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ESTIMATION OF RADIONUCLIDE RELEASES IN ATMOSPHERE FROM CERNAVODA NPP BASED ON CONTINUOUS GASEOUS EFFLUENT MONITORING

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ABSTRACT

Monitoring of gaseous effluents from Cernavoda NPP is performed to assess the environmental impact of the plant operation. The results of the monitoring program are used to evaluate the population doses in order to ensure that the emissions of radionuclides in air are below regulatory limits and radiation doses are maintained ALARA. It complements, but is independent from the Operational Environmental Monitoring Program for Cernavoda NPP.

Gaseous effluent monitors provide continuous indication of the radioactivity content in atmospheric emissions. Except for noble gases, these monitors also collect samples for later detailed analysis in the station Health Physics Laboratory. This paper presents the main equipment and the results of the gaseous effluents monitoring program in order to assess the impact of Cernavoda NPP operation and to predict the future releases as function of radionuclides concentrations in CANDU systems, based on the identified trends.

1 INTRODUCTION

Proper ventilation is necessary to maintain a safe and comfortable workplace in any nuclear power plant; however, the ventilation exhaust is also a potential pathway for the release of radioactivity into the environment. Cernavoda CANDU 6 NPP (700 MWe) central ventilation system collects potentially contaminated air from four sources:

(a) Central Contaminated Exhaust System
(b) Reactor Building Exhaust System
(c) Spent Fuel Bay Exhaust System
(d) Upgrader Tower Exhaust System

The ventilation systems at Cernavoda NPP Unit 1 are designed so that air from all areas, which could become contaminated, is drawn through banks of filters before being discharged from the stacks. High Efficiency Particulate Air (HEPA) filters are used, which remove 99.97% of all particles having a diameter of 3 microns or more. Activated charcoal filters are used usually sandwiched between two HEPA filters to remove radioiodines. The final HEPA filter is to trap any charcoal dust, which escapes from the charcoal filter. Most systems have prefilters to remove any larger particles. The combination will allow less than 0.5% of the radioiodines to pass through. In areas of the station where heavy water systems exist, the Closed Cycle Vapour Recovery System recovers much of the tritium.

The emissions are mainly gases but they could contain particulates and vapor (radiodines and tritium) as well. All gaseous effluents are exhausted at the stack, which disperses it to the environment. A sample of the airflow in the stack is extracted and routed to the Gaseous Effluent Monitor (GEM) for continuous monitoring of respectives radionuclides.

2 GASEOUS EFFLUENT MONITORING

2.1 Gaseous Effluent Monitoring System (GEM)

The release of radionuclides from the ventilation exhaust stack is continuously monitored by extracting and routing to the Gaseous Effluent Monitor (GEM) a representative air sample for direct measuring and subsequent analysis. GEM monitors the release of particulate, radioiodine and noble gases and collects water vapour (for tritium) and gases containing carbon (C-14) on absorbers for further detailed laboratory analyses. Air is drawn, by electric pumps, via three sample tubes, which protrude into the main stack flow. The samplers are approximately isokinetic and flow-measuring devices provide information about flow rates with the ability to generate alarm signals when the sample flow moves outside predetermined limits (e. g. because of a filter blockage).

The GEM provides the following functions:

- ♦ High activity alarms alert the Main Control Room operator if there is an unexpected increase in particulate, radioiodine or noble gas activity in gaseous effluents.
- ♦ The total activity alarm setpoints are established at 5% of the daily Derived Emission Limits (DELs) of the respective radionuclides monitored on Particulate, Iodine and Noble Gases channels.
- ♦ Particulates, radioiodines, gases containing carbon (C-14) and water vapour (for tritium) from the sample flow are collected or absorbed on filters for later analysis in the site Health Physics Lab and comparison with the DELs.

2.1.1 The Particulate Monitor (GEM)

The Particulate Monitor samples and measures β-emitting radioactive particulates. A representative sample of the main stack airflow is drawn via an isokinetic sampler and a flow measuring device through a glass-fiber filter paper Gelman Type A. Any radioactive material accumulated on the filter is viewed by the plastic scintillator detector which is sensitive to alpha and beta radiation. The detector electronics discriminates between alpha and beta radiation. The signal is proportional to the total activity accumulated on the filter.

This information, together with the data from the stack flow monitor is used by the GEM's microcomputer to calculate the total activity discharged since the last filter change and the current discharge rate. If the total activity discharged or the current discharge rate exceed the pre-set setpoints, visual and audible warnings are provided at the Electronics' Cabinet and signal are also sent to the Main Control Room. Signals are also generated in the event of a system fault, or when the system is under maintenance.

A flow measuring device (CT Platon "Flobar") is mounted in the sample line and monitors the flow through the filter. Alarm signals are generated if the sample flow moves outside predetermined limits.

The activity range is 10^{-4} to 10 GBq/day.

2.1.2 The Iodine Monitor (GEM)

The Iodine Monitor samples and measures ^{131}I. The iodine monitor is bolted directly to the Particulate Monitor so that the exhaust air from the latter enters the Iodine Monitor. The exhaust air from the Particulate Monitor is drawn through a TEDA-activated charcoal filter (F&J Specialty Products Type TE3M.5) which retains iodine. The filter cartridge is viewed by a scintillation counter fitted with a sodium iodide crystal (NaI:Tl) which is sensitive to gamma radiation and which provides a signal related to the energy of the incident gamma ray.

The Control Electronics provide compensation for the effect of background radiation and generate display and alarm/status information in the same way as for Particulate Monitor. The activity range is from $4 \cdot 10^{-5}$ to 40 GBq/day.

2.1.3 The Noble Gas Monitor (GEM)

The Noble Gas Monitor measures gamma emitting noble gases ^{41}Ar, ^{133}Xe, ^{135}Xe and ^{88}Kr. Air sampled from the stack is drawn into a stainless steel chamber with two sealed “wells” into which gamma detectors are fitted. These two detectors are of different types and sensitivities in order to monitor two overlapping activity ranges.

The Low Level Detector is a large scintillation counter fitted with a phosphor. The detector signal output is proportional to the product activity·energy for the gas present in the sample chamber at a time. The activity range is from 10^{-2} to 100 TBqMev/day.

The High Level Detector is a Geiger-Mueller counter with an approximately uniform Bq MeV response. The activity range is from 10^{-1} to 1000 TBqMev/day. [1]

A TEDA-impregnated charcoal filter is fitted upstream of the Noble Gas Monitor chamber in order to remove iodine which would otherwise interfere with the noble gas measurement.

A flow measuring device (CT Platon “Flobar”) is mounted in the sample line and monitors the flow through the Noble Gas Monitor chamber.

2.1.4 Pitot Head and Flow Measuring Device (GEM)

The Pitot Head is fitted inside the stack to measure the velocity of the main stack airflow. This information is used to calculate the activity discharged via the stack.

2.2 Gaseous effluent monitoring program

The gaseous effluent monitoring program is designed to assess radioactive releases at the point of emission in order to provide a measure of the total amount of each type of radioactivity emitted. At the same time the results were used to assess doses from radioactive effluents and maintain radiation doses to a member of the design dose objectives and the limits approved by the competent authority (DELs).

Derived Emission Limits (DELs) represent the upper limit for the release of a single radionuclide from a single facility for airborne or liquid effluents. This upper limit is derived from the regulatory dose equivalent limit, 1 mSv in case of Romanian regulations, by analitical models of all significant environmental pathways to an individual in the most exposed group (i.e. “critical group”). [2]

In conclusion the gaseous effluent monitoring program has two main objectives:

- ♦ to continuously monitor the emissions of radioactivity and alert to changes from process or procedural failures and can take steps to minimize the release.
- ♦ to measure actual releases of radioactivity in order to demonstrate that the regulatory emission limits have not been exceeded.

2.3 Laboratory Analyses

After the filter media have been removed from the GEM, detailed analyses are done by the Health Physics Laboratory to determine more accurately the radioactivity of the emissions. Analytical sensitivity requirements of the methods were established in terms of specific activity in gaseous effluent. They have been derived considering the lower detectable activity as $5 \cdot 10^{-2}$% DEL. These values ensure that even if all the radionuclides are under the detection limit their summation will be less than the operating target of 5% DEL.

Gamma emitting particulates collected on filters are daily analysed by gamma ray spectrometry. Gross beta analyses are also performed on each filter. If gross beta activity summed for a week is equal with or exceeds 5% of weekly DEL for the most restrictive beta-gamma radionuclide of gaseous effluents radiostrontium analysis will be performed on the set of particulate filters used during the week.

Charcoal cartridges are measured daily by gamma spectrometry to identify radioiodines.

Tritium (as tritiated water) is extracted biweekly from the filter media (molecular sieve) and is measured by liquid scintillation counting (LSC) method.

A bubbler-type collector is used to capture carbon dioxide from the stack air sample (NaOH solution). C-14 is measured by using LSC method. This analysis is performed weekly.

A computer database of the radioactivity discharged by gaseous effluents is maintained and the information is given in periodic reports.

3 SUMMARY AND DISCUSSION OF MONITORING DATA

Gaseous emissions from Cernavoda NPP were at low levels as are presented in Figure 1. Dose values associated with all radioactive emissions were below 1% of annual DEL.

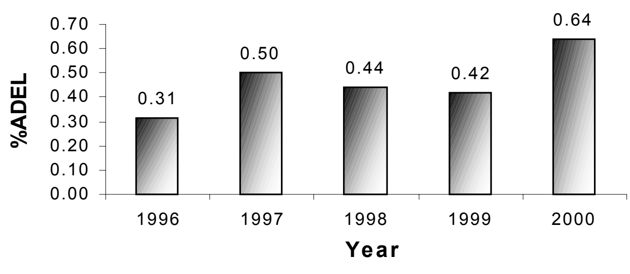

Figure 1: Cernavoda NPP gaseous emissions, 1996 – 2000

Table 1 presents detailed annual emissions for the main radioisotopes. The activities discharged every year were below 1% from the authorized DELs for all the significant radionuclides. Excepting tritium, ^{14}C, and noble gases minor quantities of activation products such us ^{51}Cr and ^{95}Nb were only occasionally registered which proves the efficiency of the ventilation systems. No radioiodines were measured, and we must say that there was no defective fuel last in the two years of operation.

Table 1: Cernavoda NPP gaseous emissions between 1996 – 2000

Isotope	**Annual DEL (kBq)**	**%Annual DEL**				
		1996	**1997**	**1998**	**1999**	**2000**
C-14	1.1E+11	3.21E-02	1.63E-01	2.64E-01	1.55E-01	2.12E-01
Cr-51	1.4E+12	-	-	-	-	4.33E-08
H-3(oxide)	5.3E+13	2.61E-03	4.88E-02	9.67E-02	1.62E-01	3.97E-01
Nb-95	3.3E+09	-	-	-	-	2.40E-06
Noble Gases*	2.2E+13	2.79E-01	2.05E-03	8.12E-02	9.89E-02	3.22E-02
Total Releases		3.14E-01	5.00E-01	4.42E-01	4.17E-01	6.41E-01

*In case of noble gases DELs are expressed in kBq MeV

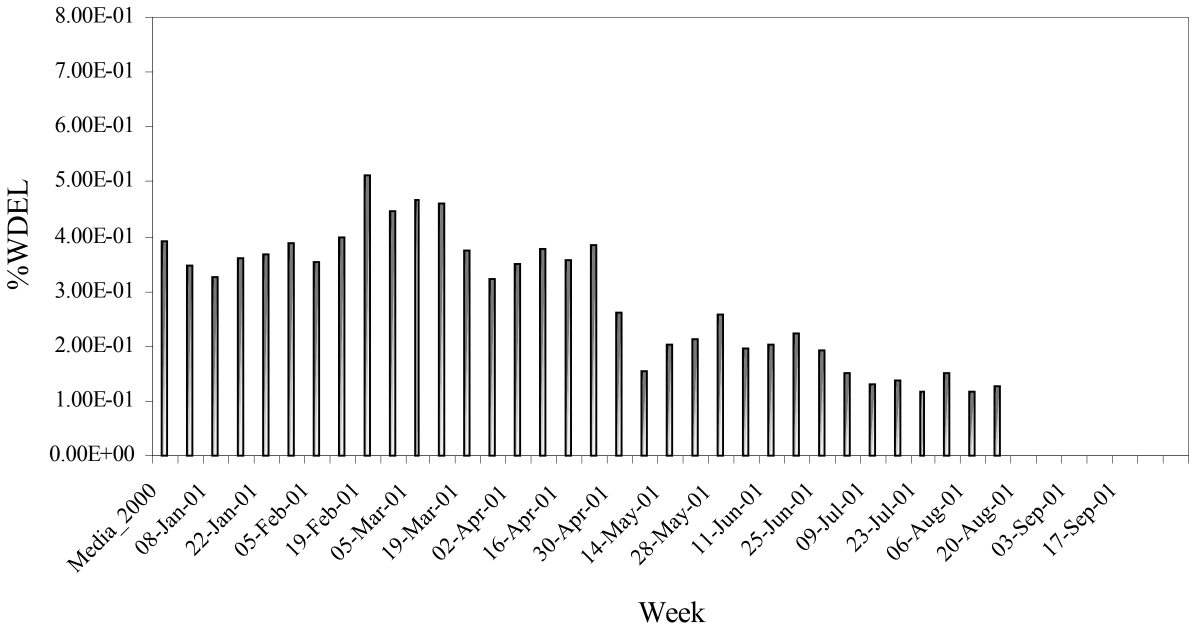

Figure 2: Weekly tritium emissions in 2001

Tritium emissions were also below 1% of annual DEL. A statistical analysis of weekly tritium emission data revealed an erratic evolution around a growing trend due to the build-up in the main systems of the reactor. Based on this trend estimate it is expected that in normal conditions mean emissions would be well below the operational limit of 5% DEL over the life time of the plant. [3]

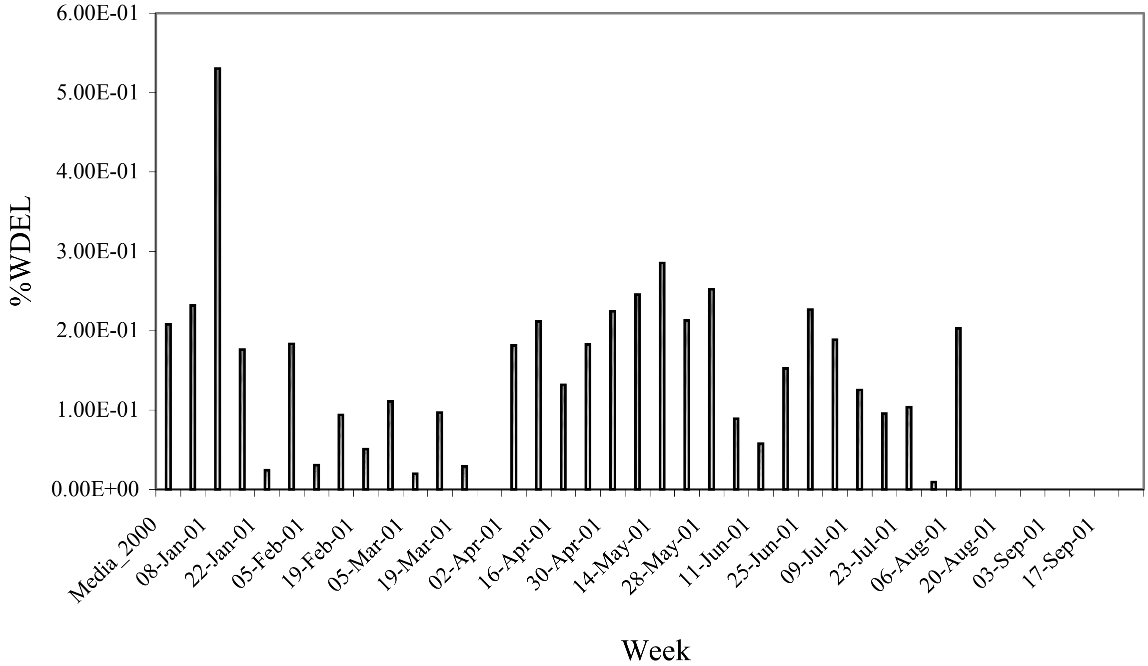

Figure 3: ^{14}C emissions in 2001

Carbon emissions were also below the operational limits (see Table 1). The highest ^{14}C annual airborne emission that have occurred was 0.26% DEL in 1998. The emissions picture of ^{14}C emissions is rather complicated by the occurrence of a number of excursions associated with particular events as illustrated in Figure 3 for the second week of January 2001.

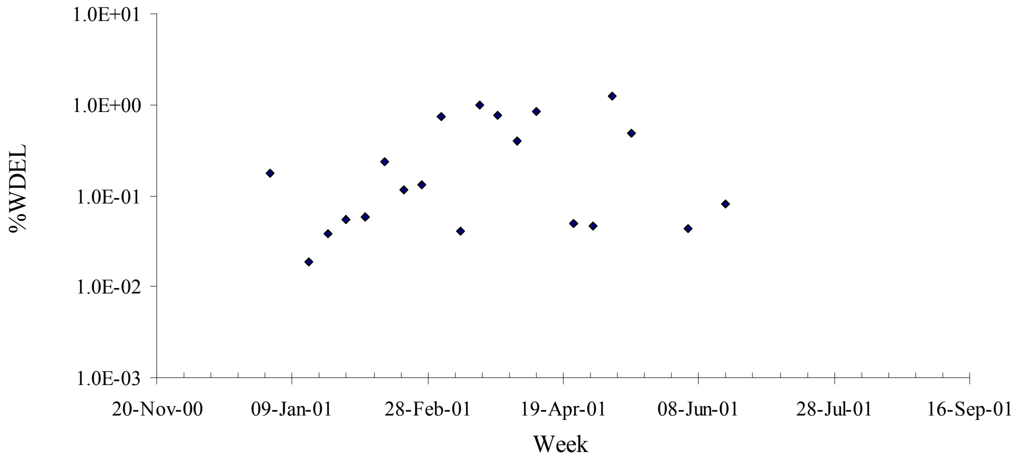

Figure 4: Noble gases in gaseous effluents, 2001

Noble gases emissions were generally very low as is shown in Table 1. Between 1996 and 2000 the annual emissions varied between 2.05E-03 and 2.79E-01 % DEL. Some higher values, up to 1% WDEL were observed in 2001 for short time periods (Figure 4). Special investigations including "in situ" gamma ray spectrometry established that the main contributor was ^{41}Ar formed by neutron activation.

4. CONCLUSIONS

Gaseous effluents monitoring system and monitoring program provide a comprehensive surveillance of the radioactivity of gaseous effluents from Cernavoda NPP.

Due to the design features of CANDU 6 systems, including ventilation, radioactive emissions of Cernavoda NPP were maintained at low levels since the beginning of commercial operation.

The environmental doses associated with radioisotopes emissions in atmosphere are very low, generally below 1% of the Derived Emission Levels approved by the Romanian competent authorities.

REFERENCES

[1] NE Technology Ltd., *Instruction Manual for Gaseous Effluent Monitoring System, Type MSO248,* Beenham, Berkshire, 1995.

[2] Canadian Standard Association, *CAN/CSA – N288.1 - M87 Guidelines for Calculating Derived Release Limits for Radioactive Materials in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities,* 1987.

[3] E. Bobric, I. Popescu, V. Simionov, R. Ibadula, "The Influence of Tritium Build-up in Cernavoda NPP Systems on Gaseous and Liquid Emissions After Four Years of Operation", Proc. IRPA Regional Congress on Radiation Protection in Central Europe, Dubrovnik, Croatia, May 20-25, 2001.