IMPROVING OCCUPATIONAL RADIATION EXPOSURE USING ALARA TOOLS: PERFORMANCE INDICATORS

NUCLEARELECTRICA
Puterea Viitorului

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INTRODUCTION

Optimization of protection in operation begins at the planning stage and continues through the stages of scheduling, preparation, implementation and feedback.

At the top level, the optimization of protection covers the organizational structure needed to enable the correct allocation of responsibilities. It is used for decisions at all levels, from simple day to day operational problems to major analyses of different types of plant design.

The optimization ideas also applies to procedures established to prevent or mitigate the consequences of incidents in the workplace, that could lead to individual radiation exposure.

INTRODUCTION

ALARA is an important element of the global approach to radiological protection and management commitment to ALARA has been clearly stated by “Radiation Protection Principles, Policy and Regulation”.

Radiation Protection compartments provide technical support, supervision, doses management, data bases.

RP personnel closely collaborate with working groups and make them aware for being responsible for doses they received.

Radiation workers, ALARA coordinators, first line supervisors, and managers are directly responsible for controlling and reducing radiation doses.

INTRODUCTION

The actual levels of individual and collective effective doses reveal the effectiveness of implementation of the Radiation Safety Policies and Principles established by the management of the Cernavoda NPP.

Despite the increased number of professionally exposed workers after starting the operation of Unit 2 in 2007, the collective doses did not increased accordingly.

A continued station focus on collective radiation exposure reduction has resulted in top industry performance for CANDU designed reactors over the last 10 years, reducing station dose from 917 man mSv in 2012 to 388 man mSv in 2015.

INTRODUCTION

Collective dose provides indication about plant radiological condition in connection with personnel behavior. Best dose performance is a result of a balanced combination between those two factors. ALARA principle has much qualitative and less quantitative connotations, that's why its implementation is opened to several methods or particular approach.

First level of implementation is using microALARA techniques converted into radiation protection measures for every radiologic risk activity.

INTRODUCTION

Regarding plant radiological condition, an aggressive policy to reduce individual exposure was applied since 2005, including:

- a strict control of D2O leaks and leaks reduction program
- providing dryers availability
- optimization of personnel access in R/B
- using appropriate RP protective equipment
- hot spot management program
- implementation of RWP system.

INTRODUCTION

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To improve human behavior, we had to find out the near-misses.

Two directions were considered in correcting personnel behavior: define ALARA performance indicators for working groups and elaborate periodically trend analyses for radiation protection deficiencies.

Trend analysis include:

- quarterly value for strategic performance indicators,
- monthly distribution of abnormal condition reports by type of deficiency
- number of deficiencies evolution for the last four quarters.

ALARA PERFORMANCE INDICATORS

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Radiological performance of the plant

Plant Performance Indicators related to ionizing radiation exposure and radioactive materials management have been established to improve station and work groups' performance.

They are assessed and reported periodically to reflect the objectives and permanently mark out achievements and breakdowns. If target values are exceeded, "abnormal condition reports" are generated.

If the abnormal condition is classified as "event" an interdepartmental investigation team is designated by the plant management to identify both direct and root causes. Based on the conclusions of the investigation report, corrective and / or preventive actions are established.

ALARA PERFORMANCE INDICATORS

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Radiological performance of the plant

The main indicators are the collective dose and the distribution of individual doses.

The targets for these indicators are based on a generic description of the major radiological jobs to be performed (based on estimated frequency, duration, dose rates and number of workers exposed) correlated with statistical (historical) values.

After implementing ALARA and RWP programs, a continuous station focus on collective radiation exposure reduction resulted in top industry performance for CANDU designed reactors over the last 8 years, reducing station dose from 271 man mSv / unit in 2007 to 194 man mSv / unit in 2015. (fig. 1)

ALARA PERFORMANCE INDICATORS

Total Collective Dose. Internal Collective Dose

Collective effective dose is an adequate representation of the collective detriment, very useful tool as a measure of radiological performance and Radiation Protection programs efficiency.

Collective Dose and Collective Internal Dose are assessed monthly, quarterly and annually for the entire plant and for major work groups: Operations, Mechanical Maintenance, Electrical Maintenance, Service Maintenance, Fuel Handling, Radiation Protection, Non-destructive Examination and Others (security, operating support group, technical (RSEs and RCEs), chemistry).

ALARA PERFORMANCE INDICATORS

Total Collective Dose. Internal Collective Dose

The major contributor to the internal dose of occupational exposed workers is the tritiated heavy water (DTO), which is present chronically at many work locations.

Between 2004 and 2007, internal dose percentage to total collective dose , due to tritiated heavy water, was relatively high, compared with other CANDU plants. Cernavoda Plant management made an action plan to **reduce heavy water leaks** and to **improve Vapor Recovery System efficiency**.

Strong commitment of the organization to implement ALARA program resulted in low collective doses for six consecutive years of operation.

ALARA PERFORMANCE INDICATORS

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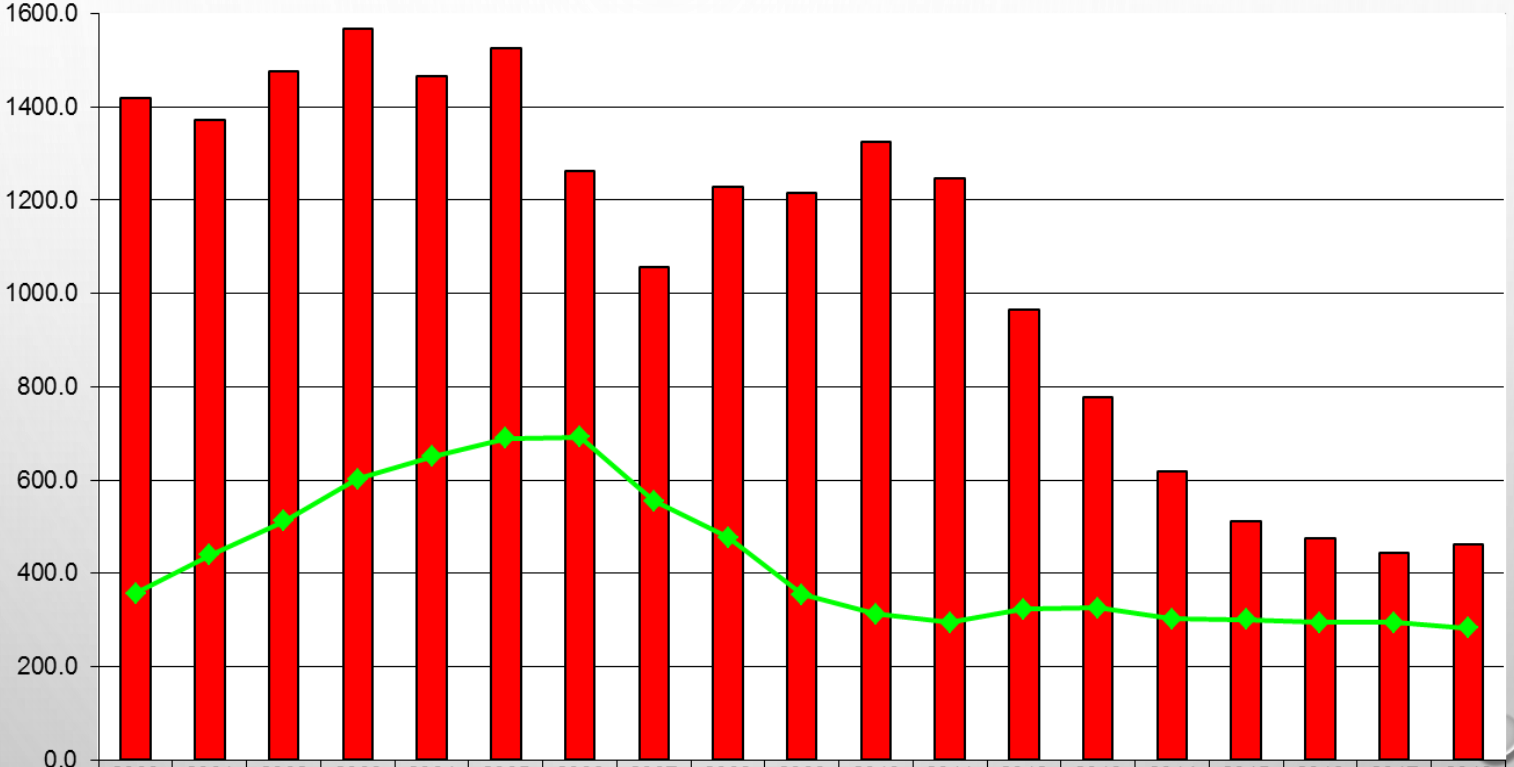
Collective dose, om mSv / unit, 4 years rolling average (Cernavoda vs. CANDU 6)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Media CANDU-6	1419.9	1373.1	1475.5	1569.0	1467.0	1526.5	1261.5	1055.5	1229.0	1216.0	1324.5	1246.7	964.00	776.50	619.00	512.25	473.75	443.75	461.39
Cernavoda	357.15	438.78	512.00	602.45	650.08	689.27	691.91	555.04	476.95	354.71	312.86	294.27	322.93	325.91	301.53	300.92	294.68	294.48	282.20

ALARA PERFORMANCE INDICATORS

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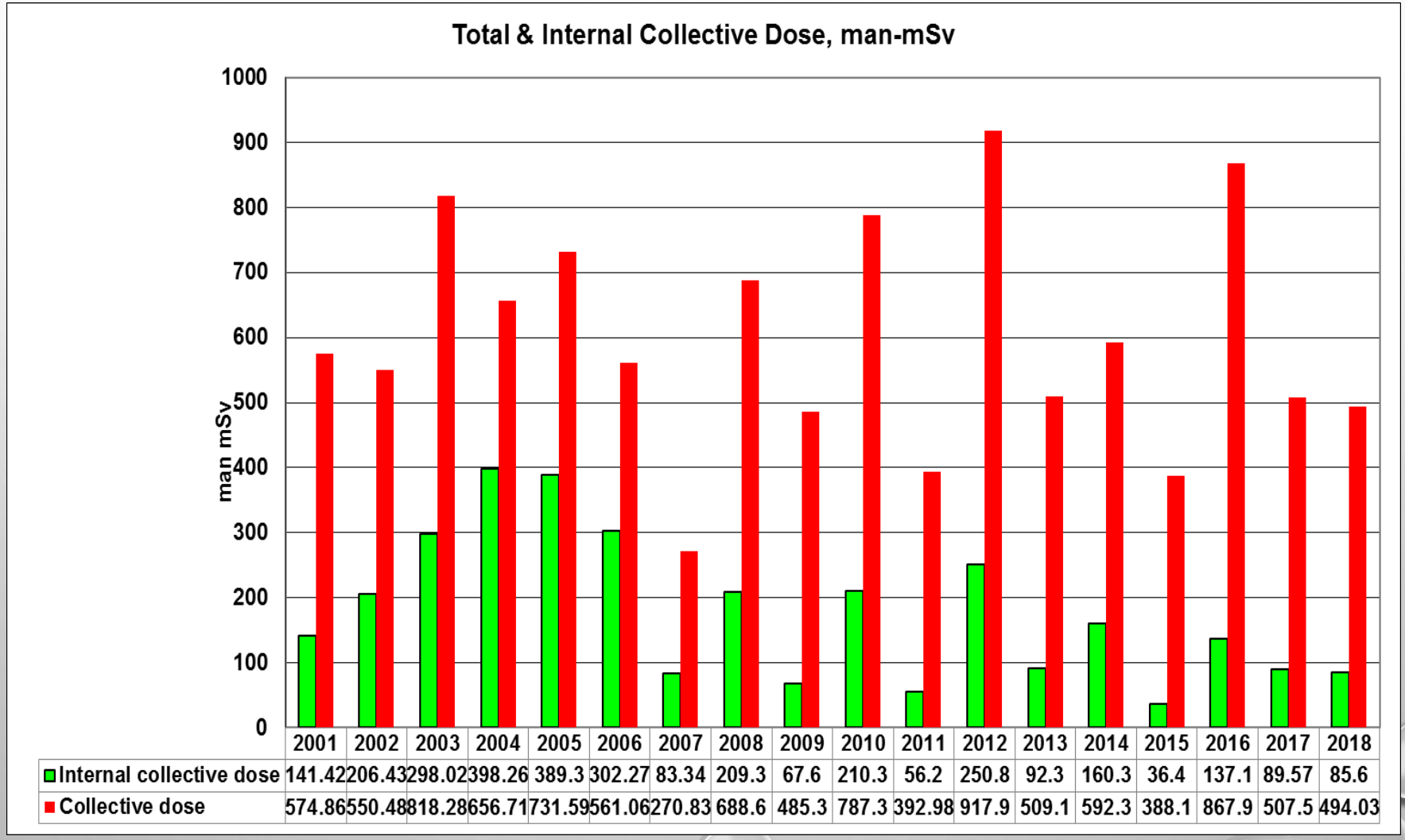

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Internal collective dose	141.42	206.43	298.02	398.26	389.3	302.27	83.34	209.3	67.6	210.3	56.2	250.8	92.3	160.3	36.4	137.1	89.57	85.6
Collective dose	574.86	550.48	818.28	656.71	731.59	561.06	270.83	688.6	485.3	787.3	392.98	917.9	509.1	592.3	388.1	867.9	507.5	494.03

ALARA PERFORMANCE INDICATORS

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Total Collective Dose. Internal Collective Dose

Since 2006 collective doses decreased, after implementing ALARA and RWP programs:

- Working groups and plant management have been taking the ownership of the ALARA process through performance indicators with challenging targets;
- Site personnel, RP and working groups supervision took responsibilities for significant radiological risk- work. Supervisory review and oversight in the field are required commensurate with increasing radiological risk.
- Radiation work permits incorporate protective radiological risk criteria with appropriate levels of radiological risk.

ALARA PERFORMANCE INDICATORS

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Total Collective Dose. Internal Collective Dose

- Managers, first line supervisors, ALARA coordinators and radiation workers are responsible for controlling and reducing radiation doses.
- Since 2015 high radiological risk activities are supervised by both first line and RP supervisors, starting with pre-job briefing phase.
- Radiation Monitoring System (RMS) has been implemented contributing to collective dose reduction by improving radiation hazard control and reducing RP personnel routine exposure.

ALARA PERFORMANCE INDICATORS

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Total Collective Dose. Internal Collective Dose

The station ALARA committee and the technical ALARA committee continue to provide the strategic direction for achieving consistent low collective dose on both units.

Meeting semi-annually and monthly respectfully, these committees provide a critical assessment of performance in meeting ALARA goals and implementing the five-year dose reduction plan initiatives.

The use of departmental ALARA coordinators in planning and tracking exposure for radiological work activities has assisted in reducing both individual job and overall department dose.

ALARA PERFORMANCE INDICATORS

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Total Collective Dose. Internal Collective Dose

A continuous **five-year dose reduction plan** is used with activities identified, approved, and funded to help drive future dose reduction initiatives.

International mission team at Cernavoda NPP during November 2015 stated as "Strength": "A continued station focus on collective radiation exposure reduction has resulted in top industry performance for CANDU designed reactors over the last 8 years, reducing station dose from 52 rem in 2007 to 26 rem in 2015. Currently, both units are in the top quartile for all WANO stations."

ALARA PERFORMANCE INDICATORS

Total Collective Dose. Internal Collective Dose

Also WANO International mission evaluation team during November 2018 stated: "Performance remains exemplary. Collective radiation exposure is maintained below industry goals with substantial margin and is among the best performance for heavy water reactors. In addition, online collective dose exposure is well managed. Leaders have developed a station specific radiation protection index to identify precursor behaviors and to take action before consequential events. "

NEW ALARA PERFORMANCE INDICATORS

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The awareness of Radiation Protection in the station became a topic in planning meeting agenda. Twice a month, collective dose distribution by working groups is presented to plant management, including senior supervisors of working groups, who can analyze spent dose budget versus monthly target.

First "ALARA Annual Report" has been issued for 2008 to present station ALARA performance, reflecting the exact state of radiation programs efficiency and identifying areas to be improved.

NEW ALARA PERFORMANCE INDICATORS

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In order to further improve plant performance related with exposure of radiation workers ALARA committee approved the implementation of new performance indicators :

- Unexpected acute individual external exposures
- Unexpected acute individual internal exposures
- Improper response to EPD's dose rate alarm
- Maximum individual dose
- Maximum individual internal dose
- Personnel Contamination Events (inside Radiation Controlled Area – RCA)
- Internal contaminations with radio-nuclides other than tritium
- Unexpected contamination of surfaces
- Personnel contamination identified at the exit of the RCA

NEW ALARA PERFORMANCE INDICATORS

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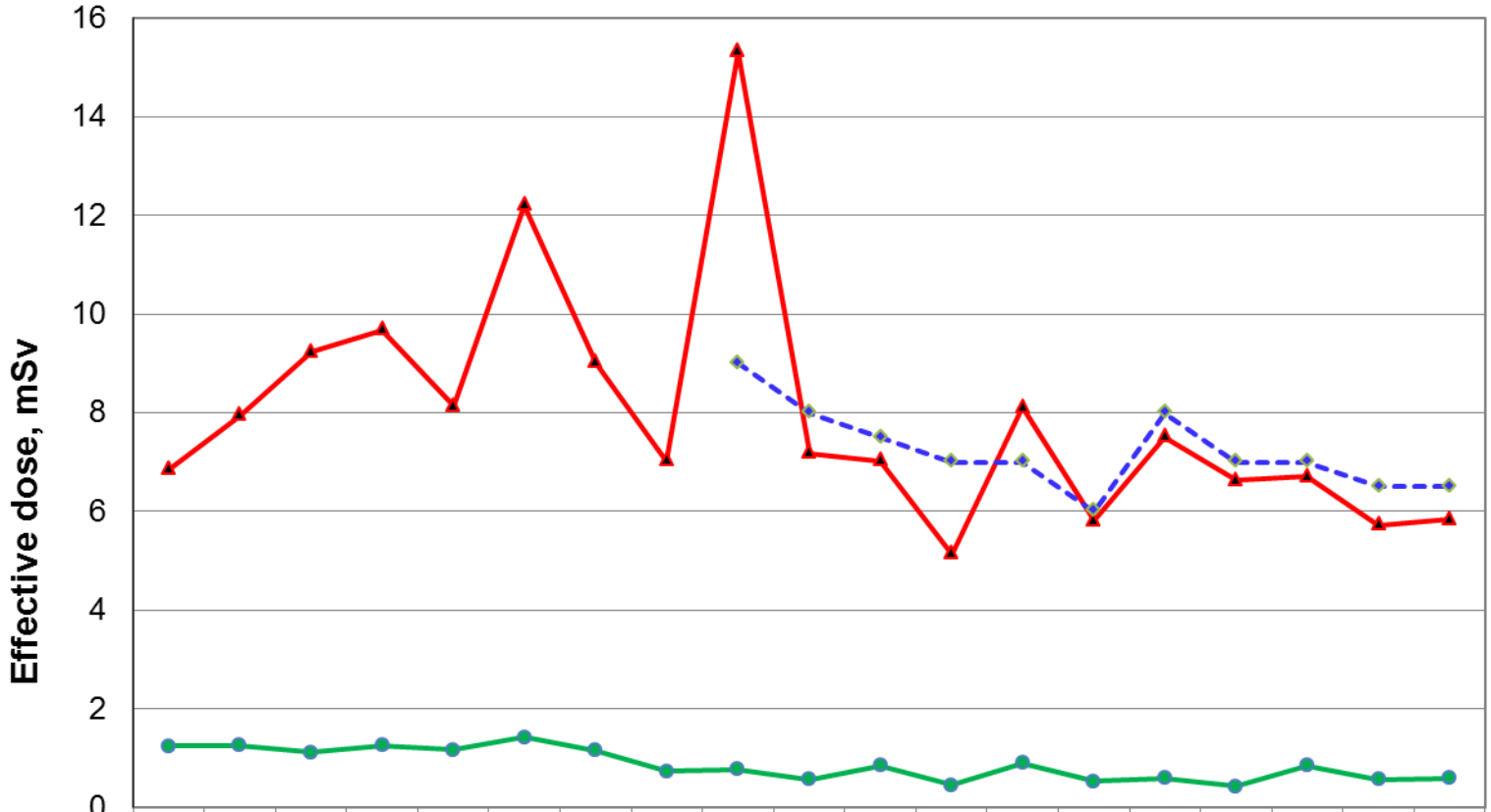
"Maximum individual dose" performance indicator, monitors maximum value of individual doses received by workers over a year from planned exposure; excepting 15.3 mSv dose in 2008 due to an external acute unplanned exposure, this indicator (for each reporting working group and for the plant) helped us to achieve a relative even distribution of doses among members of the working groups, reflected by the average individual dose (total collective dose / number of exposed workers). 70% of the received doses are below 1 mSv.

NEW ALARA PERFORMANCE INDICATORS

Evolution of maximum & average individual doses, mSv



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Maximum individual dose	6.85	7.94	9.23	9.68	8.14	12.21	9.01	7.03	15.32	7.18	7.02	5.13	8.11	5.81	7.51	6.63	6.71	5.72	5.84
Dose target									9	8	7.5	7	7	6	8	7	7	6.5	6.5
Average Dose	1.25	1.26	1.12	1.26	1.17	1.42	1.15	0.74	0.77	0.57	0.85	0.45	0.9	0.53	0.59	0.43	0.85	0.57	0.59

NEW ALARA PERFORMANCE INDICATORS

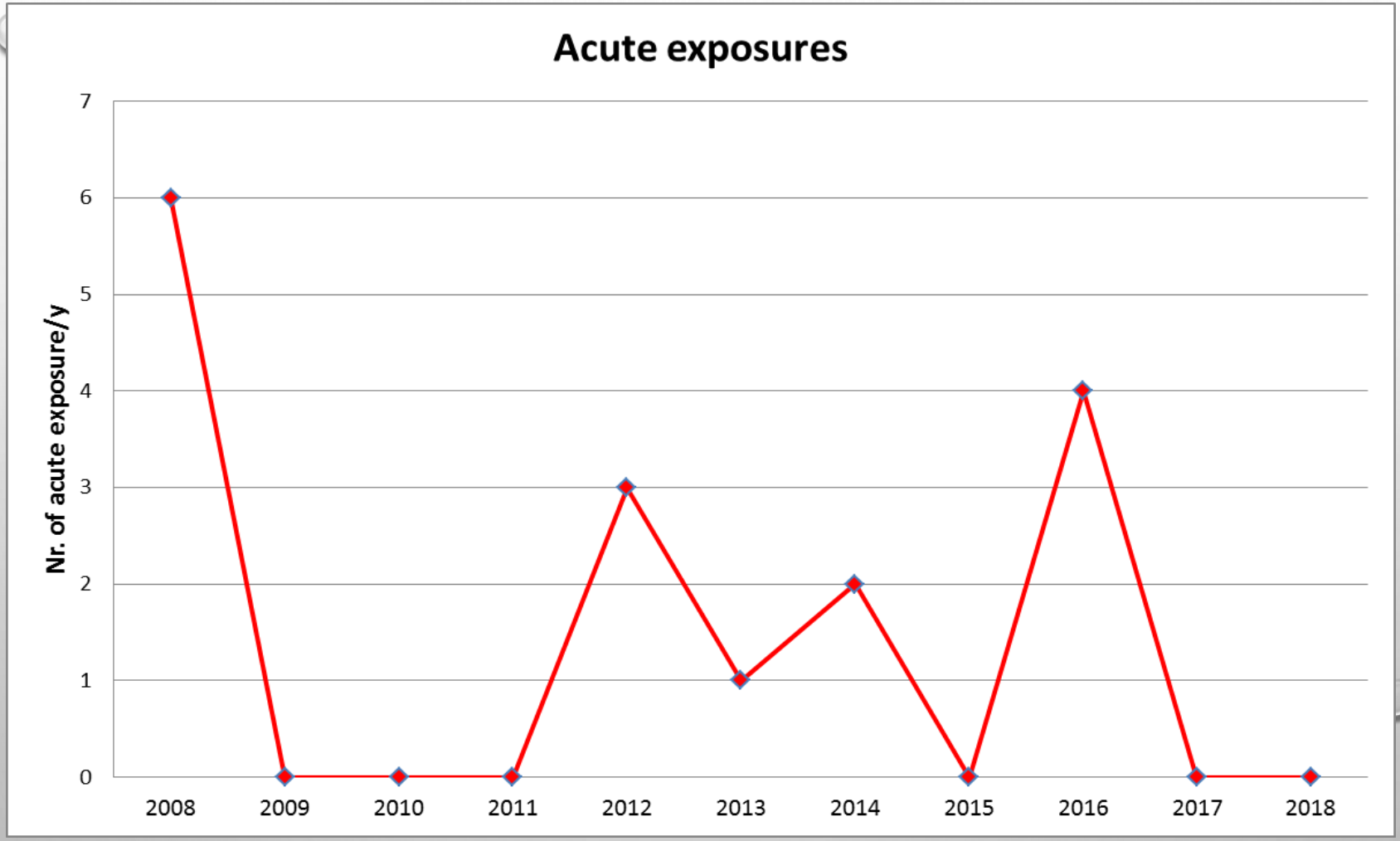
Starting 2012 a negative trend is recorded for **acute exposures** (committed dose higher than 1 mSv, in single unplanned exposure).

In 2016 3 of 4 cases were caused by **inappropriate access in non-operational ventilated tents** installed to control tritium concentration outside working area.

Analyses reports revealed weaknesses in RP procedures addressing rules for entering ventilated tents: radiological conditions surveillance inside the tent and appropriate respiratory protection are mandatory both if the tent is operational or not.

Corrective actions aimed improvement of RP procedures addressing installing / using / dismantling ventilated tents, as well as working practices of operators and maintainers.

NEW ALARA PERFORMANCE INDICATORS



PLANNED OUTAGES DOSES

Based on internal operating experience, planned activities, and predicted radiological conditions, ALARA coordinators establish collective dose objective for the planned outage for next year.

These values were discussed and agreed during every monthly October meeting of ALARA Technical Committee.

PLANNED OUTAGES DOSES

Radiation Work Permit Process systematically identify jobs / activities performed in radiological risk areas, and radiological conditions are evaluated so appropriate protective measures are identified and implemented.

RWP system allows dose accounting for specific jobs: each activity/task/routine/specific job performed in radiological area, and based on the results the efficiency of assessment process can be evaluated.

For the repetitive activities these information are valuable, allowing further ALARA improvement.

PLANNED OUTAGES DOSES

Radiation Work Permit for activities with an estimated collective external dose above 5 man mSv are discussed and approved during ordinary / extraordinary Technical ALARA Committee meetings.

The pre-job and post-job RWP analysis involve personnel from all the plant work groups and also the ALARA Committee.

During planned outages collective external doses, for all activities as well as for each activity evaluated through RWP system, and individual effective doses, are monitored on a daily basis.

This kind of surveillance allows us to prevent any of RP&ALARA PI objectives to inadvertently be exceeded.

PLANNED OUTAGES DOSES

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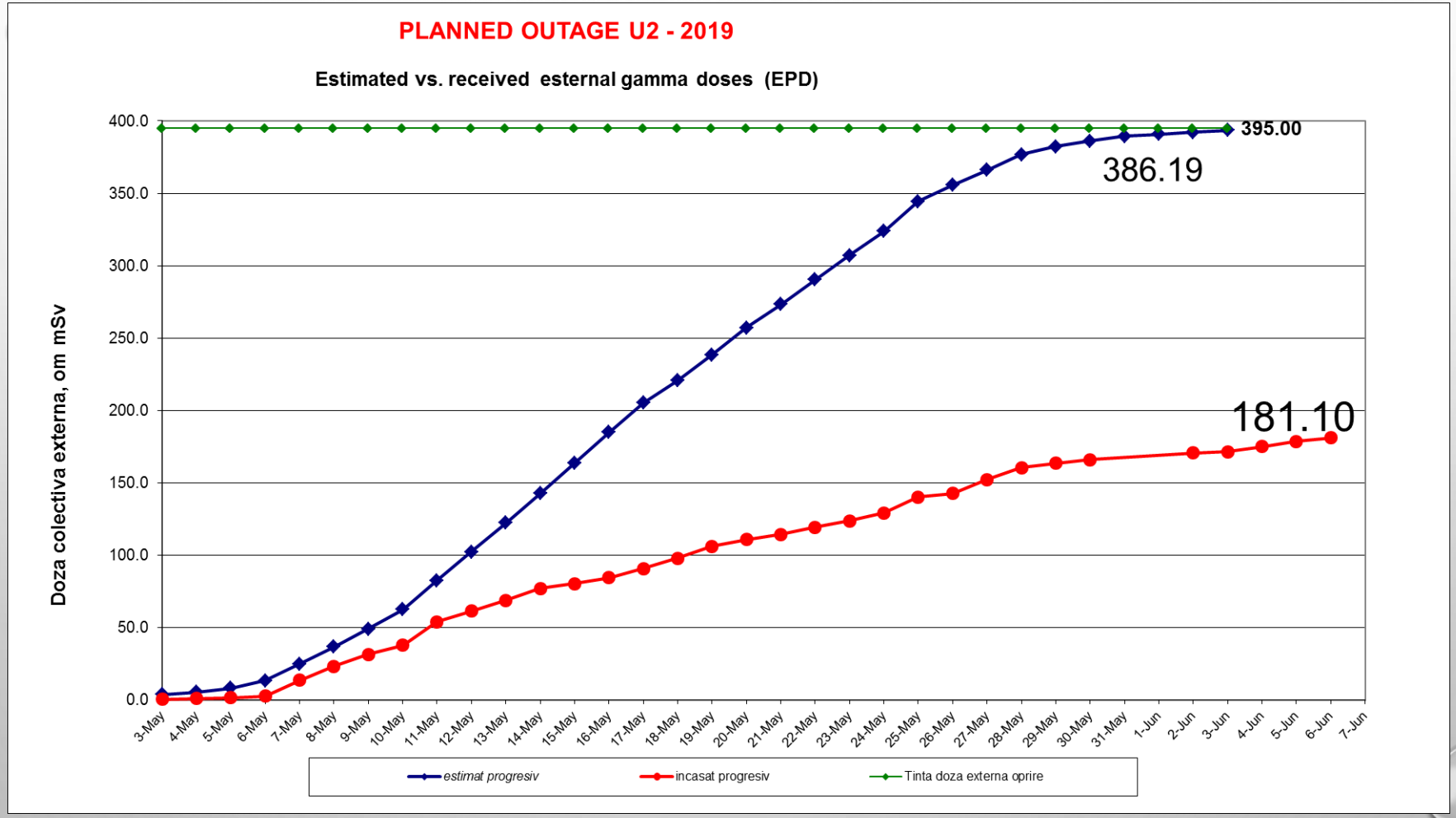

TREND ANALYSIS RESULTS

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Integrated root cause analysis for inappropriate response to EPD dose / dose rate alarms opened our vision to identify all radiation protection deficiencies, group them against causal factors, follow the trend and make conclusions or corrective actions whenever are needed.

Since 2013, quarterly trend analysis are made and discussed with working groups from Production Division during radiation protection and industrial safety meeting.

TREND ANALYSIS RESULTS

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Radiation protection deficiencies included in this analysis are:

1. Heavy water leaks
2. Use of RWP and work planning
3. Contamination control deficiencies
4. Radioactive material control deficiencies
5. Inappropriate EPD alarm response
6. Adverse trend for ALARA indicators
7. Protective individual equipment deficiencies
8. Radiological conditions
9. Human Performance

TREND ANALYSIS RESULTS

"Contamination control" has been a hot issue since 2013 and RP department developed actions plans to reduce number of violations of procedure and this theme is annually analyzed into a focused self-assessment report.

"Radiological conditions" and "Heavy water leaks" accounts for equipment defects generating increased radiation dose rates.

In order to improve radiological conditions, RP Department implemented a program for hot spot management and upgraded tritium in air monitoring system in Unit #1 & 2.

Efforts were made to accelerate implementation of support system with good impact in radiological condition: portable dryers, installing air dehumidifier in reactor building.

CONCLUSIONS

ALARA performance indicators are useful if they are used to identify the low level errors generated by poor radiation protection working practice with exposure consequences.

RP personnel grant support and supervision for high radiological risk, but worker alignment are important to achieve exposures that are kept ALARA.

Since the objective of the optimization of radiological protection is to keep individual and collective doses below the appropriate dose constraints, the most relevant indicator is the dose (collective or individual).

Good results for dose are the outcome of good adherence to the radiation protection procedures.

Thank you for your attention!

Questions?