Analysis of Gaseous Effluents during Normal Operation of Planned Nuclear Power Plants at Pątnów Localization in Poland

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1. Introduction

One of the most important objectives of nuclear system analysis during normal operation of the NPP is to determine the impact that it will have on the environment. Due to the certain safety limits [1] regarding radioactive release the NPP should not exceeds, it is crucial to calculate the reactor's radioactive release during normal operation. There are a number of radioactive effluents that can be released in a gaseous during the normal operation of NPPs. In order to ensure public safety, it is essential to assess the radiological effects of the radioactive release during normal operation of the NPPs. According to a statement made in September 2021, six pressurized water reactors with combined capacity of 6-9GWe will be built by 2040 in order to reduce Poland's dependence on coal [2]. In accordance with the adopted schedule, construction of the first nuclear power plant will begin in 2026, with the first reactor (with a capacity of 1-1.6 GWe) to be commissioned in 2033. The following units will be implemented every two to three years. As part of a large commitment to embrace nuclear energy in the country, at the end of the year 2022 Polish authorities announced the choice of the two locations and two technologies of the first commercial nuclear power plants in the country. Westinghouse AP1000 reactors were selected by the Polish government to build the country's first nuclear power plant in location of Lubiatowo-Kopalino, on the coast of the country in Choczewo municipality in Pomerania. In the meantime, Poland's ZE PAK, Polska Grupa Energetyczna and Korea Hydro & Nuclear Power have signed a letter of intent to coordinate on a nuclear power plant project in central Poland, evaluating the feasibility of building South Korean APR1400 reactors on Pątnów site. Following the planned construction of the first Polish commercial nuclear plants, concerns were raised from the public and regulatory bodies about radioactive materials released into environment. The presented study's objective is to analyze the radioactive release of proposed nuclear power plant (NPP) in the Pątnów location in Poland during normal condition.

2. Methods and Results

In this study, the GALE [3] mathematical calculation modeling code was used to obtain the releases of radioactive materials in gaseous effluents of APR1400 reactor during normal operation conditions. Following this, Hotspot software was used to calculate the radiation risk to downwind areas using GALE code results as source terms and incorporating metrological data for the localization.

The methodological parameters used for analyze were as follow: 3 m/s of wind speed, 270° as the wind direction, C slightly unstable condition for the atmospheric stability class. All the parameters were found by analyze of the weather data from the nearest meteorological station measurements from June 2019 to March 2023 [4]. The wind rose represented on the Fig. 1 was created by using WRPLOT.

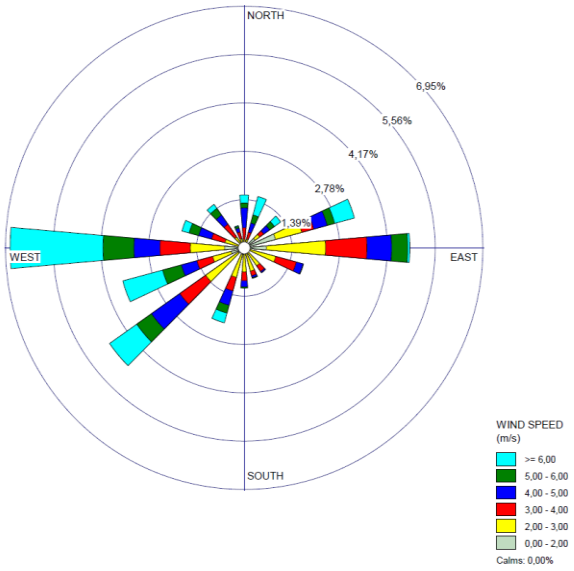

Fig. 1. Wind rose obtained from weather data

Based on the nuclear reactor type specification [5], GALE code calculated the gaseous effluents produced by the plant. The attained gaseous source terms include noble gases, iodine, radioactive particulates, tritium and ^{14}C. The findings were compared with Environmental Report for APR1400 reactor type [6]. A comparison of the results from GALE code calculations and the Environmental Report is presented in Table I. The release rates of the elements follow a similar trend with reasonable ranges.

Table I: GALE calculation and environmental report data of radioactive gaseous release [4]

Nuclide	Half-life	Calculation (Ci/yr)	Environmental Report (Ci/yr)

^{131}I	8.02 d	7.90E-04	1.80E-03
^{132}I	2.29 h	2.20E-02	4.80E-02
^{133}I	20.81 h	5.40E-02	2.30E-02
^{134}I	52.52 min	1.30E-01	7.90E-02
^{135}I	6.57 h	9.60E-03	4.60E-02
^{85m}Kr	4.48 h	3.00E+00	7.00E+00
^{85}Kr	10.78 y	6.90E+02	4.90E+03
^{87}Kr	76.35 min	1.00E+00	2.00E+00
^{88}Kr	2.84 h	3.00E+00	5.00E+00
^{131m}Xe	11.93 d	1.90E+02	2.20E+03
^{133m}Xe	8.39 ms	1.60E+01	1.30E+02
^{133}Xe	5.25 d	4.00E+00	7.00E+01
^{135m}Xe	15.30 min	6.00E+00	8.00E+00
^{135}Xe	9.14 h	1.80E+01	5.10E+01
^{137}Xe	3.82 min	0.00E+00	3.00E+00
^{138}Xe	14.09 min	1.00E+00	3.00E+00
^{51}Cr	27.70 d	5.90E-04	9.70E-05
^{54}Mn	312.08 d	4.30E-04	5.70E-05
^{57}Co	271.75 d	8.20E-06	8.20E-06
^{58}Co	70.87 d	2.30E-02	4.80E-04
^{60}Co	5.27 y	8.70E-03	1.10E-04
^{59}Fe	44.6 d	7.70E-05	2.80E-05
^{89}Sr	50.52 d	3.00E-03	1.60E-04
^{90}Sr	28.90 y	1.10E-03	6.30E-05
^{95}Zr	64.03 d	1.00E-03	1.00E-05
^{95}Nb	34.99 d	2.40E-03	4.20E-05
^{103}Ru	39.26 d	7.70E-05	1.70E-05
^{106}Ru	373.59 d	7.50E-05	7.80E-07
^{125}Sb	2.76 y	6.10E-05	6.10E-07
^{134}Cs	2.07 y	2.30E-03	4.80E-05
^{136}Cs	13.16 d	8.00E-05	3.30E-05
^{137}Cs	30.17 y	3.50E-03	9.00E-05
^{140}Ba	12.75 d	4.00E-04	4.20E-06
^{141}Ce	32.50 d	3.90E-05	1.30E-05
^{3}H	12.32 y	1.10E+03	1.60E+02
^{14}C	5.71E+03 y	7.30E+00	7.30E+00
^{41}Ar	109.34 min	3.40E+01	3.40E+01

The radiological risk during normal operation of APR1400 at the Pątnów site was calculated using the Hotspot program with the input of source terms from GALE code and metrological data. Effective release high was entered as 76.4 m, which corresponds to the high of APR1400 Containment Building. The Total effective dose equivalent was determined. During normal operation with small doses and short half-life, iodine and majority of noble gases pose fewer hazards than in an accident involving high release doses. Due to its half-life of around 12 years, tritium is the most dangerous gaseous release during normal operation condition. The highest dose earned during analyze was 2.75E-06 Sv/yr for the tritium and ^{14}C mixture at the distance 0.71 km away from the power plant. A dose of this magnitude is below the limits set by 1mSv per year for the public. In Fig. 2, the calculated TEDE for all atmospheric stability classes (A-F) for the four mixtures of radioactive sources is shown as a function of downwind distance.

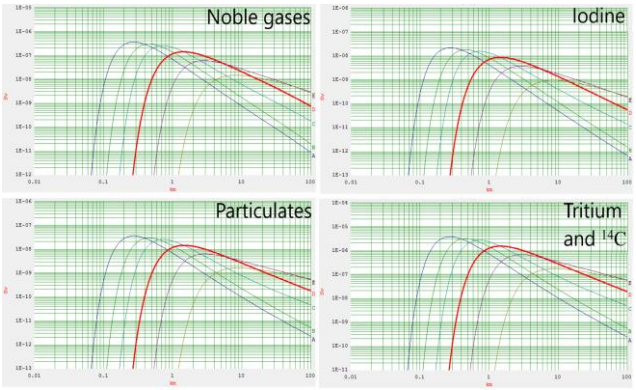

Fig. 2. The TEDE results for mixtures as a function of downwind distance

3. Conclusion

In this study the radioactive gaseous release during normal operating condition for the planned Korean APR1400 reactor in the site of Pątnów in Poland was analyzed. The radioactive release obtained from GALE code and the meteorological data from the nearest weather station, was used as the input for the HotSpot software in the TEDE calculations. The GALE results were compared with Environmental Report for APR1400 reactor type. This comparing indicates that elements release rates follow a similar trend with reasonable ranges. The TEDE values were found to be below the regulatory limits.

Acknowledgement

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