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Swiss Federal Nuclear Safety Inspectorate ENSI

Depleted Zinc Addition Experience at Swiss NPPs

January 13, 2014, Ft. Lauderdale

J. Hammer
ENSI

Agenda

- Introduction to ENSI
- Depleted Zinc Addition
- Current state in Switzerland
- The way forward

Introduction to ENSI

ENSI is the Swiss Federal Nuclear Safety Inspectorate

- Created in 2009, successor of HSK
- Mission:
  - Supervise reactor and radiation safety and security in all Swiss nuclear installations:
    - Nuclear power plants
    - Research and training reactors
    - Interim storage facilities
  - Approve safety-relevant changes to nuclear installations within the current licences
  - Supervise the safety of transports of nuclear materials to and from nuclear installations
  - Assess the safety of proposed solutions for the geological disposal of radioactive waste
  - (Supervise safety of new nuclear power plant projects)

- *ENSI is responsible for the safety and security evaluation during the entire life cycle of all Swiss nuclear facilities*
- *But ENSI is not the Licensing Authority for Nuclear Power Plants*

ENSI: Staff and Finance

Staff

- 150 employees
- Professions:
  physicists, mechanical/electrical/civil engineers, chemists, geologists, geophysicists, IT specialists, biologists, psychologists, political scientists, lawyers etc.

Finance

- Budget: 55 million CHF around 55 million US$
- Funded from fees and regulatory charges paid by operators of nuclear facilities (covering a bit more than 90% of budget);
- Swiss Confederation (research, communication)

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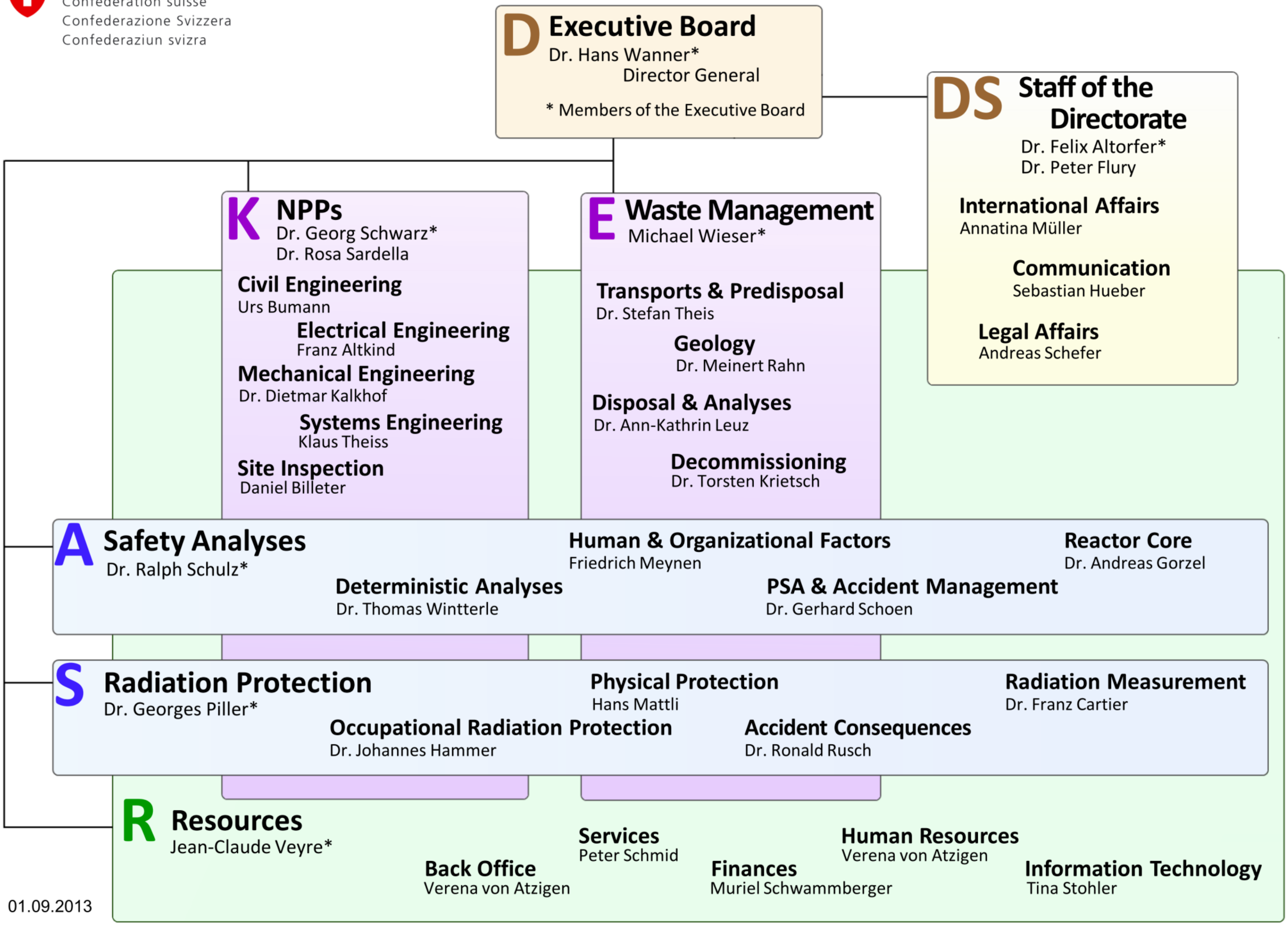

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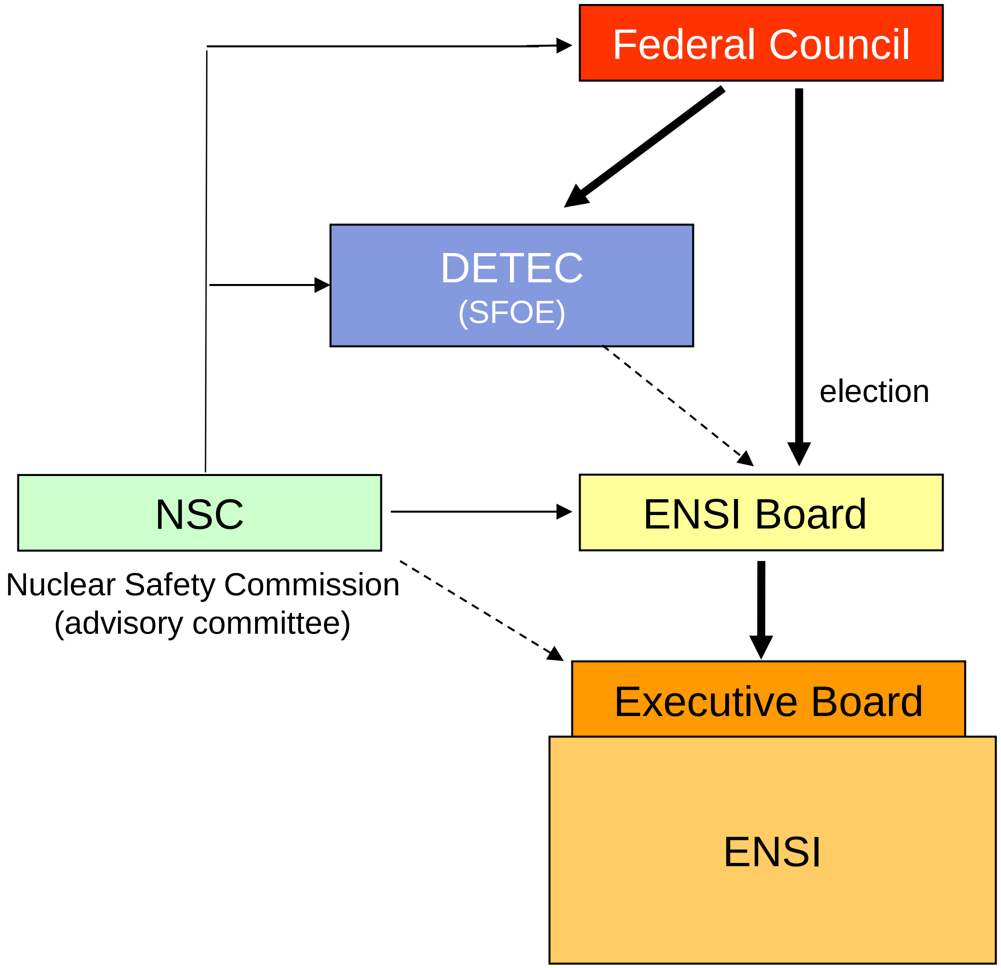
ENSI's institutional framework



Responsible for:
- DETEC: Construction and operation licenses
- SFOE: Other nuclear licenses (transport, trade, import, export) and safeguards

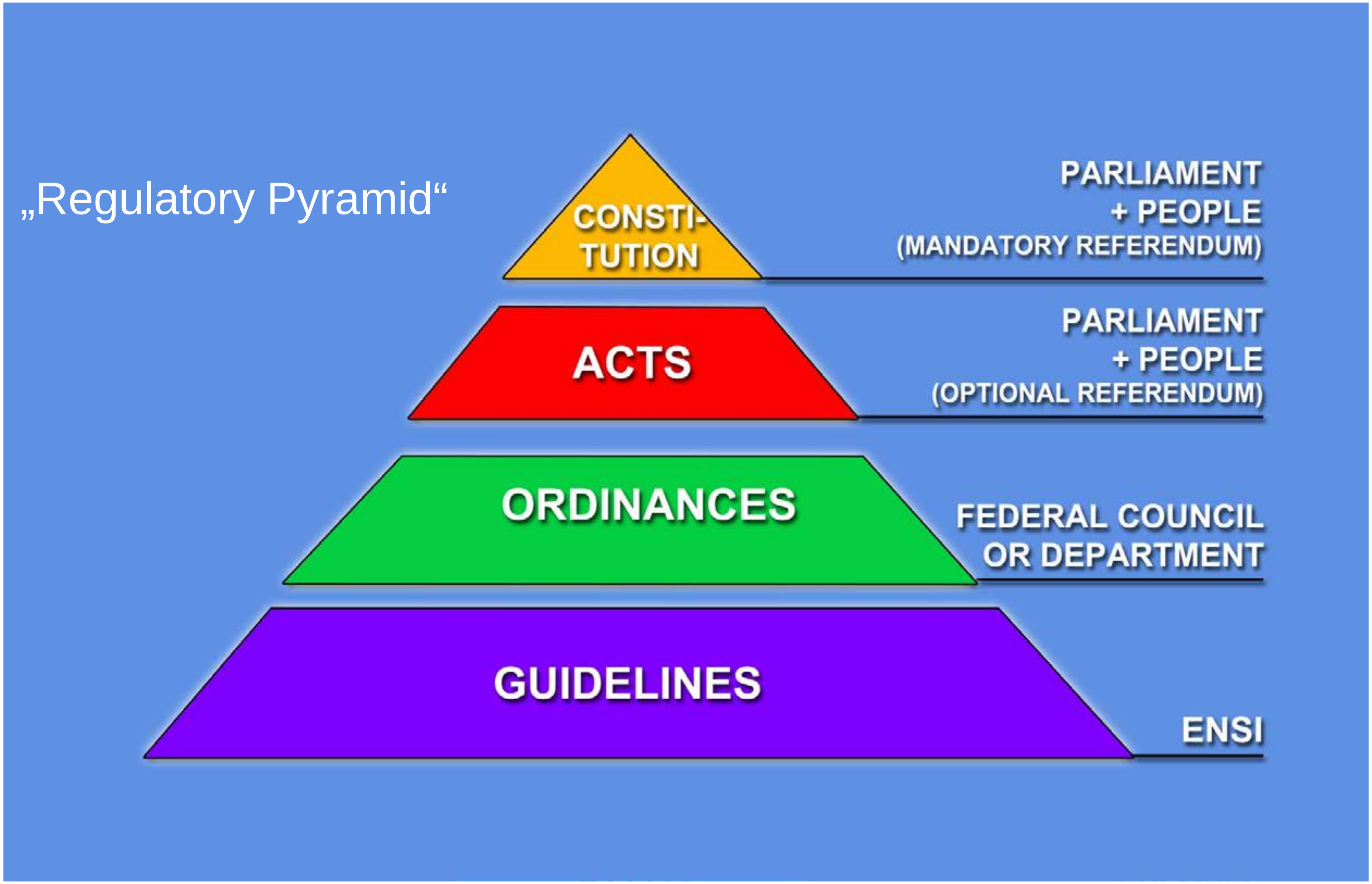
Responsible for:
- Strategic objectives, organization, budget
- Supervision of management activities
- Election of ENSI executive management

Responsible for:
- Executive management of ENSI
- Reviews/decisions on nuclear safety and security
- External representation

Legal form
- Body constituted under public law, own legal persona
- Operationally independent; institutionally and financially independent since 1 January 2009

DETEC: Department of Environment, Transport, Energy and Communications
SFOE: Swiss Federal Office of Energy

The Swiss Regulatory Pyramid



Depleted Zinc Addition

Depleted Zinc Addition

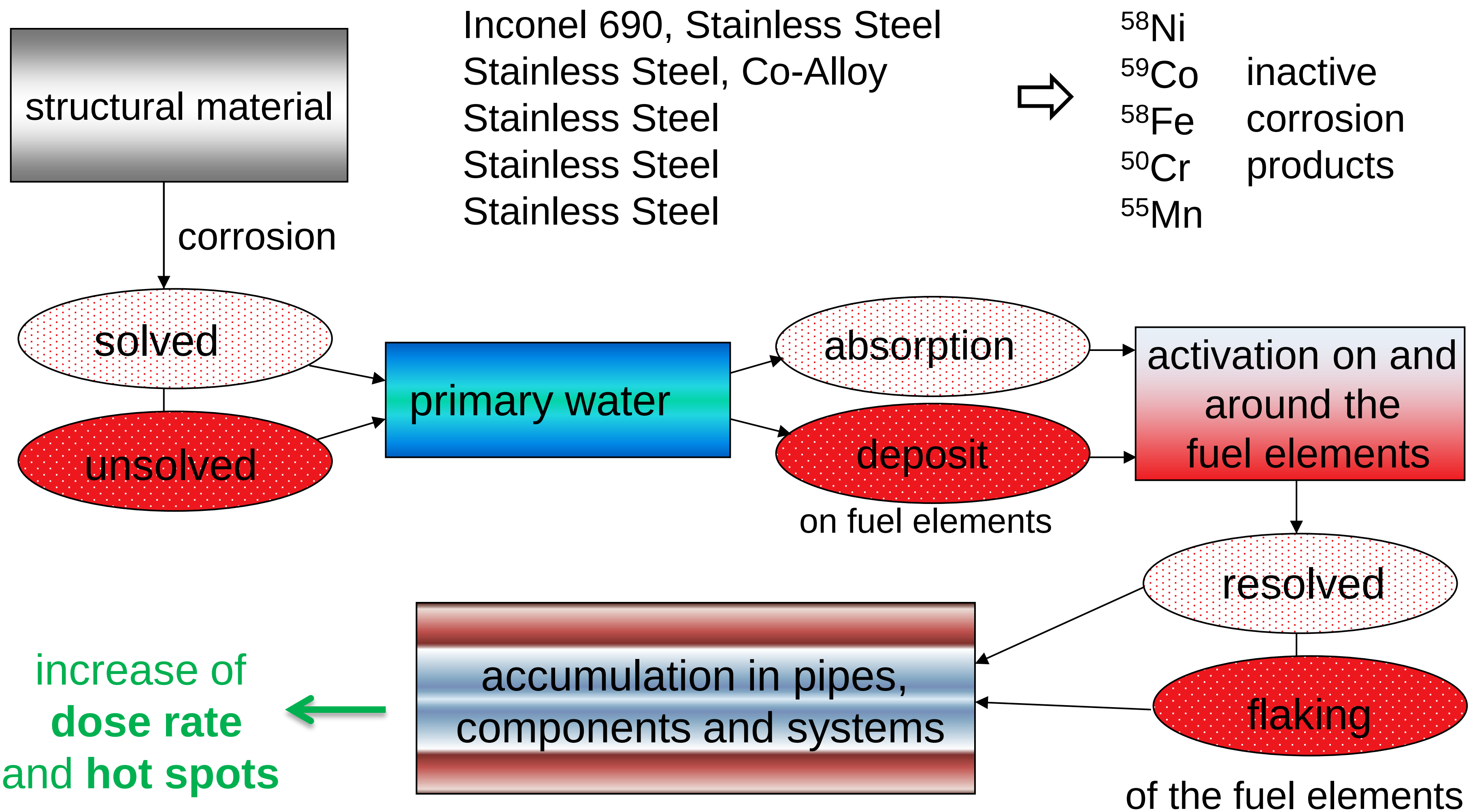
Why is it important for RP to minimize corrosion*?

*) corrosion := metal corrosion and metal release

solved and unsolved corrosion products
from primary circuit components

^{58}Ni
^{59}Co
^{58}Fe
^{50}Cr
^{55}Mn
....

Activity build-up (I)



Activity build-up (II)

structural material

				$t_{1/2}$	h_{10} [(mSv/h)/GBq]*
Inconel 690, Stainless Steel	⇨	^{58}Ni (n, p)	⇨ ^{58}Co	70,86 d	0,147
Co-Alloy, Stainless Steel		^{59}Co (n, γ)	^{60}Co	5,27 a	0,366
Stainless Steel		^{58}Fe (n, γ)	^{59}Fe	44,51 d	0,175
Stainless Steel		^{50}Cr (n, γ)	^{51}Cr	27,7 d	0,005

*Radiological Protection Ordinance, Switzerland

Activation Products

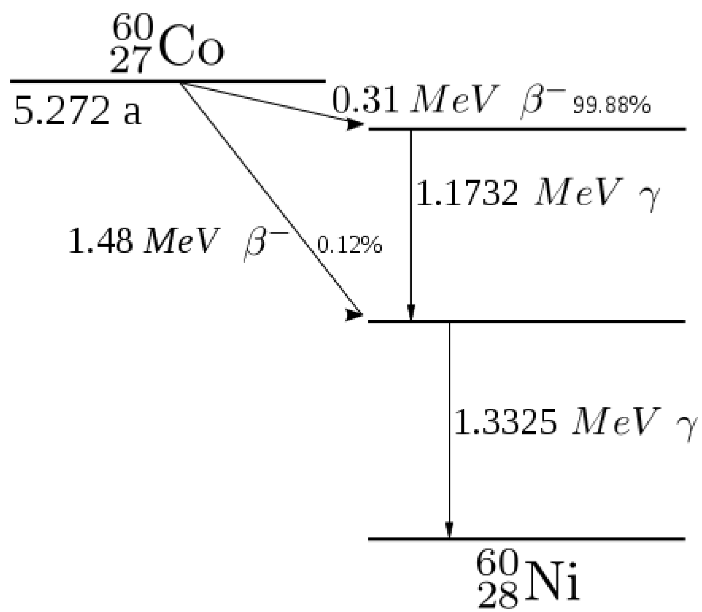
^{60}Co

^{58}Co

^{59}Fe

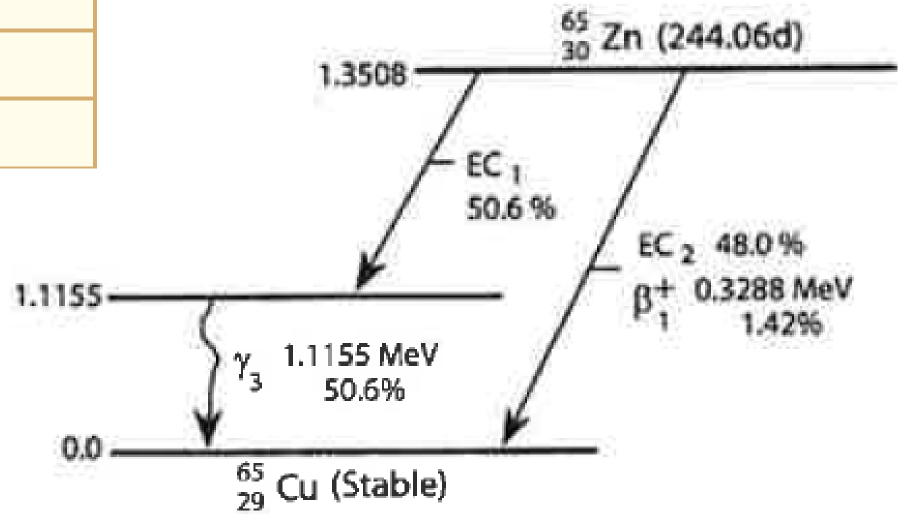
^{51}Cr

....



Isotopic composition of natural zinc

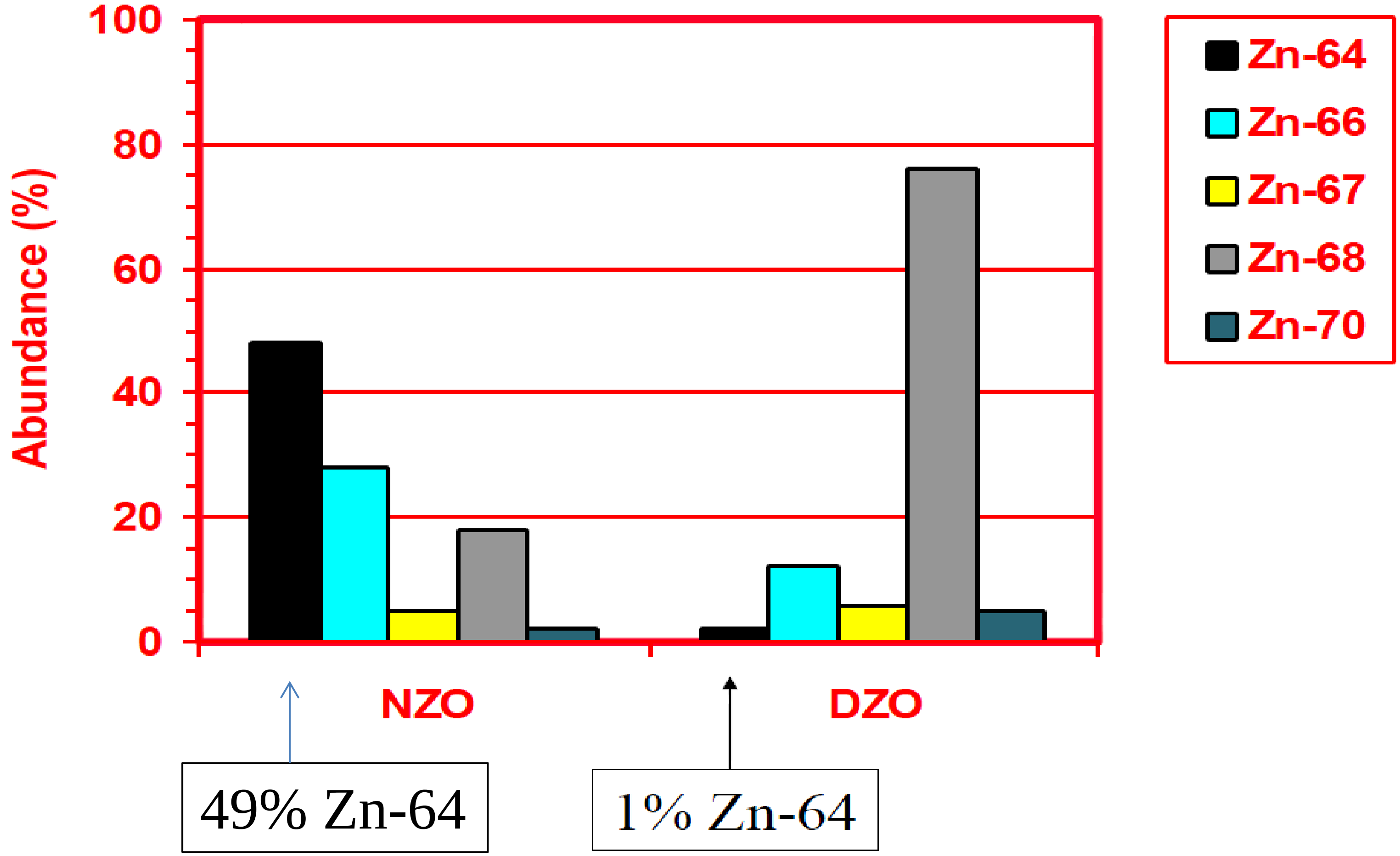
Isotope	Concentration [%]
^{64}Zn	48.6
^{66}Zn	27.9
^{67}Zn	4.1
^{68}Zn	18.8
^{70}Zn	0.6



^{65}Zn is produced by the by the neutron flux in the core region due to the nuclear reaction ^{64}Zn (n,γ) ^{65}Zn.

^{65}Zn is a hard γ-emitter with 1.11 MeV energy and 245 days half-life time.

Distribution of stable Zinc Isotopes in Natural and in Depleted Zinc

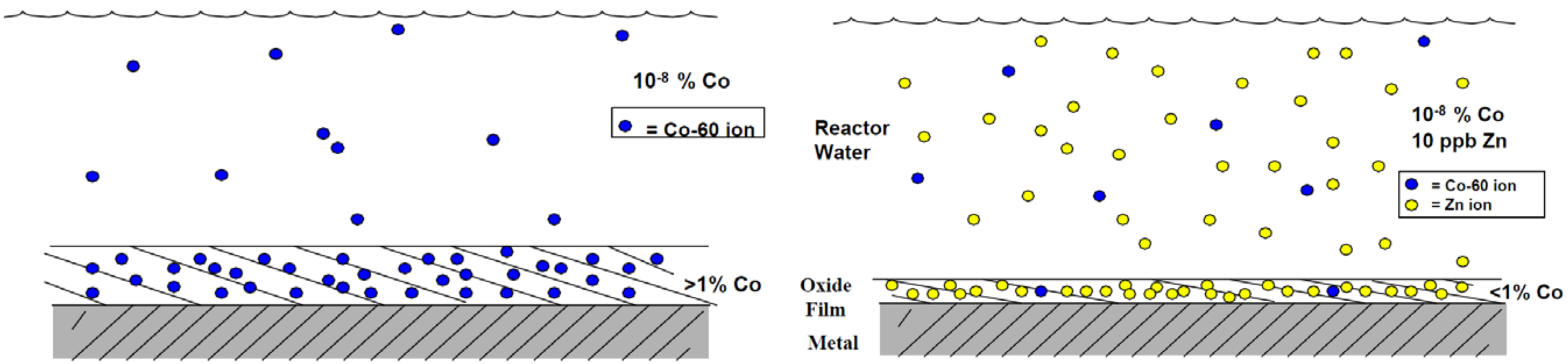


↳ Dose rate reduction due to water chemistry

The addition of zinc has two effects:

- Due to formation of thinner oxide layers on the surface of the structural materials, the corrosion rate and hence the input of corrosion products into the primary water is mitigated.

- The Zn-isotopes build more stable spinells compared to Co-60, hence the enclosure of Zn into the oxide layers is preferred compared to Co-isotopes.



Addition of DZO into the feed water shows the following results:
concentration in the primary water should be around 5 to 10 ppb

- ☺ The total thickness of the oxide scale of the structural materials is reduced.
- ☹ It seems that in the oxide scales already enclosed Co is not, or at least not completely exchanged for Zn.
- ☺ The already enclosed Co is reduced by decay, hence the dose rate is reduced by time.
- ☺ There is a competition concerning the enclosure into the oxide scale between the isotopes of Zn and Co.
- ☺ The enclosure of Zn into the oxide scales is compared to Co preferred.


Current State in Switzerland

Current State in Switzerland

NPP	type	in operation	DZO injection
KKM	BWR	since 1972	since 1998
KKL	BWR	since 1984	since 1992
KKG	PWR	since 1979	since 2005
KKB1	PWR	since 1969	not foreseen
KKB2	PWR	since 1971	not foreseen

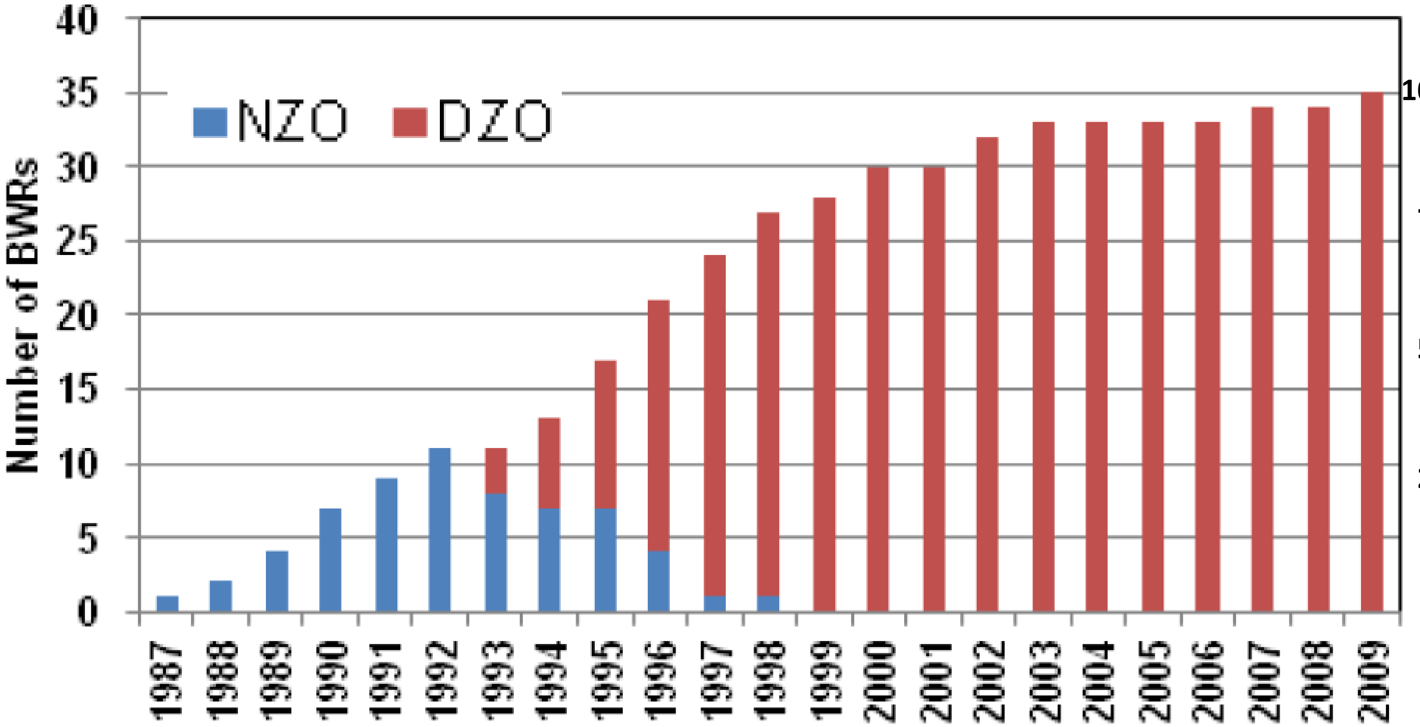


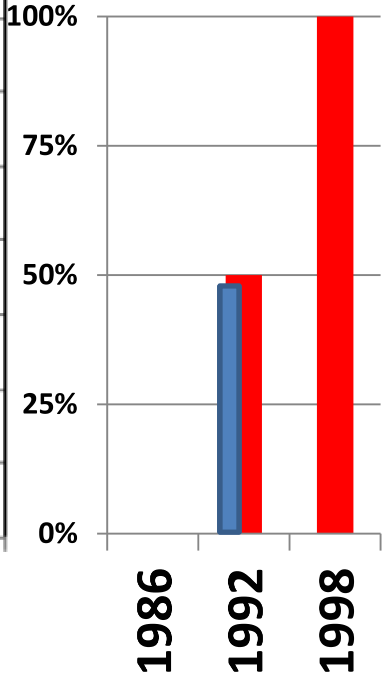

Zinc injection history at U.S. and Swiss BWRs

Since 2009 all 35 U.S. BWRs are injecting depleted zinc oxide DZO into the reactor feed water for control of shut down radiation fields.

U.S.-BWRs

CH-BWRs



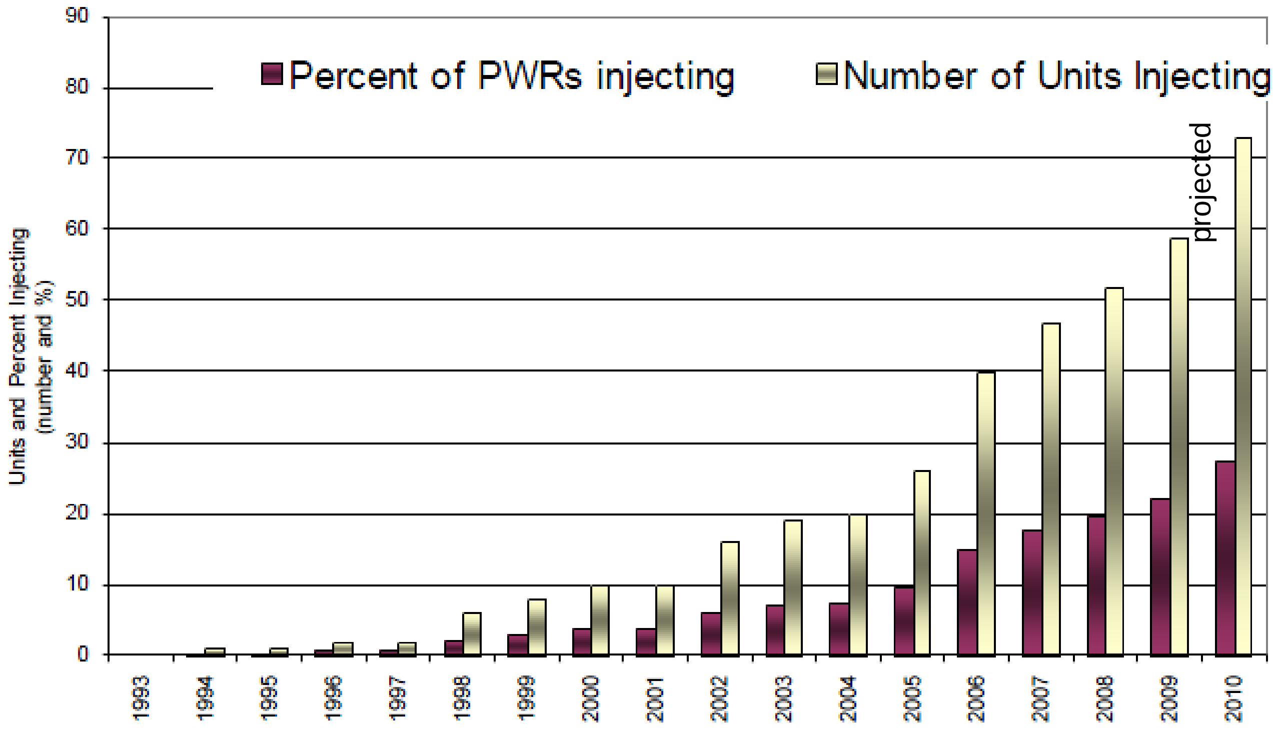


S.E. Garcia (EPRI) et al., NPC 2012, Paris, France

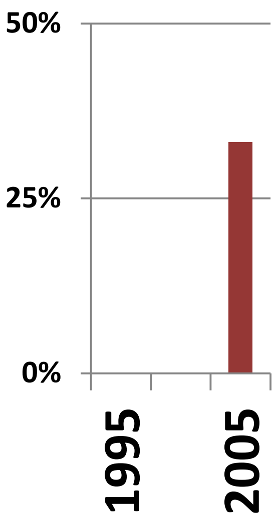
Zinc injection history at U.S. and Swiss PWRs

The injection of DZO has increased to 59 units worldwide (Dec. 2009):
23 % of the worldwide PWR fleet and 51 % of the U.S. fleet.

Worldwide-PWRs



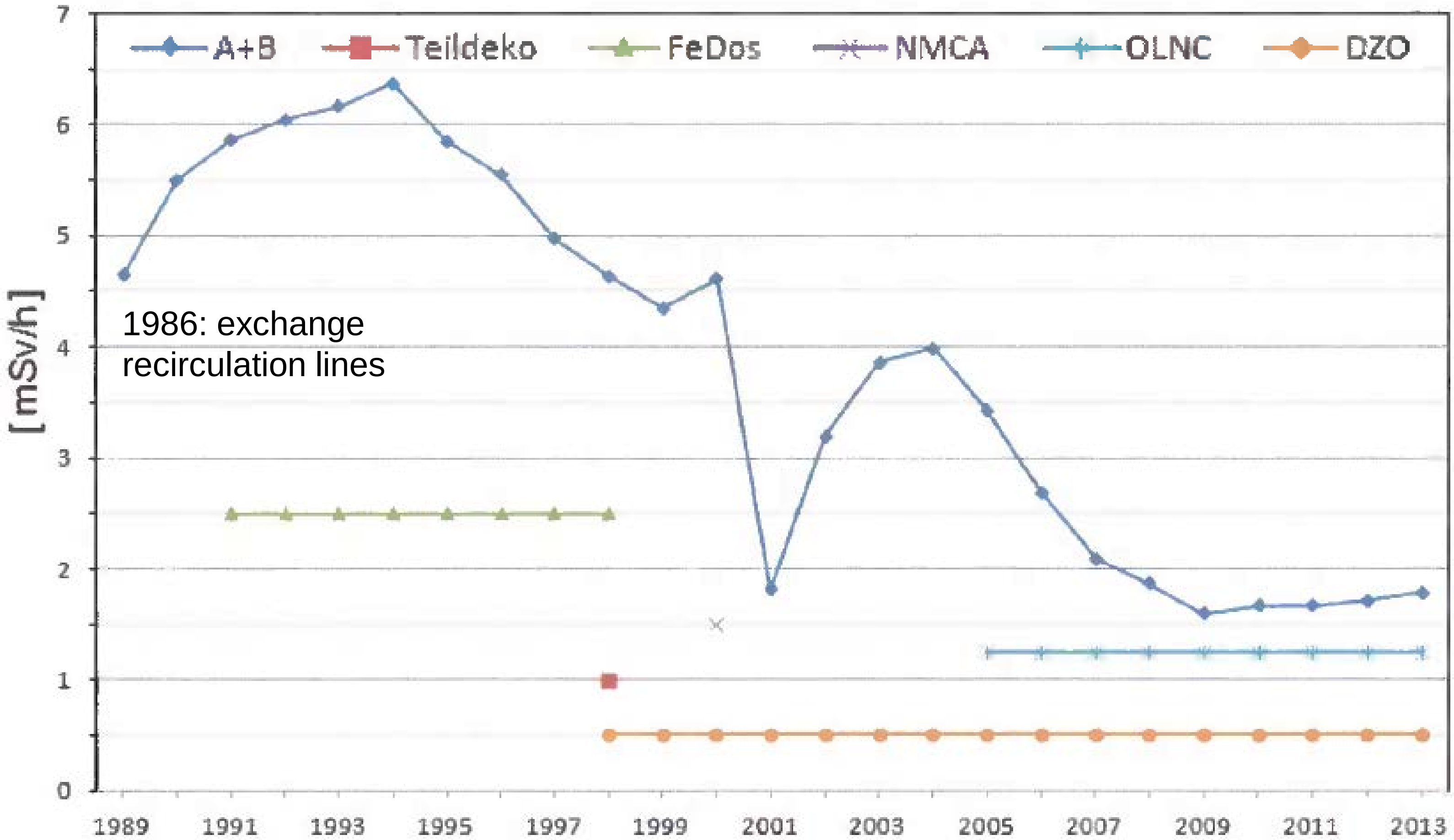
CH-PWRs



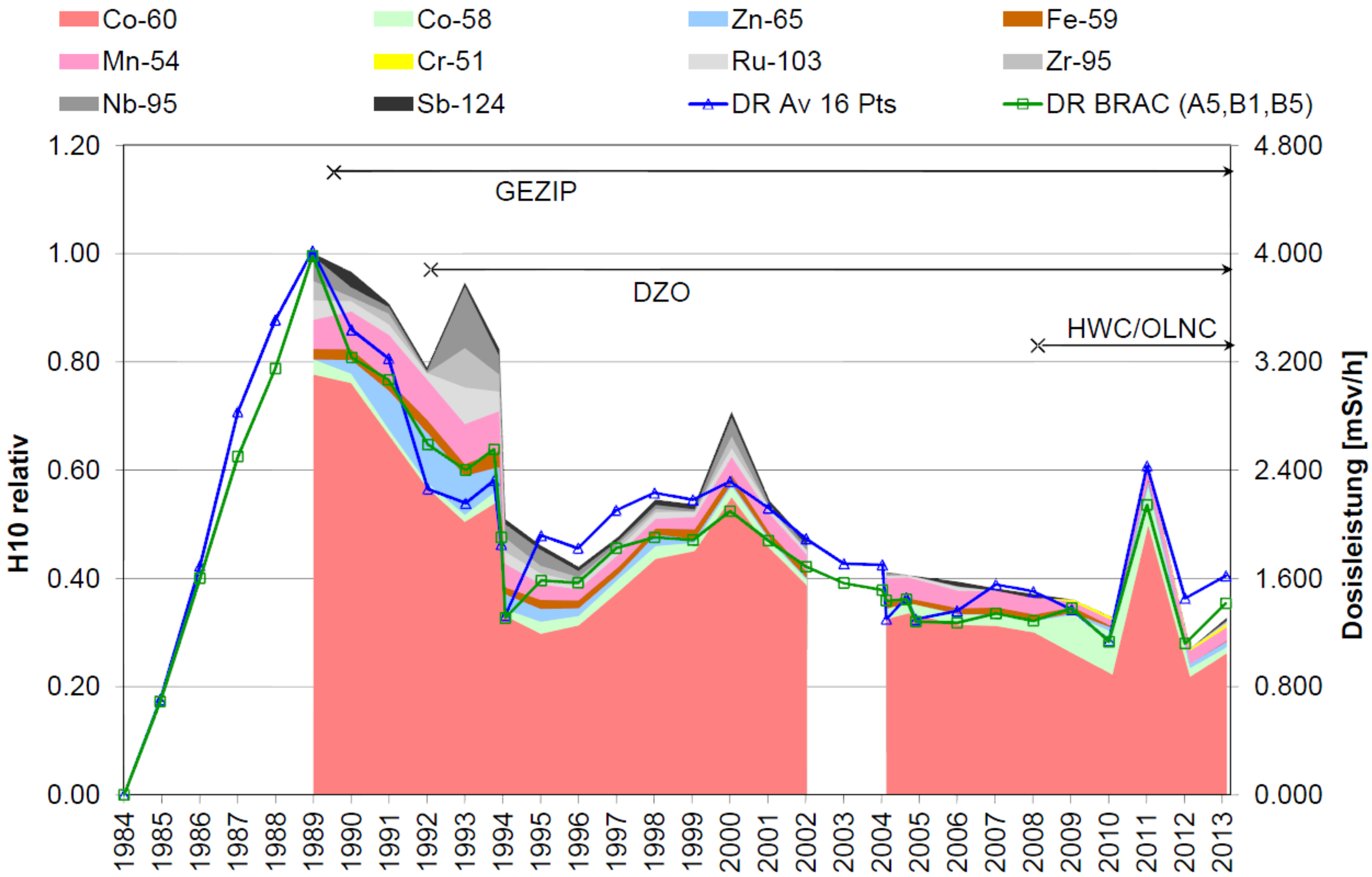
K. Fruzzetti (EPRI) et al., NPC 2010, Quebec, Canada

Mühleberg Nuclear Power Plant, KKM

The changes of the dose rates cannot clearly be explained with DZO addition due to the several other modifications performed.

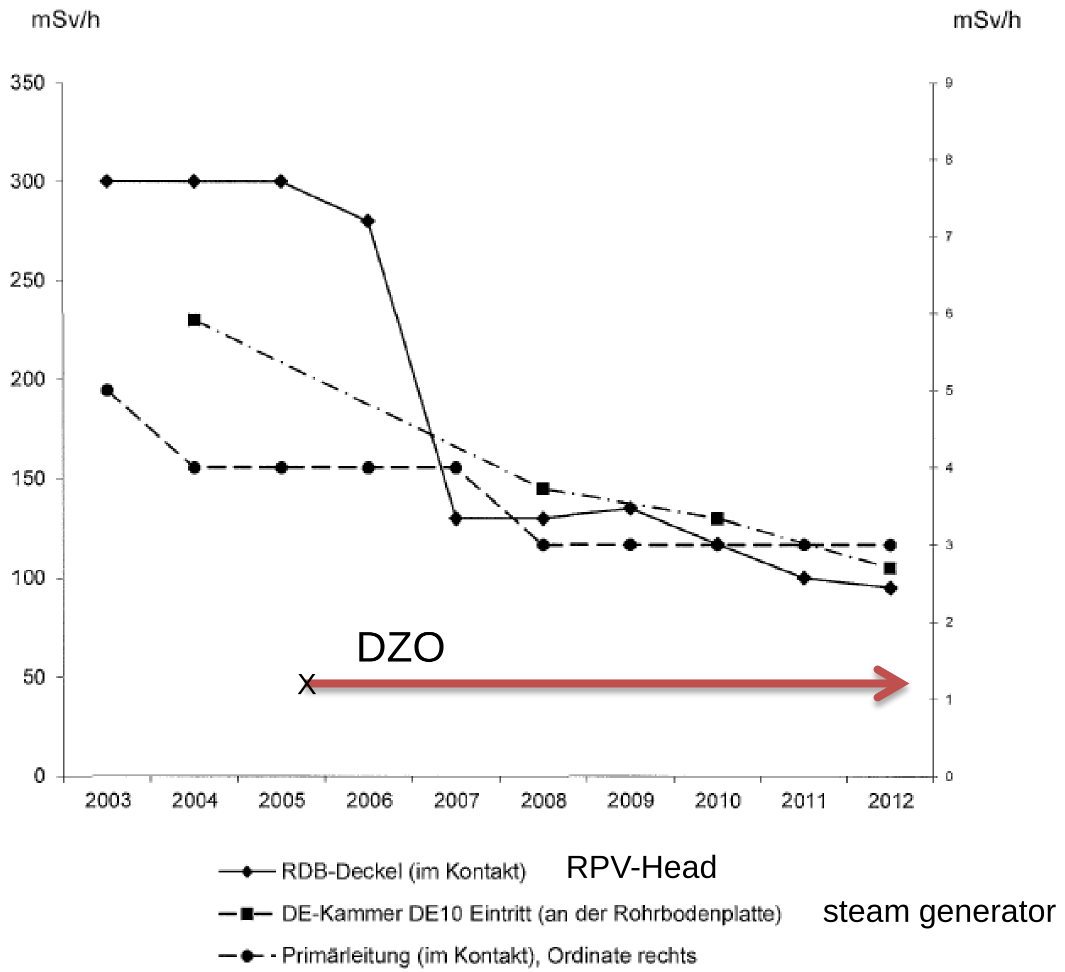


Leibstadt Nuclear Power Plant, KKL



Gösgen Nuclear Power Plant, KKG

The reduction of dose rates is clearly related to the addition of DZO.



The way forward

The way forward

- → Addition of Zinc as DZO continued
- → avoiding of Cobalt containing materials particularly in the primary circuit
- → an effective reactor water clean up system can lead to a reduction of the dose rate!
- → Observation of dose rates at the Beznau NPP

The main goal is:

Minimizing the exposure of workers

for more information please visit:

www.ensi.ch

www.ifsn.ch

http://twitter.com/#!/ENSI_CH

Thank you for your attention!

and

many thanks to my co-workers

in particular H. Glasbrenner