VGB POWERTECH

Tritium in German NPP
Relevance on Radiation Protection

ISOE Symposium 2012

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H-3 in German NPPs - Relevance on RP

- In Germany 2 types of NPPs are in operation

  - BWRs (2 plants in operation)

  - PWRs (7 plants in operation)

Physical properties of H-3

$$\text{H-3} \longrightarrow \text{He-3} + \beta^- + \nu^-$$

Half-time:	**12,3 years**
max. β-energy:	**18,6 keV**
mean β-energy:	**5,7 keV**
max. range in tissue:	**6 μm**

Chemical form of H-3 in LWR

- Nearly exclusive HTO

- HT negligible
  - Measurement in PWR - stack air <2% of HTO
  - small realease at cuttting BWR control rods or neutron sources

H-3 production in a NPP (1300 MW-Reactor) [Bq/a][1)]

	BWR	PWR	Transition to PCC
Ternary fission	9E14	9E14	< 0,001
B-10 (n,2α) control rods	1E14	-	< 0,001
B-10 (n,2α) water	-	4E13	1
Li water	-	1E12	1
H-2 (n,γ) water	6E11	6E11	1

[1)] Bonka, 1982

Comparision: natural H-3 production: 7,2 E16 Bq/a (UNSCEAR)

H-3 transition to PCC[1)] (1300 MW Reactor) [Bq/a]

	BWR	PWR
Ternary fission	< 9E14	< 9E14
B-10 (n,2α) control rods	< 1E14	-
B-10 (n,2α) water	-	4E13
Li water	-	1E12
H-2 (n,γ) water	6E11	6E11
Sum	< 2E12	4,2E13
typical total release/a	1E12	3E13

1) Primary Coolant Circuit

Typical H-3 concentration in NPP

- **BWR**

  Water-/steam circuit: ca. 1-2E08 Bq/m³
  Spent fuel pool: ca. 1-2E08 Bq/m³

- **PWR**

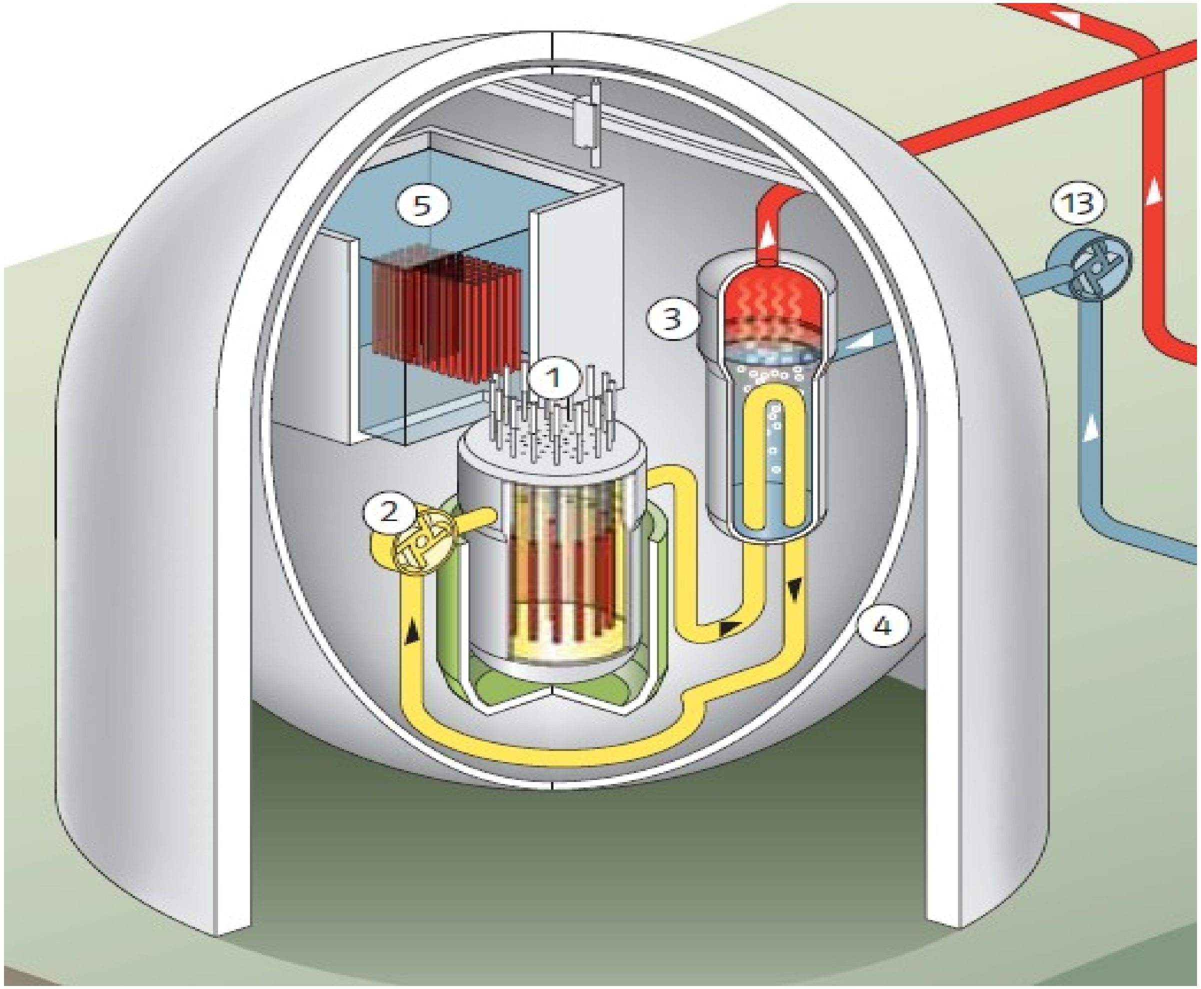
  Primary coolant circuit: ca. 1E10 Bq/m³
  Spent fuel pool: some E09 Bq/m³

H-3 in LWR - conclusions

– H-3 in BWR is irrelevant for radiation protection
  Room air concentration <<1E03 Bq/m³

- H-3 in PWR may be relevant for RP

German PWR - Containment



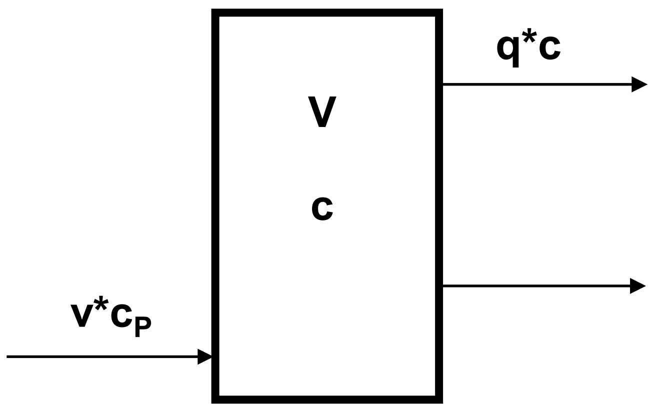
Sources and sinks for H-3 in room air

- **Sources**
  - Evaporation from spent fuel pool / reactor pool during shutdown
  - *Leakages (negligible)*

- **Sinks**
  - Exhaust air of containment
  - *Circulation cooling (negligible)*

→ **PWR-Containment may be relevant**

Calculation model for H-3 concentration in room air of PWR containment



V:	Containment volume	[m^3]
v:	Evaporation rate	[kg/h]
c_P:	H-3 concentration pool	[Bq/kg]
c:	H-3 concentration room air	[Bq/m^3]
q:	Exhaust air rate	[m^3/h]

$$dc/dt = v*c_P /V - q*c/V$$

$$c(equi.) = v*c_P/q$$

Equilibrium concentration in PWR containment air

$$c(\text{equi.}) = c_P * v / q \quad [Bq/m^3]$$

- c_P: H-3 concentration in spent fuel / reactor pool [Bq/kg]
- v: Evaporation rate [kg/h]
- q: Exhaust air rate of room [m³/h]

Parameters determining H-3 concentration in room air

3 parameters:

- **H-3 concentration in spent fuel pool / reactor pool during shutdown**
- **Evaporation rate**
- **Ventilation rate of containment**

H-3 concentration in spent fuel/reactor pool

- H-3 concentration in spent fuel pool / reactor pool (shutdown) is direct proportional to H-3 concentration in room air

- How to reduce H-3 concentration in spent fuel pool / reactor pool?

  change pool water

  → increase discharges

Evaporation rate

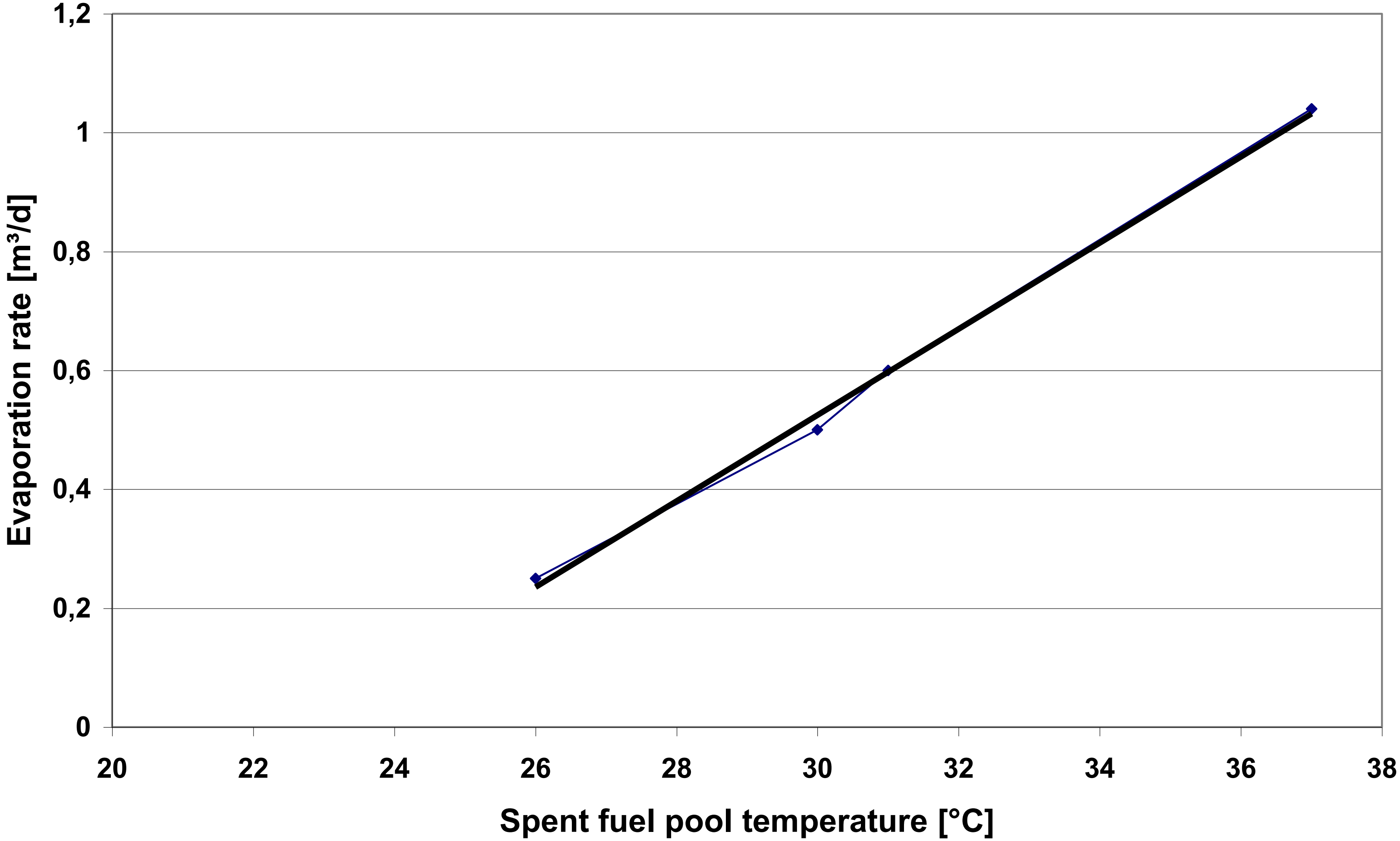
– **Evaporation rate is direct proportional to H-3 concentration in room air**

– **How to reduce evaporation rate?**

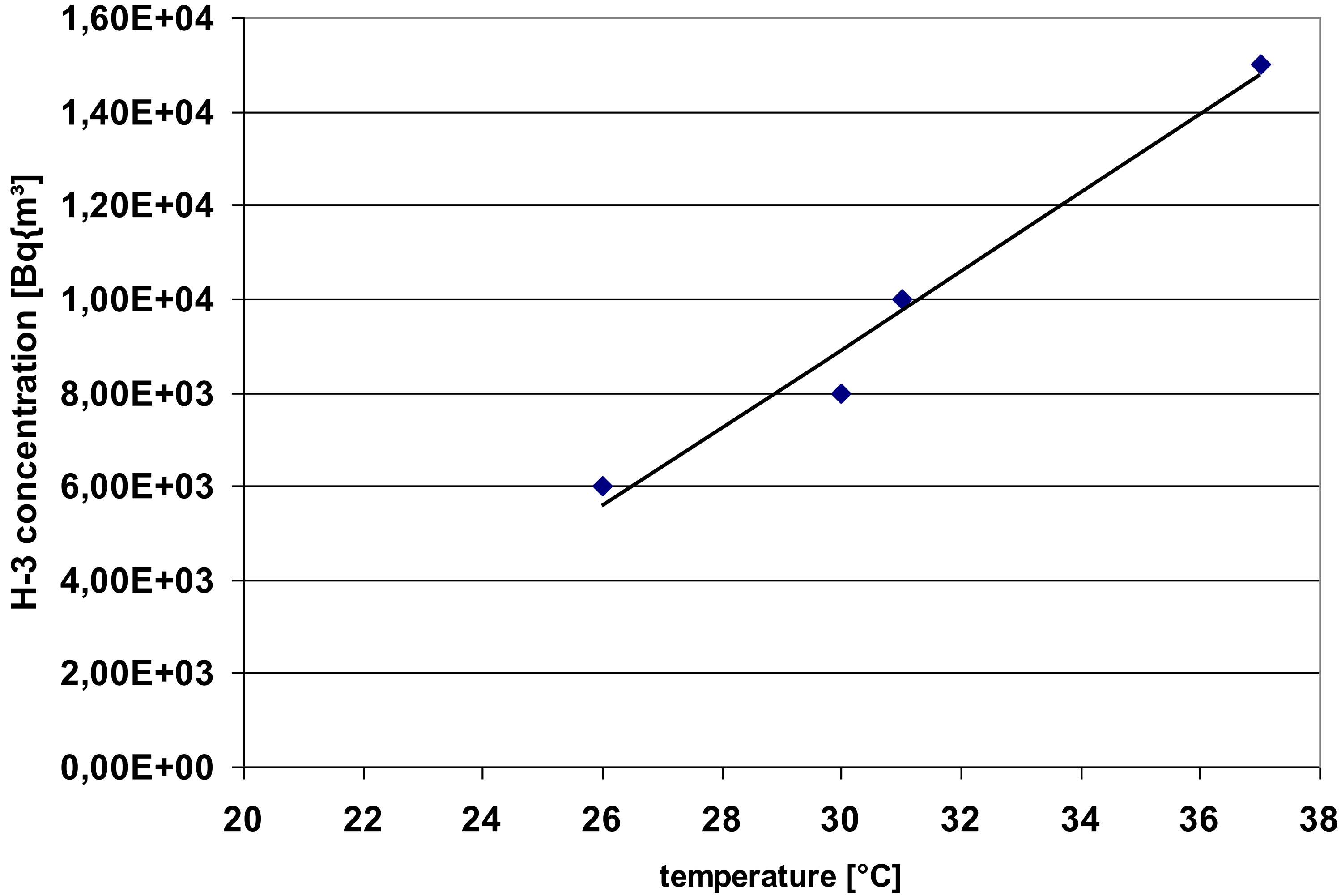
- *increasing humidity of supply air*
  (problems with condensation, conditions of work)

- lowering temperature of spent fuel pool

Evaporation rate vs. temperature of spent fuel pool



H-3 concentration vs. temperature of spent fuel pool



Ventilation rate of containment

– Ventilaton rate is inverse proportional to H-3 concentration in room air

– Ventilation rate is defined by design

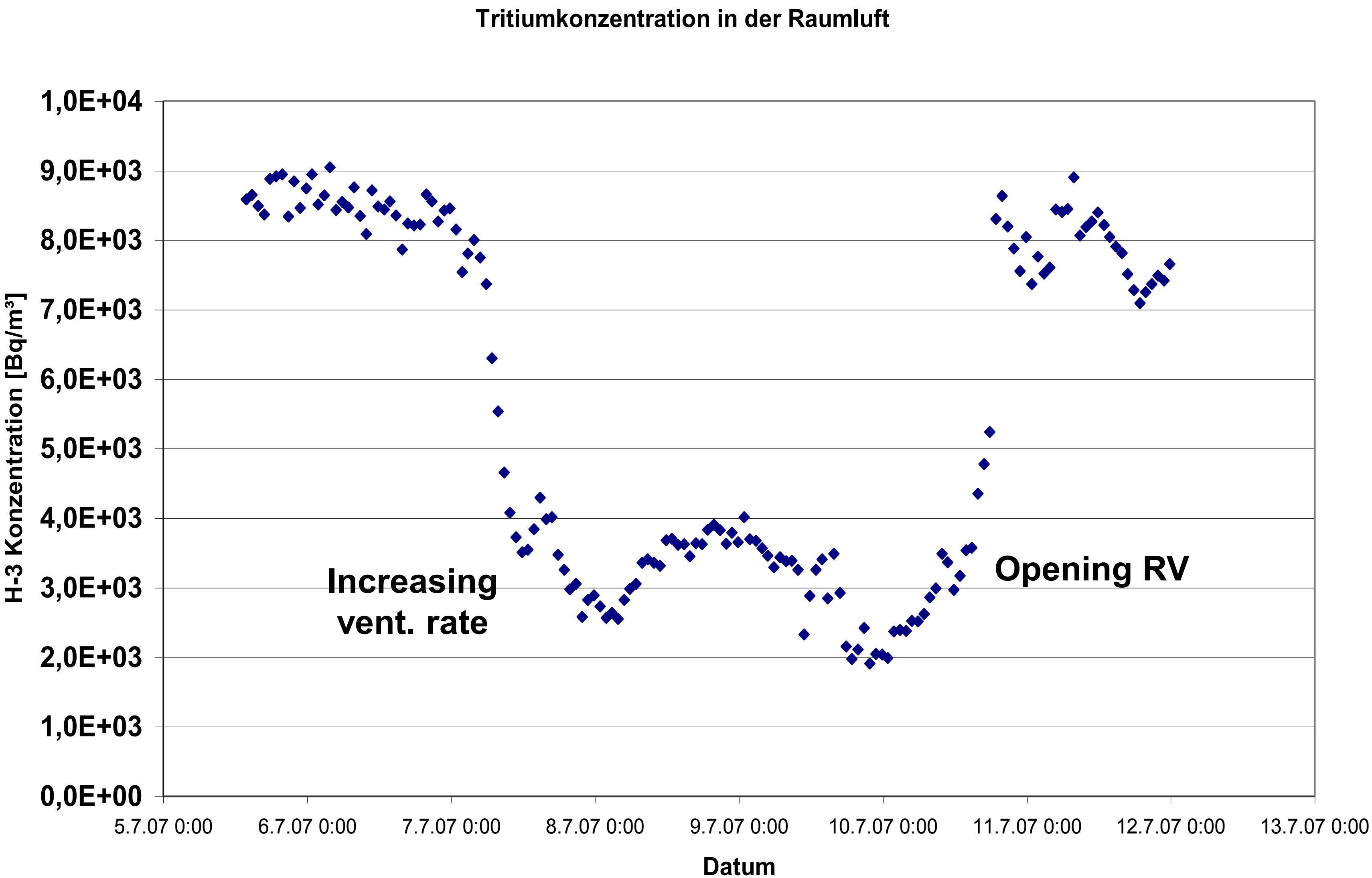
→ normally no influence

KKI 2 during operation : 5.000 m³/h

– But:

KKI 2 during shutdown: 25.000 m³/h

Ventilation rate of containment-measurement



Radiation exposure due to H-3

Conversion factors:

- γ-Submersion: 0 (Sv/s)/(Bq/m³)
- β-Submersion: 0 (Sv/s)/(Bq/m³)
- Contamination: 0 $\mu Sv h^{-1} Bq^{-1} cm^{2}$
- **Inhalation: 1,8E-11 Sv/Bq (HTO)**

  1,8E-15 Sv/Bq (HT)

Dose due to H-3 exposure in room air

$$E = e \times c \times v \times t \times 1{,}5 \ \ [Sv]$$

E: effective dose	[Sv]
e: conversion factor	1,8 E-11 [Sv/Bq]
c: H-3 concentration	[Bq/m³]
v: rate of inhalation	1,2 [m³/h]
t: exposure time	[h]

1,5: factor for intake by dermis

German regulatory requirement regarding incorporation

- 0,5 mSv/a < Exposure < 1mSv/a:

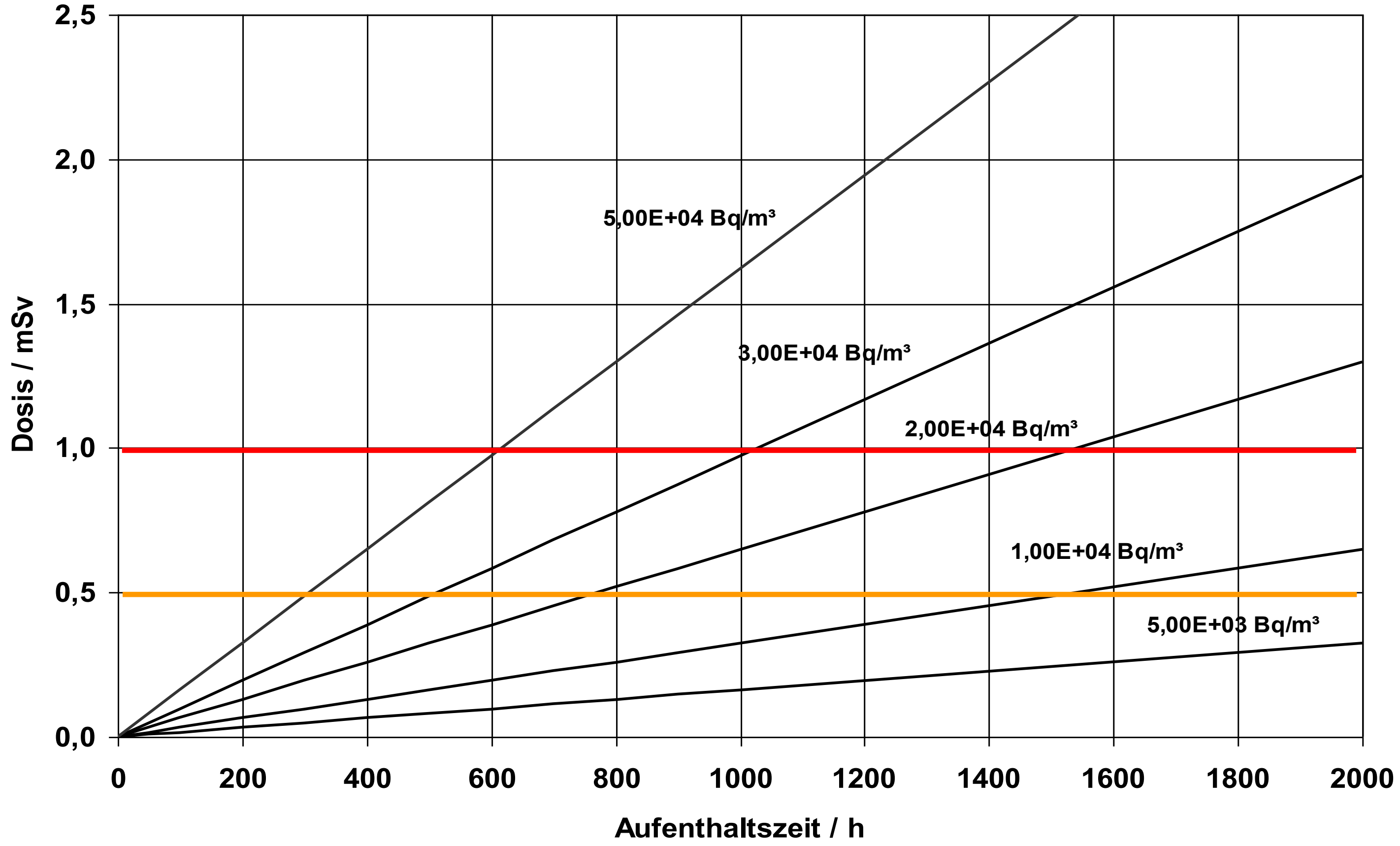
  verfication: exposure < 1mSv/a

- Exposure < 0,5 mSv/a:

  no measures

- Exposure < 0,05 mSv/month: = 0

H-3 Dose as function of exposure time and H-3 concentration



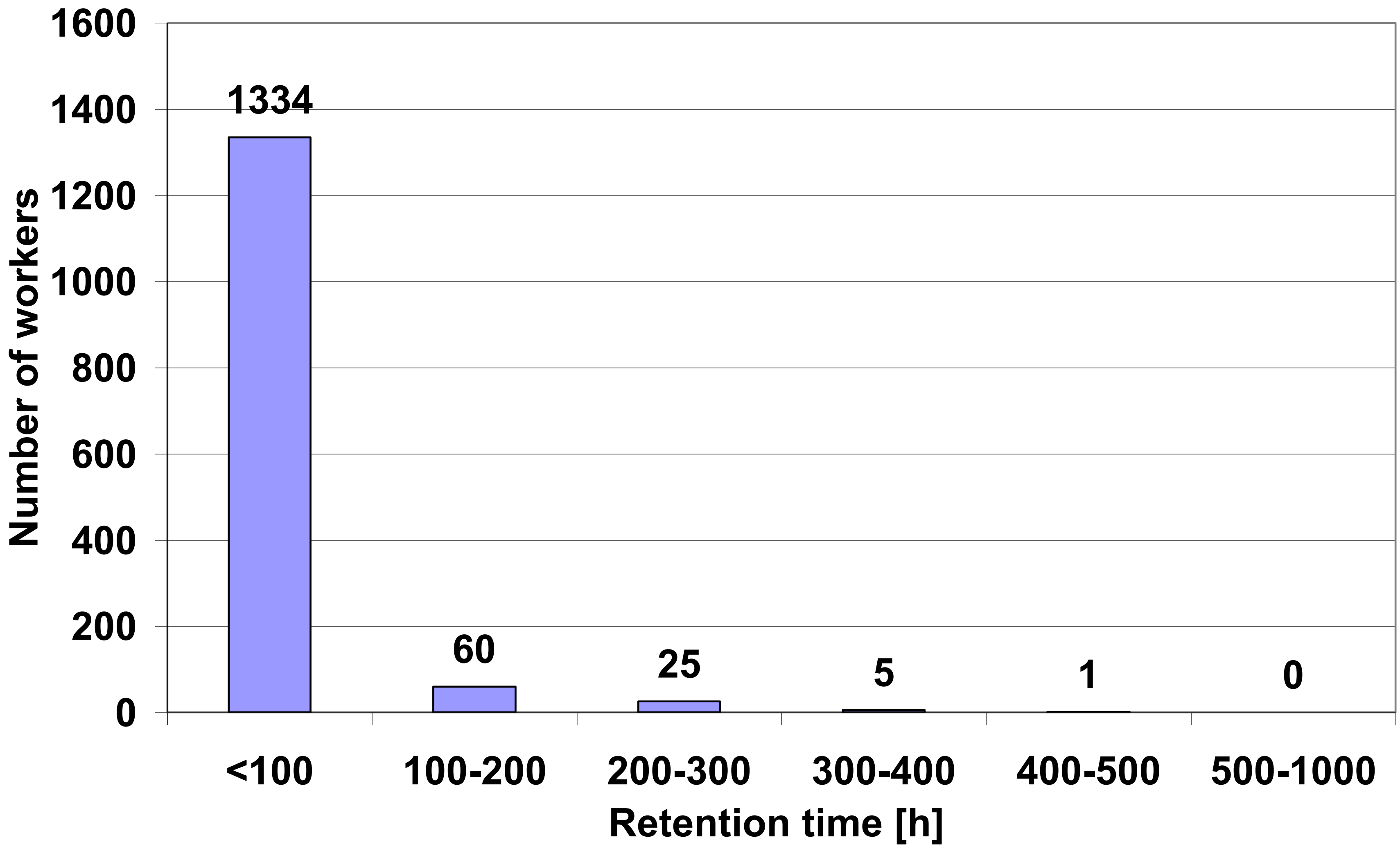
VGB – Exposure time (questionnaire)

- Max. exposure time (containment): ca. 1000h/a

  1000h/a: 0,5 mSv conform to $1{,}5 \times 10^4$ Bq/m³

- Exposure time normally << 1000h/a

Retention time/a in containment (KKI 2, 2008)



VGB – Exposure time (questionnaire)

- **But there may by external workers with higher exposure times, up to 1500 h/a**

VGB Concept for H-3 incorporation surveillance

- **Periodic monitoring of H-3 concentration in spent fuel pool / PCC**
- **Periodic monitoring of H-3 concentration in room air**
- **If H-3 concentration room air < 10^4 Bq/m³: no action (for all BWRs)**
- **Control samples of urine of workers with highest exposure times to check representativity of dose determination**

VGB Concept $c(H\text{-}3) > 1x10^4\ Bq/m^3$ (1)

- If $c(H\text{-}3) > 10^4\ Bq/m^3$:

  Determination of exposure time T(0,05), which could lead to an exposure of >=0,05 mSv per month

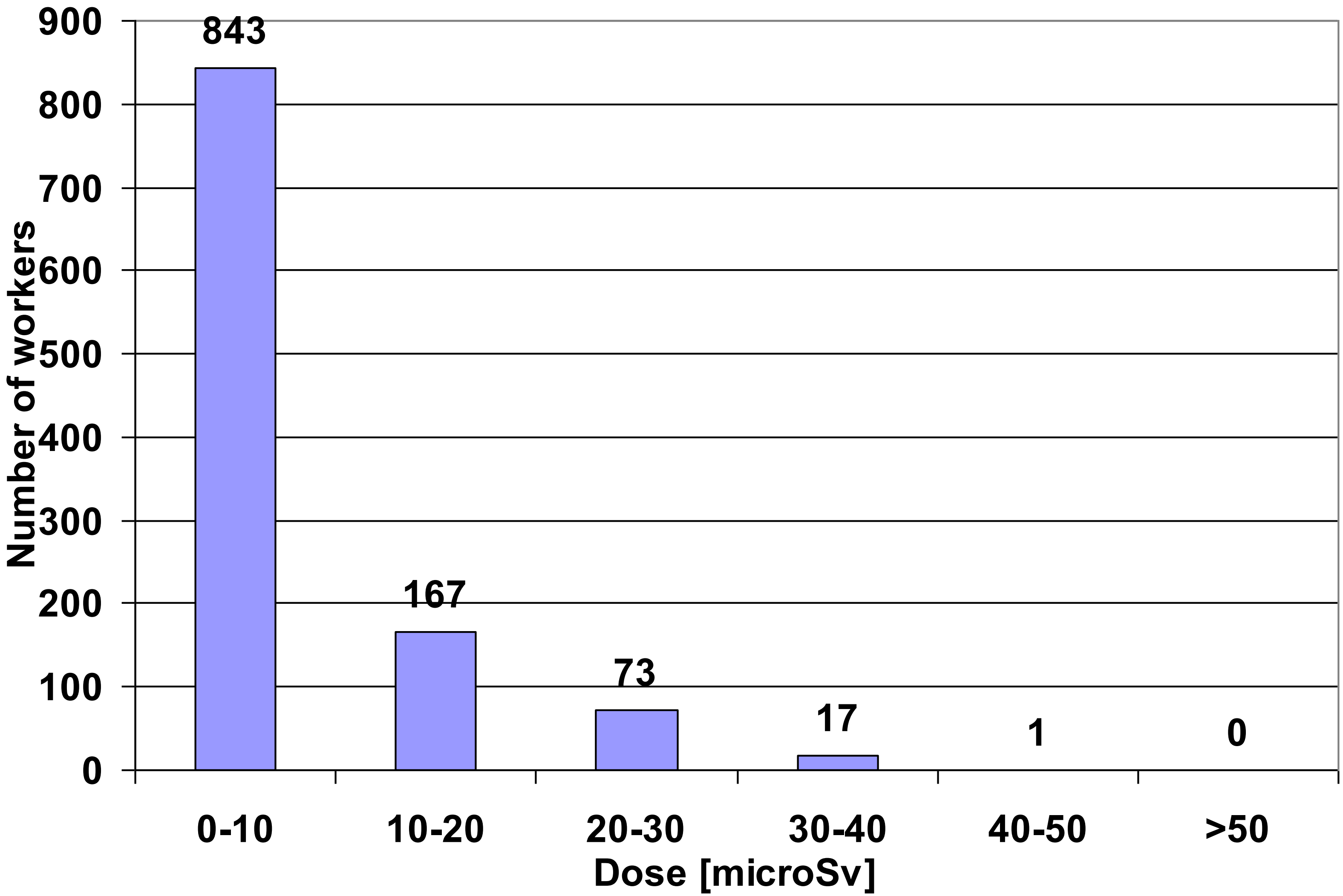
  e.g.: $c = 5x10^4\ Bq/m^3$ → T(0,05) = 31h

VGB Concept c(H-3) > 1x104 Bq/m³ (2)

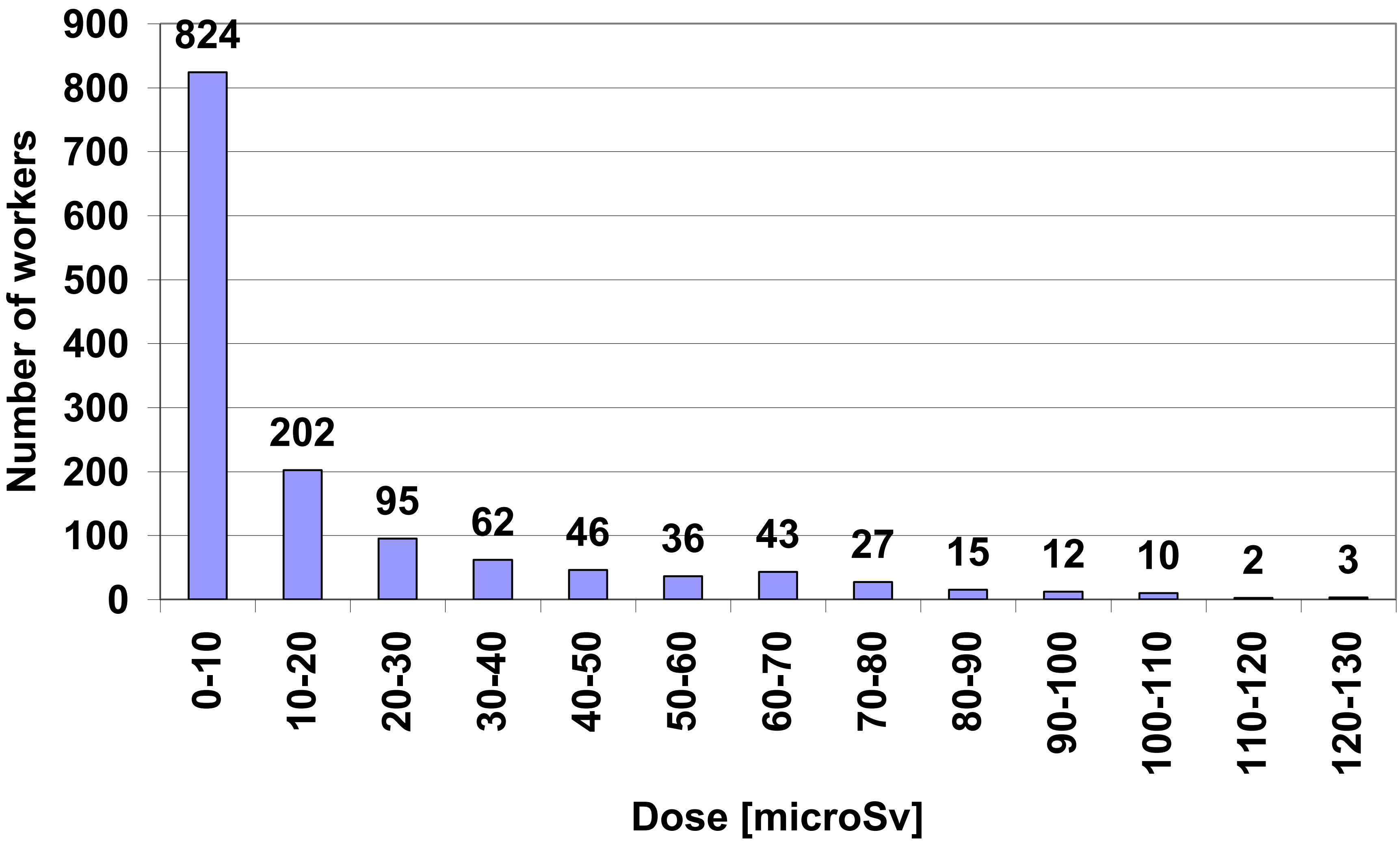
– If exposure time > T(0,05):

- Calculation of H-3 dose
- Information to responsible radiation officer (RO) (Germany: SSB)
- RO has to check if a dose of 0,5 mSv/a can be achieved
  yes: information to official dose measurement center
  determination of H-3 dose (e.g. by urine samples)

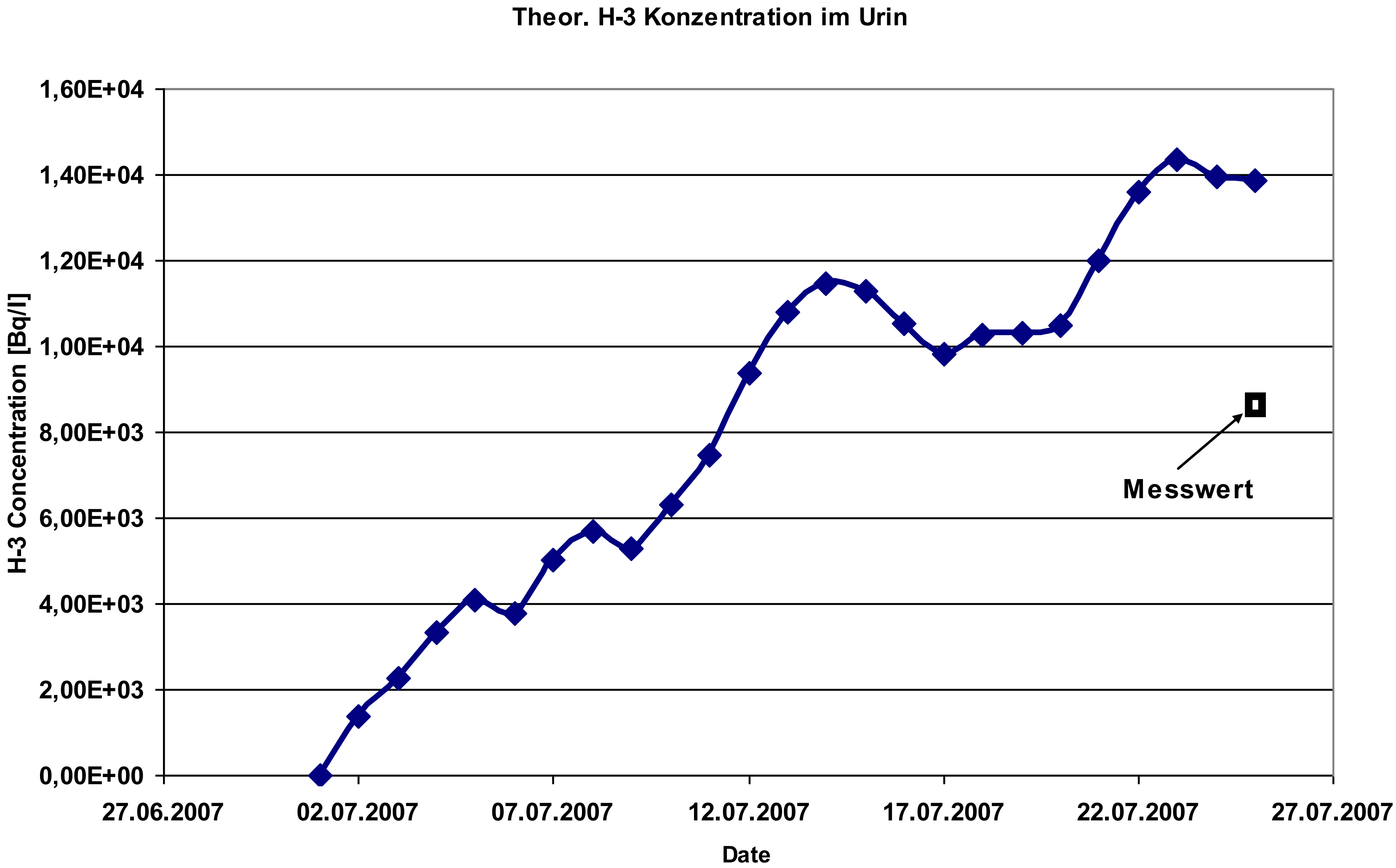
KKI 2: H-3 Dose distribution 2008 (shutdown)



NNP X: H-3 Dose distribution (shutdown 2008)



Urine measurement vs. theory



Summary

- **In BWRs H-3 doses are neglibible**
- **In PWRs measures to reduce H-3 concentration in room air have reduced H-3 concentration below 10^4 Bq/m³**
- **Only for a small number of external workers H-3 doses have to be determined**

More interest in Tritium???

- **Tritium Joven**
  Blanco
  Cosecha
- **Tritium Joven**
  Rosado

e·on | Kernkraft

Thank you for your attention