the early fatality and the cancer fatality with the module. For calculation, the user loads the output csv file named L2 for air concentration data and loads L1 for ground concentration data. When loading is completed, the module automatically calculates the dose and risk at the specific station number. The calculation finishes instantly which is displayed in a different window like figure 5. The result windows on the left shows the dose for the selected organs by the order of sievert and on the fight shows the risk for each organ calculated by the dose and the total risk, which is the sum of all organs.
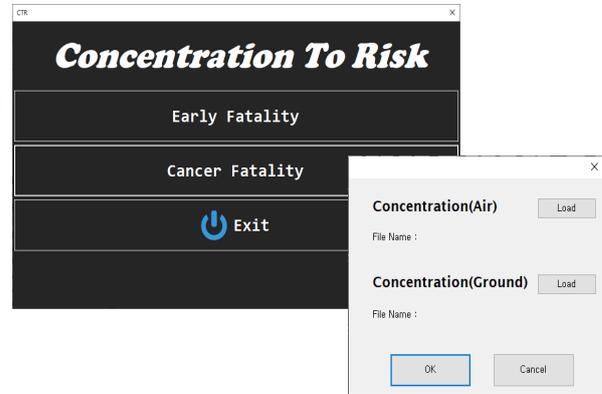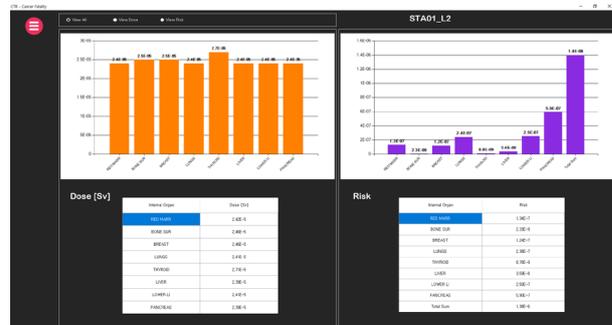

Fig. 4. CTR Module Interface 1

Fig. 5. CTR Module Interface 2

2.4.1 Dose Calculations

Calculation of air concentrations using HYRISK results in air and surface deposition concentrations for a total of 69 nuclides. Using these results, the doses for the three exposure pathways were calculated and summed.

1. Direct external exposure by radioactive material in the plume (cloudshine)
2. Exposure from the inhalation of radionuclides from the plume (inhalation)
3. Exposure to radioactive material deposited on the ground (groundshine)

The calculations for each exposure path were done using the formula for dose calculation in MACCS. Dose conversion factors used the values given in FGR13 (Federal Guidance Report No. 13). FGR13 provides dose conversion factors for 27 organs for 825 nuclides. The data were also used in the SOARCA study and were selected based on their association with the potential cancer risk factors of BEIR V used for future risk calculations.

2.4.2 Risk Calculations

For the risk calculation, a linear no-threshold model (LNT Model) was used. The LNT model is a model used for radiological protection to estimate probabilistic health effects, such as radiation-induced cancer, genetic mutations, and malformation-induced effects on humans due to ionizing radiation exposure. The LNT (2015)model can assess risks at both high doses, dose rates and at low doses, dose rates, but there is a big error in estimating low doses. Accordingly, ICRP-103 and UNSCEAR 2006 recommend that the dose-dose effect factor should be evaluated at low exposure doses. For the calculation of dose and risk, the formula for dose and risk calculation in MACCS is basically used.

3. Conclusions and Future Work
(Lee, Kim et al. 2014, Wu 2017)

Countries adjacent from Korea such as China have many nuclear powerplants alongside the same sea. At the time of evaluating the stability of nuclear power plants, interest in the impact on Korea in the event of an accident in these neighboring countries is increasing. Today, Win MACCS code is widely used for level 3 probabilistic safety assessment to evaluate the consequences for NPP accidents. However, 80km is the limit distance of the code. This study introduces a consequence analysis code called HYRISK. It is based on the HYSPLIT code which is widely used for tracking pollutant transportation throughout the atmosphere. There are 4 modules for calculation. The HYRISK module, con2stn module, MURRUS-HA and the CTR module. Each module is used for the final dose and risk calculation.

For future work, the code must be updated. Currently, four modules must be manually operated to achieve the desired result. However, for the convenience of the user, it should be supplemented so that it can be operated as a more complete integrated code. Also, the WinMACCS code is being updated with the HYSPLIT module installed. Since the current code is also based on HYSPLIT, verification procedure for the code comparing two codes is necessary, Also, since the current code derives results for one scenario, there is a DSA aspect rather than a PSA.

Acknowledgment

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