PERFORMANCE MONITORING OF RADIOLOGICAL SAFETY POLICY AT CERNAVODA NPP

NUCLEARELECTRICA
Puterea Viitorului

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CONTENTS

- Introduction
- Occupational exposure control process
  - Performance indicators. Radiological performance of the plant
  - Planned outages doses
- Radioactive Material Control Process
  - Environment radioactive waste releases
- Conclusions

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

A strong program is necessary to identify the presence and to avoid the spreading of radioactive contamination, and to reduce the quantity of radioactive waste.

Radioactive material control process coordinates four programs: contamination control, waste management, radioactive effluents control and environment radioactivity control. Performance indicators have been defined for every program and they are annually revised.

Contamination control and waste management programs are directly connected with individual contamination control program, individual doses being the result of a balanced combination between source term and personnel behavior. That's why working to minimize collective and individual doses should be opened also for reducing source term initiatives and improving work practices techniques.

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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Performance indicators. 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.

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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).

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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.

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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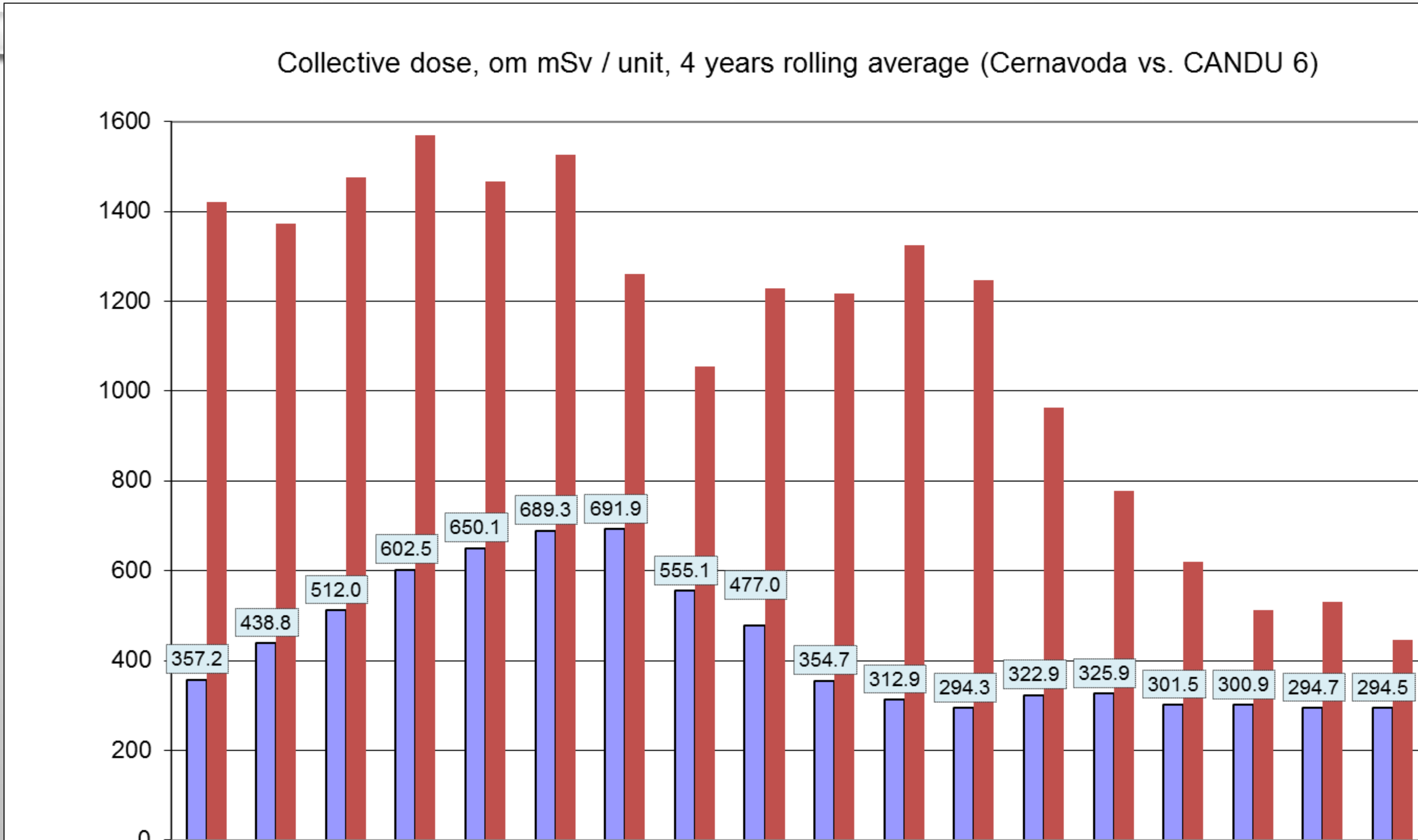

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cernavoda	357.2	438.8	512	602.5	650.1	689.3	691.9	555.1	477	354.7	312.9	294.3	322.9	325.9	301.5	300.9	294.7	294.5
CANDU 6	1420	1373	1476	1569	1467	1527	1262	1056	1229	1216	1325	1247	964	776.5	619	512.3	531	446

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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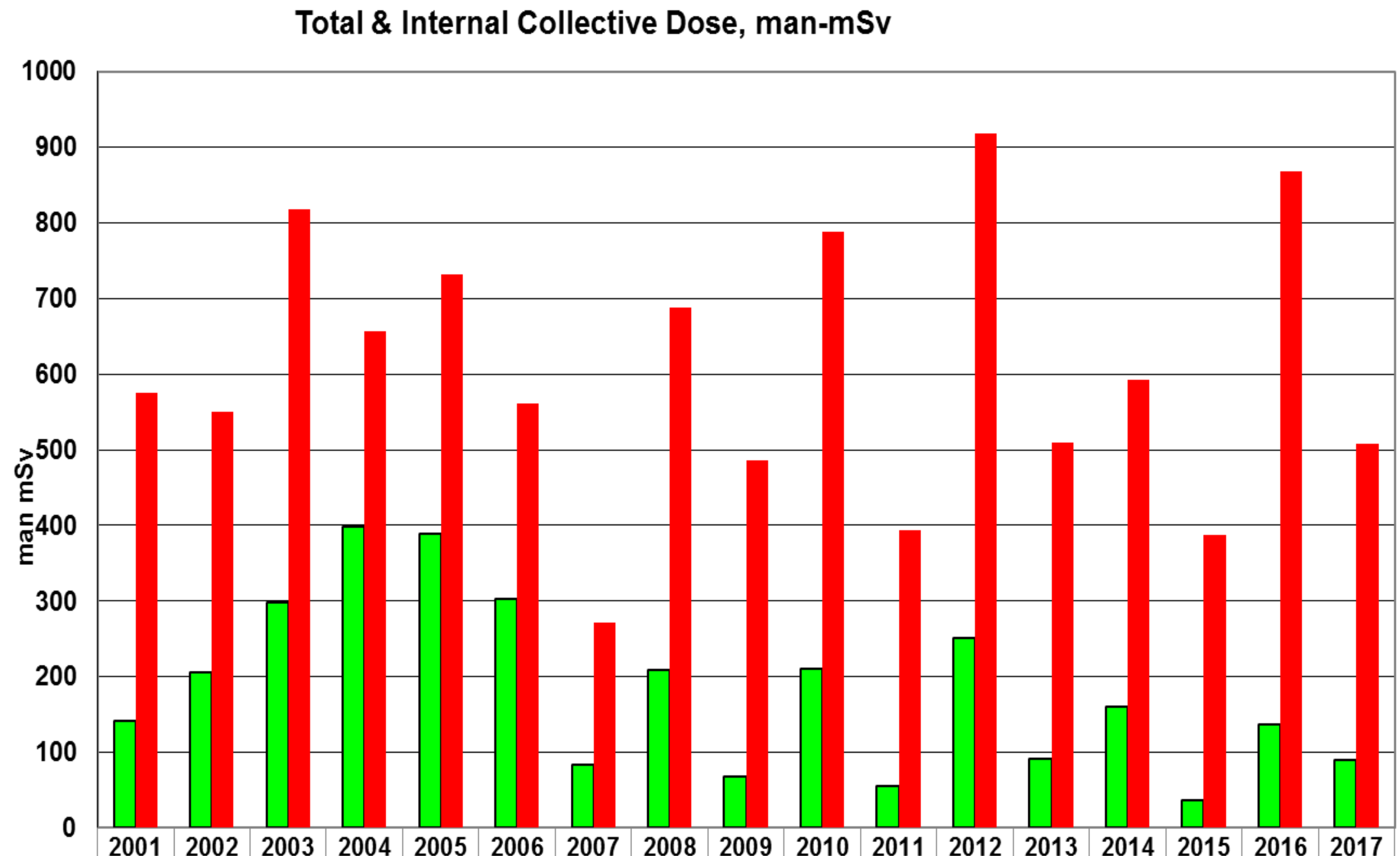

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Internal collective dose	141.42	206.43	298.02	398.26	389.3	302.27	83.34	209.3	67.6	210.3	56.2	250.8	92.3	160.3	36.4	137.1	89.57
Collective dose	574.86	550.48	818.28	656.71	731.59	561.06	270.83	688.6	485.3	787.3	392.98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

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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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.**

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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.**

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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Total Collective Dose. Internal Collective Dose

Since 2009 to 2015 the collective dose per operating unit at CNE Cernavoda had values between 196 and 459 man•mSv, performance which classified our plant in the top of CANDU plants.

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.

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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Total Collective Dose. Internal Collective Dose

Remote tritium monitoring system allows for early detection and fix of tritiated water leaks, and along with the use of personal protective equipment, has helped to drive internal doses to their lowest recorded levels. In 2015, Unit 2 tritium dose was approximately 8% of total dose, with an overall site value of about 10%. This is way down from 27% in 2014.

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.

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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. These include new higher capacity air dryer for Unit 2 that will aid in reducing tritium concentrations in the air and a tritium recovery project is also in the planning phase.

International mission team at Cernavoda NPP during November 2015 stated these facts 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."

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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New radiation protection performance indicators

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**

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New radiation protection performance indicators

"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.

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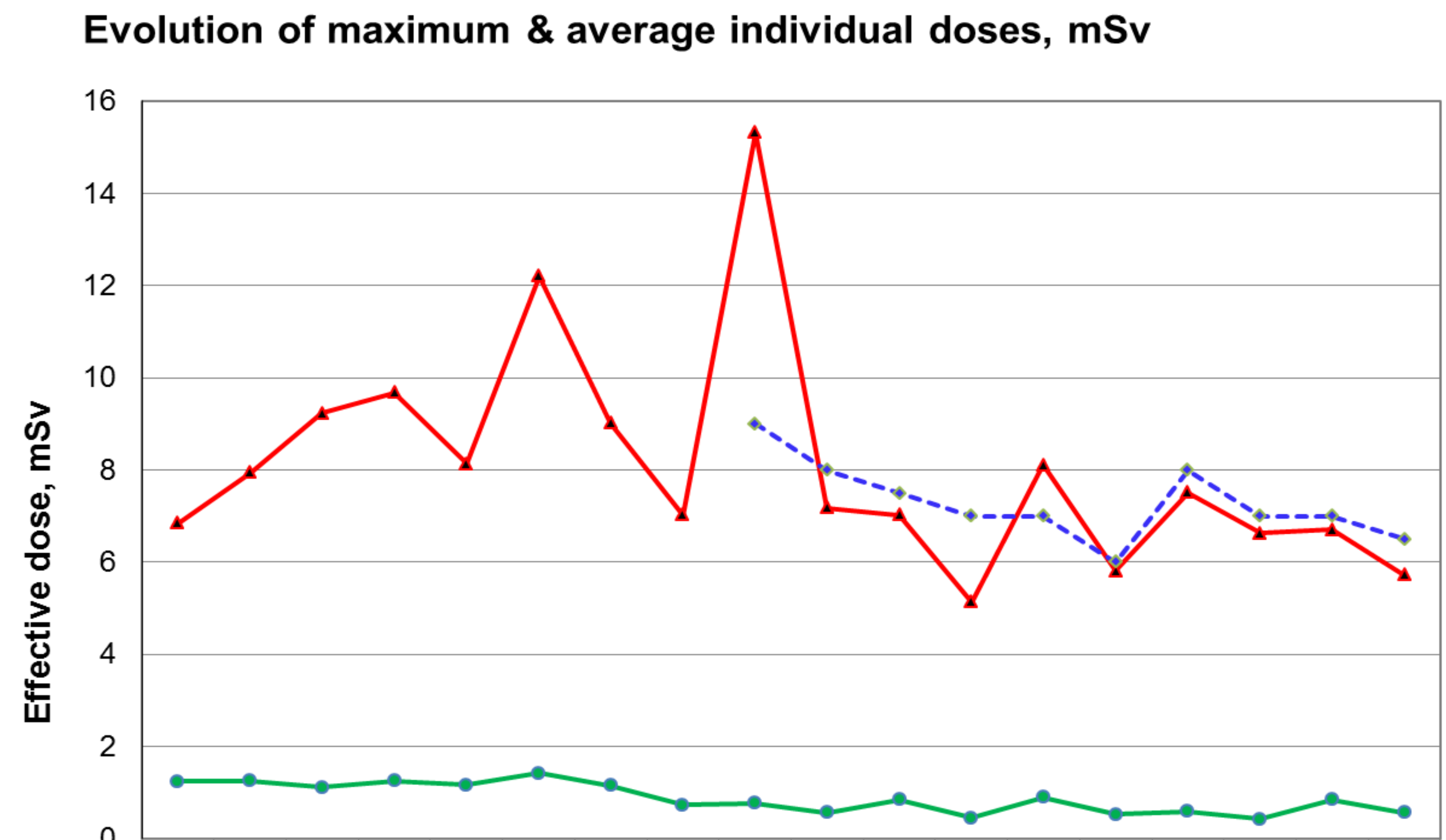
Puterea Viitorului



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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
Dose target									9	8	7.5	7	7	6	8	7	7	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

OCCUPATIONAL EXPOSURE CONTROL PROCESS

New radiation protection 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.

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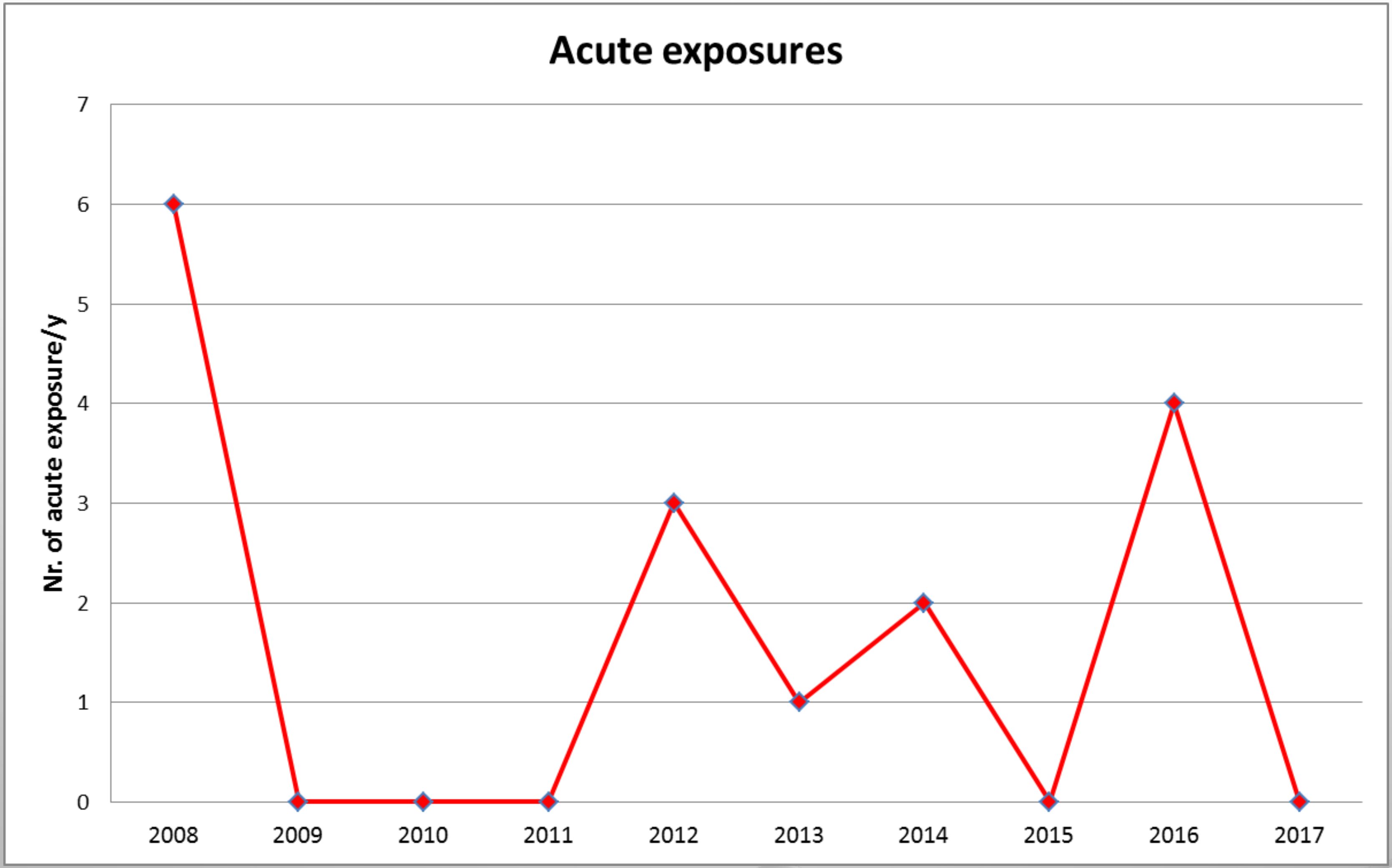

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Planned outages doses

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 2016 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.

OCCUPATIONAL EXPOSURE CONTROL PROCESS

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Planned outages doses

Radiation Work Permit includes information about:

- job duration (man – hours);
- complete and exact description of the activity;
- appropriate protective measure and equipment;
- work area / room and waiting, low dose rates, areas;
- the estimated volume and requirements for the management of solid and liquid radioactive waste;
- estimated dose rates for each work area;
- estimated collective dose for each work group and for the job;
- appropriate dosimetry.

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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.

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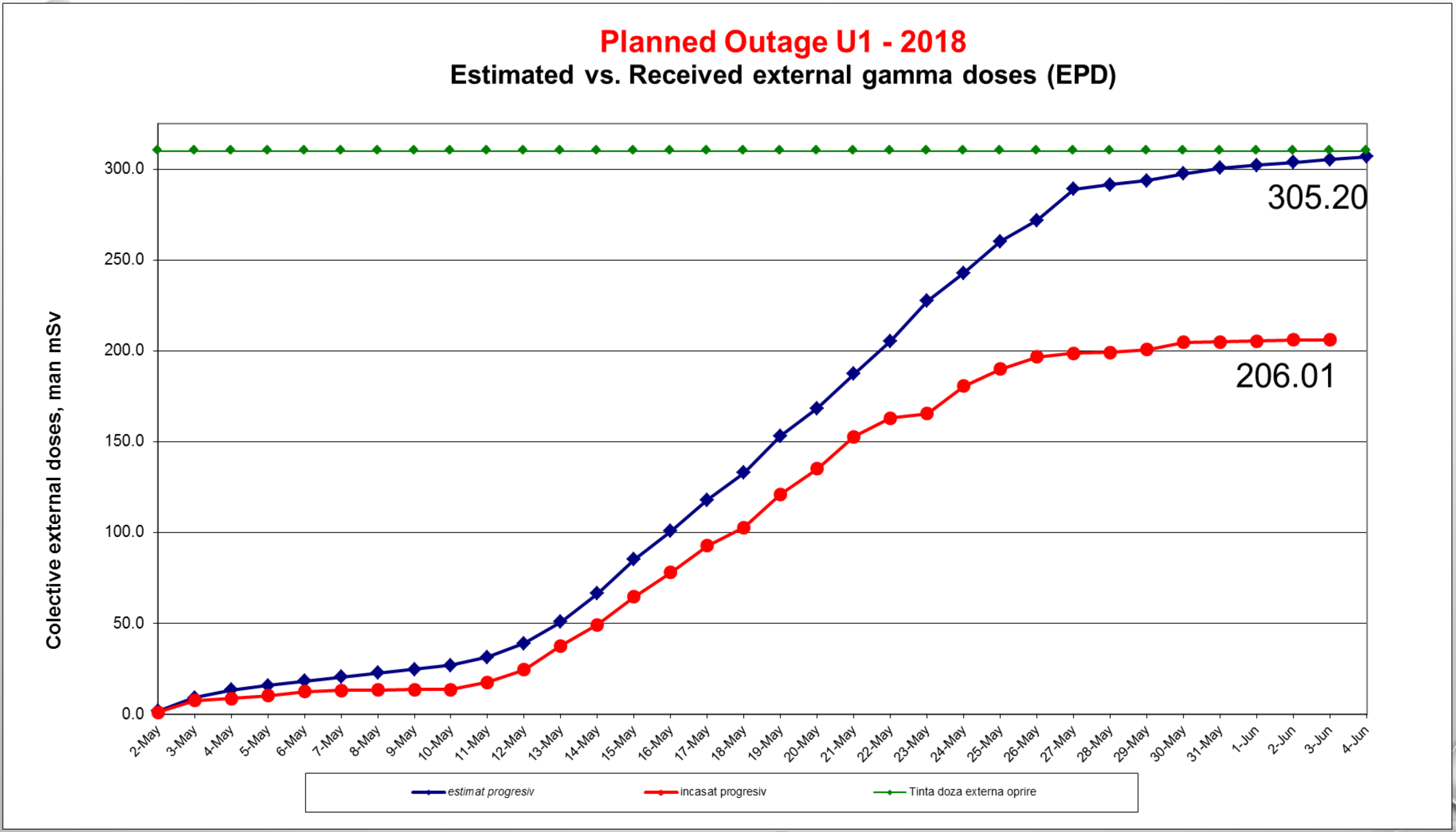

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Planning of major high collective dose outage jobs

Case study 1: U1OP-2012: "Horizontal flux detector replacement"

Without sufficient information regarding radiological conditions during planning and design phases a collective dose of 13.4 man mSv and a maximum individual dose of 4 mSv were initially estimated.

Gamma dose rate measured during the first detector extraction has been significantly higher than the expected one, and the reevaluation of estimated collective dose and protective measures has been necessary.

The new approved targets were 75 man mSv for collective dose, and 6 mSv maximum individual dose.

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Planning of major high collective dose outage jobs

Case study 1: U1OP-2012: ”Horizontal flux detector replacement”

Several challenges appeared during task completion, which requires supplementary analysis, and ad hoc solutions to reduce doses have been applied due to the configuration of working zone and the limited manipulation capabilities.

Finally, the collective external dose was 100.6 man mSv. A detailed post job ALARA and a root-cause analysis were performed in order to establish lessons to learn for further similar activities.

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Planning of major high collective dose outage jobs

Case study 2: U1OP-2016: "Magnetite layers removal from U tubes of 4 SGs"

During U#1 2016 Planned Outage, a mixed team of Cernavoda NPP, BWXT and CANDU Energy performed, for the first time at Cernavoda, removal of magnetite layers from U tubes of all four Steam Generators, activity considered to be with high radiological risk.

Estimated external collective dose was 132,5 man mSv and the received external collective dose was 153,6 man mSv.

Due to the potential of high risk of contamination with alpha emitters appropriate measures have been put in place in order to minimize the spread of radioactive material and to prevent internal contamination of personnel involved in these activities:

Planning of major high collective dose outage jobs

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Puterea Viitorului

Case study 2: U1OP-2016: "Magnetite layers removal from U tubes of SGs" (cont'd)

1. The workers have been assisted by highly trained RP Department personnel;

2. Areas that could lead to leaks of contaminated materials have been isolated with ventilated tents;

3. CAMs (Continuous Air Monitors) - installed at the exit of contaminated areas to measure the activity of beta and alpha emitters and alert on radiological conditions changes;

4. Radioactivity measurements have been performed on samples from contaminated areas to evaluate beta/alpha ratio and radionuclides mixture composition; the activity of specific beta-gamma emitters, beta/alpha ratio and whole body counting results allowed the evaluation of internal dose due to alpha emitters;

OCCUPATIONAL EXPOSURE CONTROL PROCESS

Planning of major high collective dose outage jobs

Case study 2: U1OP-2016: "Magnetite layers removal from U tubes of SGs" (cont'd)

5. Any access to contaminated areas required adequate protective equipment against airborne particulates: particulate filters, plastic suits; Tyvek suits have been used to cover the plastic suits in order to minimize the risk of internal contamination during undressing;

6. A complex pre-job briefing was held before starting activity with all workers involved. Daily, during the activity, every crew attended pre-job briefing focused at immediate tasks and radiological hazards, to refresh radiation protection measures and improve radiation protection practices .

7. Periodical whole body counting has been carried out for all personnel working in contaminated areas. One person has been identified with internal contamination (^{95}Zr / ^{95}Nb), but no dose above recording level.

OCCUPATIONAL EXPOSURE CONTROL PROCESS

Planning of major high collective dose outage jobs

Case study 2: U1OP-2016: "Magnetite layers removal from U tubes of SGs" (cont'd)

In order to reduce and to have a permanent control of external exposure the following measures were established:

1. A magnetite storage area was designed to accommodate magnetite cylinders inside a shielded enclosure:

- three walls having between 50 – 90 cm heavy concrete as the contact gamma dose rate with the shield to be <0.025 mSv/h.

- 15 cm iron lid to ensure an estimated contact gamma dose rate with shield <0.650 mS/h (on the top of the cabinets)

Gamma dose rates with the shield are between 0.005 and 0.020 mSv/h.

2. Teledosimetry has been used to control individual received doses. No worker exceeded any individual gamma dose limits and no EPD dose alarm received.

RADIOACTIVE MATERIAL CONTROL PROCESS

Radioactive material control process is implemented to reduce the risk of contamination being inadvertently released outside radiological controlled area and to avoid or maintain internal exposure to a minimum level.

Appropriate contamination control practices are in place to improve worker efficiency, reduce personnel dose and prevent the unexpected contamination events.

Performance indicators have been established to control the volume of radioactive waste.

For the environmental impact and public dose the indicators are the amounts of radioactive effluent gasseous and liquid released into the environment nearby the plant.

RADIOACTIVE MATERIAL CONTROL PROCESS

Early **detection and replacement of defective fuel** prevent contamination of PHT circuit contamination with fission products and actinides. Defective fuel is replaced with radiation protection assistance in order to minimize gaseous emissions.

All the activities performed within radiological controlled area are carefully evaluated from the point of view of radioactive materials and waste, used or produced. All the activities with a potential environmental impact are evaluated, planned and controlled as required by plant processes.

Maintenance and operation procedures provide the necessary instructions to avoid uncontrolled release of radioactive materials into the environment.

RADIOACTIVE MATERIAL CONTROL PROCESS

Work plans and procedures are evaluated and measures are established in order to reduce the volume of radioactive waste (solid, liquid or gaseous) generated during the execution of the specific jobs. **Materials and consumables** used for nuclear systems and auxiliary circuits maintenance are strictly controlled in order to prevent highly contaminated waste occurrence.

No material or waste could leave radiological controlled area or released into the environment without proper monitoring.

RADIOACTIVE MATERIAL CONTROL PROCESS

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In order to identify and measure contamination of materials, tools or waste, several equipments are available having adequate detection limits:

- **All non-radioactive solid waste generated inside radiological controlled area are mandatory monitored before free release using waste monitor, RTM 640 LNC. Alternative methods are also used for oversized objects, such as contamination measuring, and in situ gamma spectrometry.**
- **Liquid radioactive waste are continuously monitored by Liquid Effluent Monitor, and also sampled and measured by laboratory methods.**
- **Gaseous effluents are continuously measured by Gaseous Effluents Monitor.**

RADIOACTIVE MATERIAL CONTROL PROCESS

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Environment radioactive waste releases;
Derived Emission Limits (DELs)

The national regulatory body, CNCAN, established a 0.1 mSv dose constraint for each unit as the maximum dose which could be received annually by a member of the general public at the site boundary.

A nuclear power plant must restrict its radioactive waste release levels such that any person (hypothetical or otherwise) who would drink water at the outfall, breath air in the vicinity of the plant and eat food produced nearby the plant, does not ingest sufficient quantities of radioactive substances such that dose constraint would be exceeded.

RADIOACTIVE MATERIAL CONTROL PROCESS

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Environment radioactive waste releases;
Derived Emission Limits (DELs)

To facilitate the provision of acceptable release levels, all the crucial released radionuclides are limited to maximum activity (in air and water) called "Derived Emission Limits" (DELs). The maximum activity of each radionuclide allowed for annually releases depend of its capacity of contributing to individual exposure.

For an optimal control, gaseous and liquid releases performance indicators are established for each unit, and weekly for gaseous respective, monthly for liquid releases reported.

Immediate actions are taken in case of performance indicators degradation.

RADIOACTIVE MATERIAL CONTROL PROCESS

Environment radioactive waste releases;
Derived Emission Limits (DELs)

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Legal dose limit for the public is 1 mSv / year, but regulatory body established **dose constraints** of 0.1 mSv / year / operating unit, and 0.050 mSv / year for spent fuel interim dry storage facility.

We manage to keep public dose well below approved constraint and target, proving the effectiveness of our environmental program.

RADIOACTIVE MATERIAL CONTROL PROCESS

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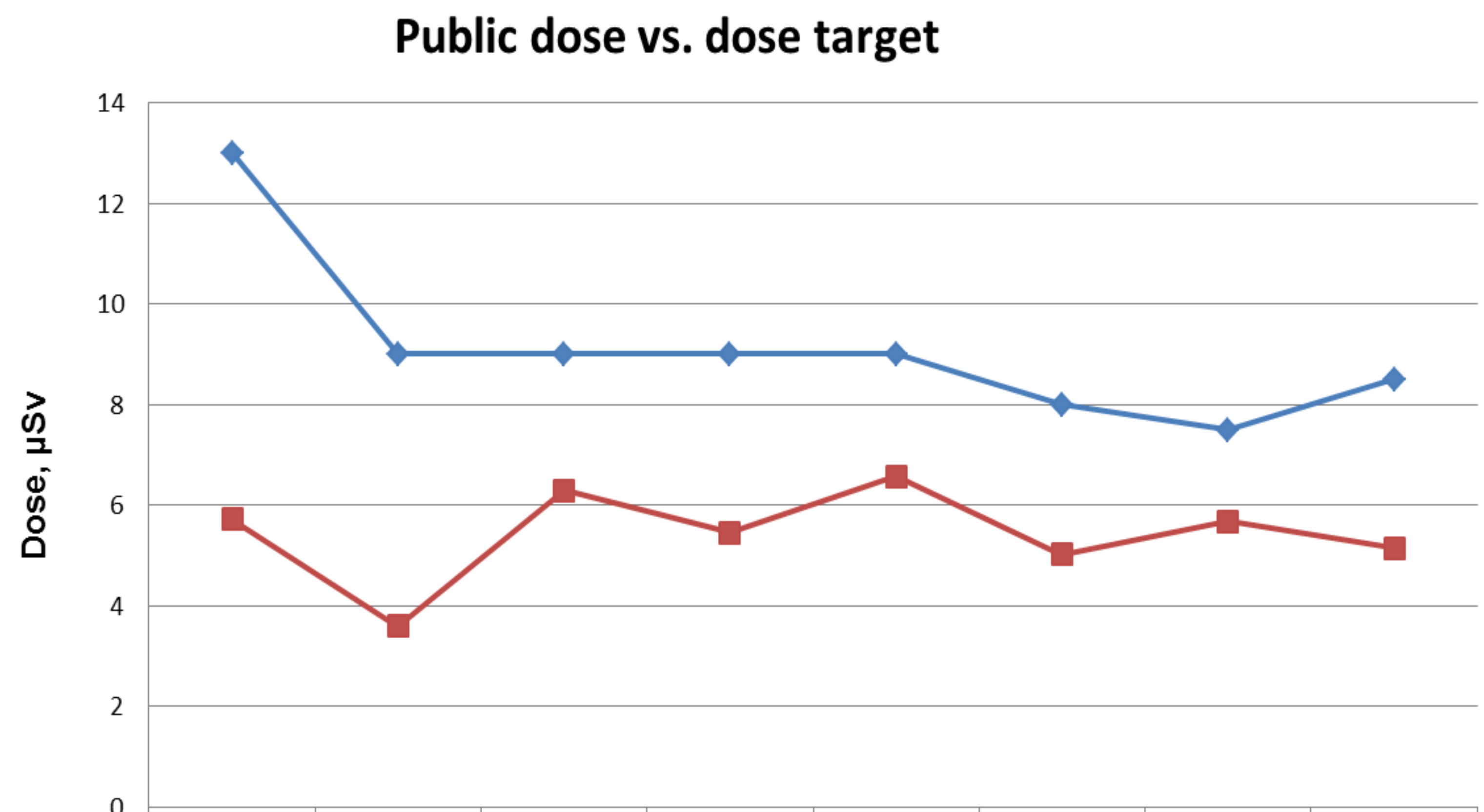

	2010	2011	2012	2013	2014	2015	2016	2017
Dose target, µSv	13	9	9	9	9	8	7.5	8.5
Public dose µSv/y	5.72	3.6	6.294	5.454	6.567	5.017	5.678	5.145

CONCLUSIONS

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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?