Development of A Consequence Analysis Computer Code, HYRISK

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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 longdistance 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.

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📙 Sample	2019-07-18 오후	파일 폴더	
hoacore10.dll	2019-07-08 오후	응용 프로그램 확장	8KB
MURRIS-HA 1.0.0.exe	2019-07-08 오후	응용 프로그램	88KB
hoacui.exe.config	2019-07-08 오후	CONFIG 파일	1KB
README.txt	2019-07-08 오후	TXT 파일	1KB
STA01_L1.csv	2020-03-18 오전	Microsoft Excel	41KB
B STA01_L2.csv	2020-03-18 오전	Microsoft Excel	42KB
🖬 STA02_L1.csv	2020-03-18 오전	Microsoft Excel	43KB
STA02_L2.csv	2020-03-18 오전	Microsoft Excel	43KB
STA03_L1.csv	2020-03-18 오전	Microsoft Excel	44KB
STA03_L2.csv	2020-03-18 오전	Microsoft Excel	45KB

Fig. 2. MURRUS-HA output specifics 1

_	18/06/11/10	190901011	18/06/10/12	18/08/11/18	18/08/11/14	18/08/11/16	18/98/11/16	18/98/11/17	18/98/11/18	18/52/11/18	18/08/11/29	HERE AND A	180001042
NOSS out							-			-			0
N002.04													
NO03 aut		6											
N004.eut												0	0
NOON out	6					0							0
Note and		0	0			0	0	0				0	0
Not? auk	6	0	0	6	0			0	0			0	D
No.8004		18,343	48,303	125.701	176.893	4.999	12.304	12.025	14.294	18.401	5.541	9.234	17.483
No03 out		10,279	12.762	\$2,904	-45.667	1,288	8.149	3.067	14,407	4.206	2.846	0.622	4.424
N010 evit		23.981	29,908	75.184	105.808	2.99	7.8	7.192	33.677	0.811	5.547	5,996	10.46
N(11 put		0.394	0.489	1,248	1.754	0.049	0122	0.119	0.545	0.942	0.094	0.042	6.171
NOTZOUR													
M013.04		2.118-18	1.596-13	1.196-13	1.108-19	1,908-15	4.140-18	2106-18	5.016-15	1.596-15	8.786-16	6.346-17	1,266-16
1014.04		6.827	6.625	28.899	54.221	CARP	1.545	2.108	10,821	2.188	1.825	0.000	8.907
NOTE OUR		2.428	1,210	1100	18,000	0.244	0.10	1.061	5.90	0.044	0.000	0.219	1.669
MALT AND		1001	0.04	6187	0.185	0.0001	0.000	0.0044	0.040	0.000	0.00010	0.00177	0.00404
April and		1.008-07	1410-07	6.755.07	8418.07	6.610.05	2.608-08	2198-08	7108-08	1.098.00	8.025.09	1.638-218	1,830,020
NOT Band													
MCCC and		774.676	940,373	3086.574	4479.265	47 857	216,212	269712	1283 824	311.606	188.047	65,289	386.248
14001 mult		1.048-05	8 548-04	1,208-08	1346-08	1426-07	\$718-07	1101-07	1188-06	8.764-07	1718-07	2.658-08	7.448-08
4022 put		244,553	294,508	860146	1217 591	12.848	67.629	68.054	101.877	77,079	45.10	14,491	75,347
NO23 out		1.006-18	5.545-19	1.976-19	1.118-19	1.676-21	4,896-21	1104-21	1.994-21	7.878-12	2.194-22	1.846-23	1.466-23
NODER		2.671	2.99	6.946	9.247	0.09	0.42	0.482	1,718	0.468	0.267	0.066	0.294
HOLS out		6.712	6.622	2.097	2.091	0.026	0.128	0.198	0.60	0.158	0.091	0.025	6.117
NO26 out	1.1	11,408	14.19	45.778	67.25	0472	8.097	4.829		4.628	2.674	0.972	6.28
1027.04		1.885-14	1.186-14	8.776-18	4.900-15	8.905-17	2.008-14	8176-17	1.706-18	5.006-17	1.838-17	1.746-18	2.826-18
NO28-out		37.148	46.177	148.678	218317	2.18	10.049	14014	60.602	14.996	9,008	1.146	17.348
Notitient		\$5.279	48.013	128.016	185,869	1.795	8.434	11.306	49.829	11.896	7,200	2.276	12.018
ACCC mult		\$70,994	704.063	2308.711	8326719	\$1.798	147,462	202.696	908.523	216.85	132.811	48.708	237.424
N001 put													
NG62 BUR		4818-08	5,875-08	1818-07	2318-07	1206-04	1218-08	1.436-08	6.428-08	1.696-08	1028-08	1206-09	1.686-08
1000.00		2278-07	2.816-01	8,250-07	1,208-08	1,798-08	8.358-04	1766-08	1000-07	1,010-08	5.718-08	1,908-08	1.048-07
NUMBER OF		0.010.010	1,228-11	2.176-11	2.160-11	5.425-15	1,050-12	1,048-12	4.616-12	1,000-12	2.214.48	7.445.03	5.765-18
MODE OUT		1446-27	1 648-17	4436.74	1275.74	8 144.31	1645-19	4165-00	7454-37	8124-00	2210-00	8575-07	6.016-01
Artist and	-												
NOTE AND		0.00383	0.00414	E dos	0.088	000124	0.0014	0.0021	0.018	0.00162	0.000889	0.000858	0.00804
NOT BUILD		8.008-11	8.746-11	2.948-10	8,408-10	1128-11	1.645-11	1.808-11	1,208-10	1,476-11	8048-12	7,788-12	8,478-11
NOLDAUA		2.848-12	8.196-12	2.198-11	2.818-11	8478-13	1208/12	1408-12	1.008-11	1.268-12	6.888-13	6.612-12	4.708-12
NO41 eut		0.00219	0.0027	0.018	0.004	0.000744	0.000976	0.001.28	0.00792	0.000817	0.000534	0.000495	0.00343
NG42 evel		2,916-04	8.248-06	1808-08	1408-05	3348-07	6.548-07	7.838-07	3.818-06	8-248-07	2718-07	1.636-07	9.738-07
NG43 put		1,106-18	7.718-18	7.818-18	6.646-19	8.788-21	1,698-20	8428-21	2.044-20	4418-21	1.818-21	1,846-22	4,778-22
NG44.out						4				4			0
NO45 PUT		0.029	0.007	6177	0.229	0.012	0.015	0.014	0.076	0.019	0.00755	0.00448	0.08
NOWLOUT		0.00762	0.00929	0.042	0.054	0.00251	0.00433	0.00014	0.016	0.00249	0.00148	0.000923	0.00588
NOUT OUT		120.0	0.026	D.127	0.165	0.00631	0.011	-8.01	0.285	0.00981	2.00545	0.00316	8.022
NO48 Aut		6.227	0.279	1,299	1.868	0.081	0106	0.101	0.828	0.091	0.063	0.081	0.199
NOR1 out	-	5.796-05	7,218-08	5.00009	0.000484	2318-08	2,985-05	2.848-08	0.000182	2.578-08	1.808-08	9248-06	6.096-05
ACR INC.	-	1.000	1.110	4.077	1000-05	4.000	2,816-06	1748-06	1498-08	2.485.08	1416-06	8.828-07	1.000-00
NUM TOUR		1.000107	1,000,000			0.000000	0.100.00	0.0000	0.000.00	0.00000	0.0000441	0.000104	0.000
hitted		0.028	0.004	0.174	0.228	0.012	0.016	0.014	0.074	0.018	0.00782	0.00442	0.01
ALC: A DEAL		200345	0.00288	8013	0.014	0.000672	1000915	0.000845	0.00412	0.000748	0.000415	0.000227	0.0014
1055.04	-	1.948-06	2.448-06	1145-05	1538-04	7 718-07	8.968-07	8428-07	6.098-06	8478-07	\$.048.07	8108-07	2.048-06
1056.04		0.000464	8-00119	0.00474	0.00744	0.000875	0.000487	0.000mla	0.00248	0.000428	0.000247	0.000+5+	0.000994
N067 put		0.000184	0.000229	0.0011	0-001-48	7,228-04	8,275-04	8.948-05	0.000418	8.146-05	4.768-05	2.918-05	0.000182
NOSEOUT		6.012	6015	0.066	0.088	0.00418	0.00647	0.00621	0.827	0.0047	0.00272	0.00155	0.00993
NOT BUILD		6.875-07	8.896-07	1,466-06	1.688-06	4.405-08	7.615-08	6.605-08	2.648-07	1.431-08	2766-08	8.716-09	4.228-08
NOSCAR		1.806-14	1.188-14	1228-14	1148-14	1.686-16	4.006-16	2.286-16	6.035-16	1.596-16	8.205-17	8.715-18	2,258-17
N061.eut		0.011	0.013	0.063	0.082	0.0041	0.00531	0.00609	0.517	0.00462	0,0027	0.00163	0.011
NO52 euk		0.004	0.029	6141	0182	0.00911	6012	0.011	0.06	0.01	2.00601	0.00364	0.004
NO\$3 mult		0.000678	0.000888	0.00188	0.005	0.000242	0.000018	0.000908	0.00159	0.000274	0.000189	9,318,08	0.000403
1054.eut		6.019	8.024	0116	0.16	0.00793	0.00877	0.00982	0.05	0.00848	0.00496	0.00908	0.02
ACCE OF		1.146-07	5.17E-07	2,868-07	8.268-07	8176-08	1408-08	1,228-06	4.736-08	9.908-09	4.968-09	1.478-09	1146-09
(1)		0.000349	0.000429	0.00142	0.00202	7,876-08	8.000112	0.000-05	0.00060-	9.206-05	\$128-06	2.418-05	(2) 111
		\$246-25	1.778-28	\$ \$16-26	1496-26	7.048-28	1,268-27	8796-28	\$346-28	1766-28	4.718-29	1748-30	5.00
NUMBER		- 0	-0					- 0				0	- 0

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. 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.

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REFERENCES

[1] (Hong, Lee et al. 2011, 2015, Wu 2017, 윤, 한 et al. 2018) [2](2015). "Nuclear Power in China." from www.worldnuclear.org/info/.../China--Nuclear-Power/.

[3]Hong, S. K., et al. (2011). "후쿠시마 원전사고 이후 원자력 발전을 둘러싼 주요 쟁점 및 향후 정책 방향." STEPI **84**.

[4]Lee, G.-Y., et al. (2014). "Analysis of the Effectiveness of Emergency Response Measures during the Design Basis Accident of the Research Reactor 'HANARO' using MACCS2 Code." Journal of Radiation Protection and Research **39**(2): 109-117.

[5]Wu, Y. (2017). "Public acceptance of constructing coastal/inland nuclear power plants in post-Fukushima China." Energy Policy **101**: 484-491.

[6]윤, 성., et al. (2018). 중국의 원자력 정책 및 연구개발 현황. 원자력정책연구 Brief Report, 한국원자력연구원 원자력정책연구센터. **46**.