EXHALATION MEASUREMENT METHODOLOGIES :

THE ERRICCA BUILDING MATERIALS RADON EXHALATION RATE INTERNATIONAL INTERCOMPARISON

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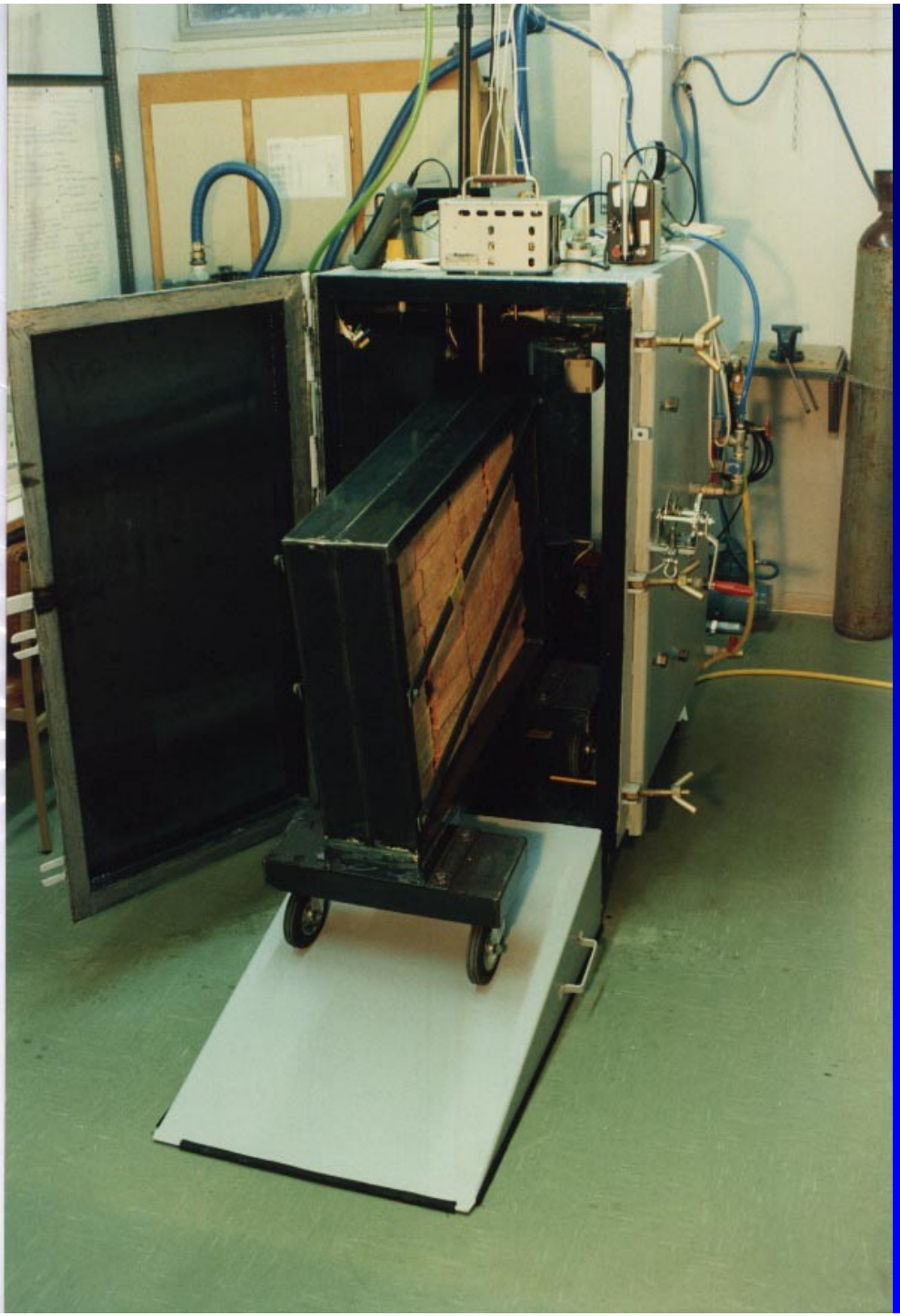
RADON EXHALATION MEASUREMENT PRINCIPLE

- ✓ ENCLOSE THE SAMPLE / STRUCTURAL MODULE IN A CONTAINER *or*
- ✓ ATTACH TIGHTLY A CONTAINER ON THE STRUCTURAL MODULE SURFACE

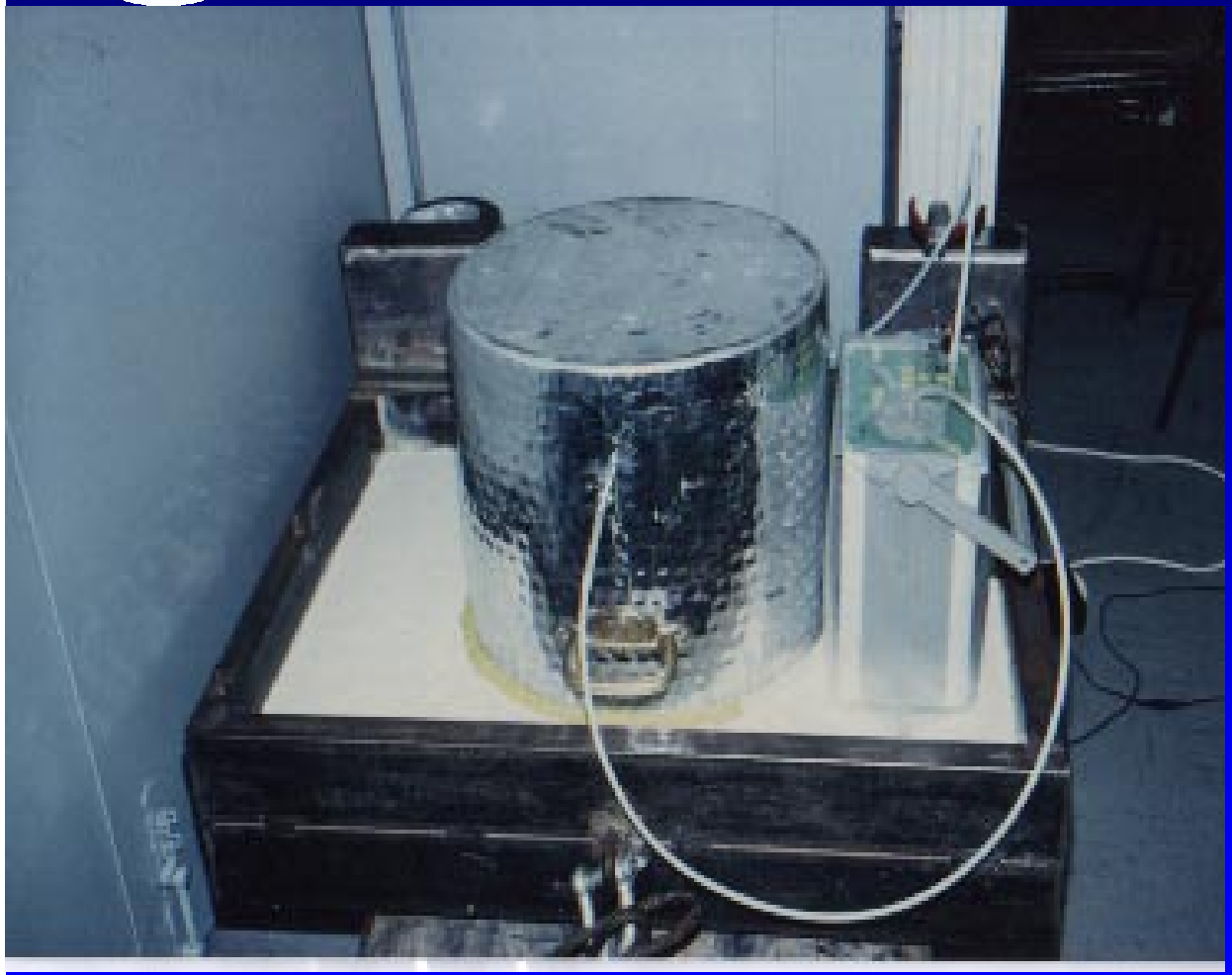
and

FOLLOW UP THE RADON CONCENTRATION GROWTH INSIDE THE CONTAINER

STRUCTURAL MODULE SPECIMENS



ENCLOSE SAMPLE / STUCTURAL MODULE IN A CONTAINER



ATTACH TIGHTLY A CONTAINER ON THE STRUCTURAL MODULE SURFACE

BEFORE CONDUCTING THE RADON EXHALATION RATE MEASUREMENT

CONDITIONING OF THE STRUCTURAL MODULE

IN LABORATORY ENVIRONMENT

(25 ^{o}C, 40 – 50% RH)

FOR A PERIOD OF 2 – 3 MONTHS IS NECESSARY

FOLLOW UP THE RADON CONCENTRATION GROWTH INSIDE THE CONTAINER

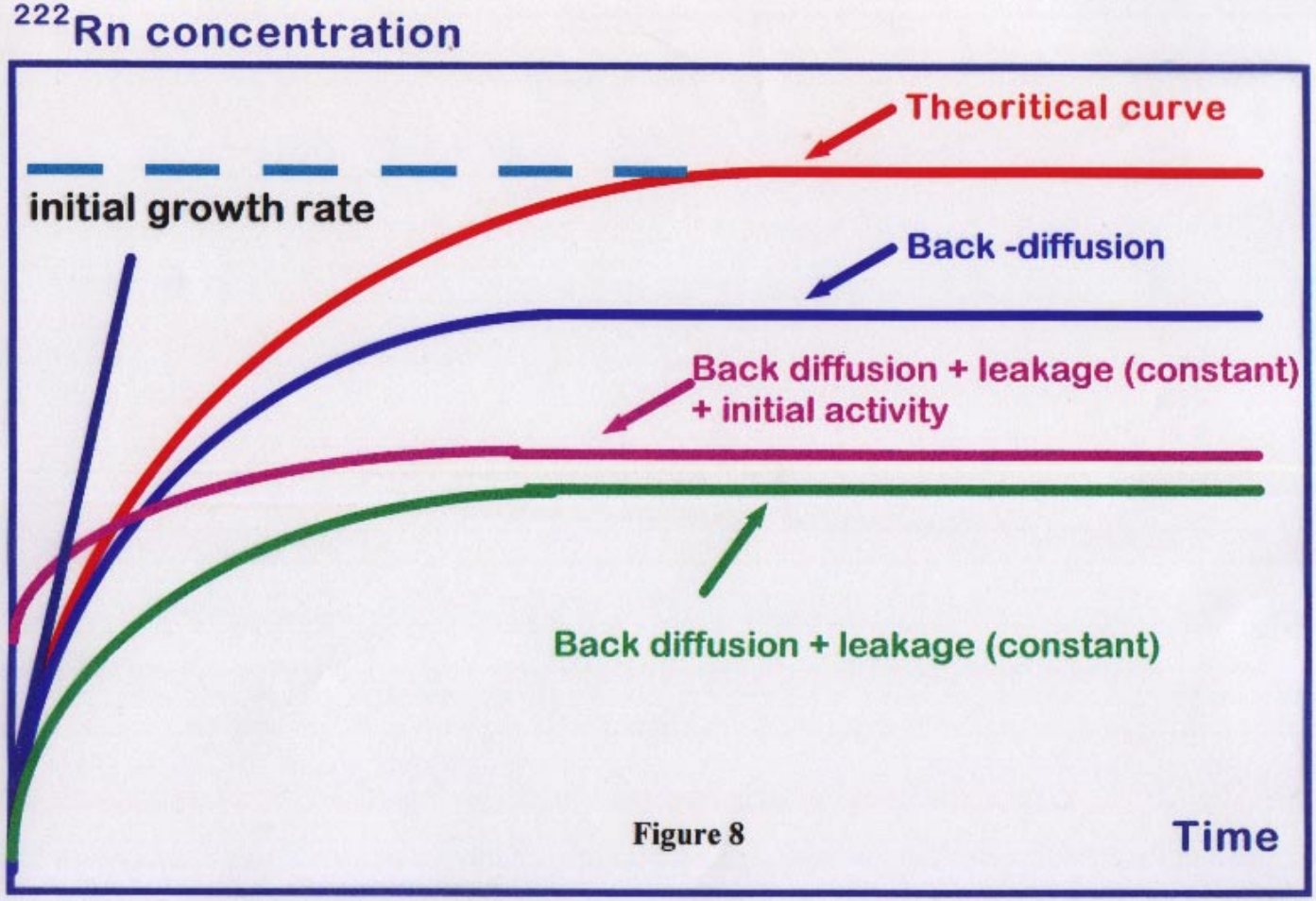


Figure 8

MATHEMATICALLY EXPRESSED…

$$C = C_o \exp(-\lambda t) + E[1-\exp(-\lambda t)](\lambda V)^{-1} \quad (1)$$

C Radon concentration (Bqm^{-3}) in the container at growth time t(h)

E exhalation rate (Bqh^{-1})

λ Radon decay constant (h^{-1})

C_o initial Radon concentration (Bqm^{-3}) in the container at time t(0h) – i.e. the background

THE EQUATION IS VALID IF…

- There is no leakage of Radon out of the container.
- The activity concentration in the container air is low compared to the activity concentration in the pore air of the samble – i.e. no back-diffusion effects.

Taking into account back-diffusion and leakage

Introducing the

Effective decay constant λ^*

$$C = C_o \exp(-\lambda^* t) + E[1-\exp(-\lambda^* t)](\lambda^* V)^{-1} \quad (2)$$

$$\lambda^* = \lambda + \lambda_{b,l}$$

$\lambda_{b,l}$ a decay constant correcting for first order removal of radon by back-diffusion "b" and leakage"l"

Implementing equation-1 (I)

1. Avoid leakage and back-diffusion effects

- Use Radon-tight containers.
- Choose the container free volume to be 10 times larger than the pore volume of the sample, and
- In principle, keep the activity concentration in the chamber air low, compared to the activity concentration in the pore air of the sample.

Therefore, it is necessary to minimize the background term (Co), especially in the case of low radon exhaling rate materials.

Implementing equation-1 (II)

2. …or Use Short Growth Time

Equation (1)

is approximated then as:

$$C = E(\lambda V)^{-1}$$

MINIMIZING BACKGROUND TECHNIQUE

INTRODUCE OLD AIR OR NITROGEN INTO THE CHAMBER

OPEN CHAMBER METHOD (CONTROLLED LEAKAGE)

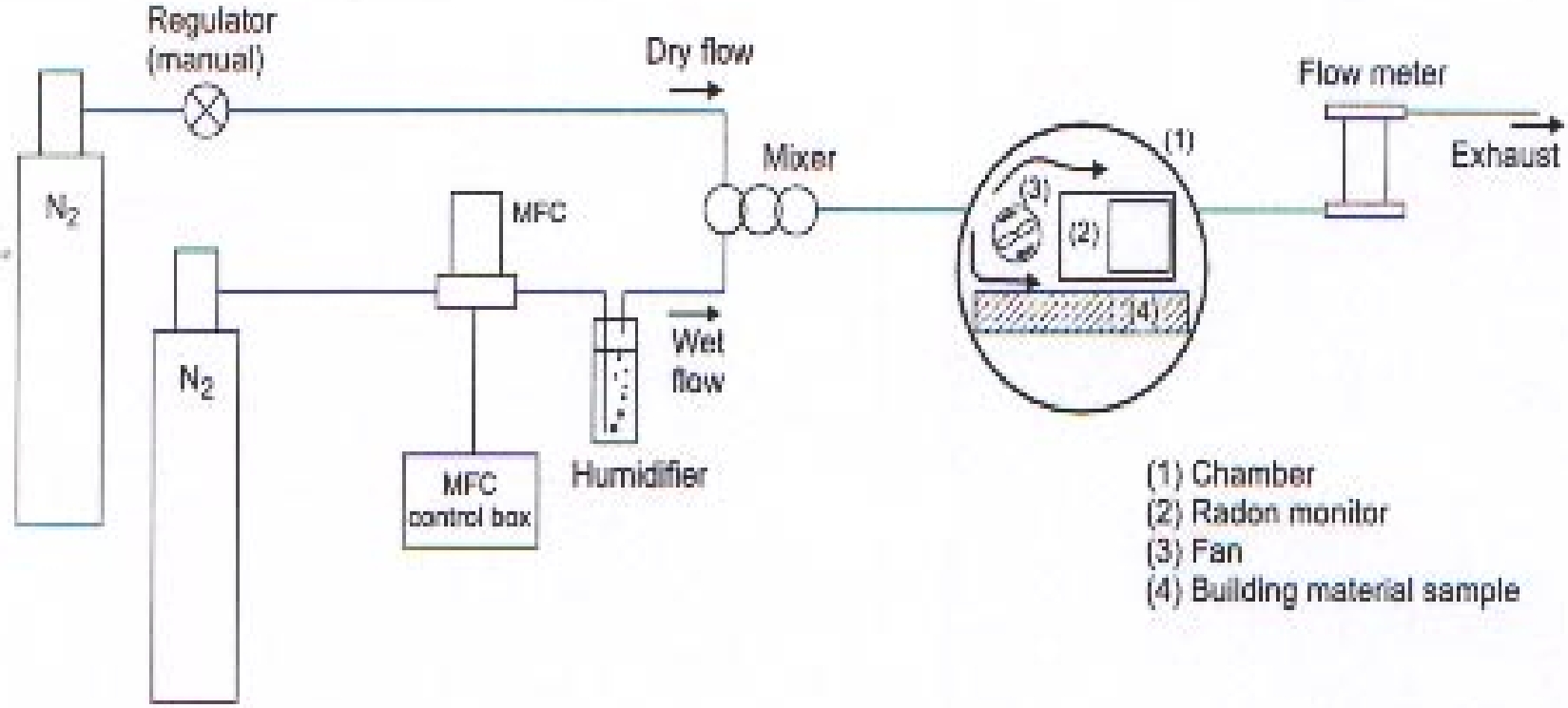


Figure 2. Experimental set-up.

MATHEMATICALLY EXPRESSED…

The steady-state Radon concentration in the container gas is given by the following equation:

$$C = E(V\lambda_V)^{-1} + Co$$

where λ_V = air-exchange rate (h^{-1})

and Co the Radon concentration of the gas being used to flush the container

ERRICCA

European Research into Radon In Construction Concerted Action

Participants:

BRE-UK (Coordinator) and other associated contractors from all over Europe

Overall Action Objective:

"the exchange of experience in research and development for radon and building construction among all participating countries, as well as to use the expertise of the more experienced in this field to the benefit of the less experienced.

Specific Action Objective No. 4:

"to consider the problem of radon emissions from materials"

<u>Specific Action No. 4 Coordinator:</u>

NUCLEAR ENGINEERING SECTION
NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NES-NTUA)

TO ORGANISE SUCH AN INTERCOMPARISON ONE NEEDS:

- Suitable and available framework
- Right ideas and fruitful suggestions
- Means of organisation
- Financial support
- Appropriate manpower
- Relevant experience
- Sponsors

FURTHERMORE …

- ✓ 6 – 8 months are needed for successful Intercomparison organisation
- ✓ Fax, e-mail and WWW communications are absolutely necessary

THE STEPS THAT WERE TAKEN:

- Participation call
- Development of Intercomparison bureaucracy
- Specimen construction
- Specimen dispatch
- Collecting results
- Formulate final report

ONE OF THE 3 SPECIMENS FABRICATED

As proposed by NES-NTUA at the March 1998 ERRICCA Meeting at Gent, Belgium:

NES-NTUA undertook the organisation of a building material radon exhalation rate European intercomparison exercise.

To this end:

- we launched a participation call for most of the radon researchers in Europe (non-ERRICCA participants included).
- we constructed **three** concrete slab specimens with dimensions 30x30x10cm and approximate weight 20 kg each, using the same aggregate, and
- we organised the specimens dispatching scheme to the participating Laboratories all over Europe.

List of Intercomparison Participants (1)

AUSTRIA
Austrian Research Centre Seibersdorf, Radiation Protection Dept.

BULGARIA
St Kliment Ohridski University of Sofia, Physics Faculty

GERMANY
SARAD GmbH, Pesterwitz

GREECE
"Demokritos" Research Center for Physical Sciences

AUSTRIA
Salzburg University, Institut of Physics and Biophysics

DENMARK
Risoe National Laboratory, Nuclear Safety Research Dept.

GREECE
Aristotle University of Thessaloniki, Physics Dept.

GREECE
National Technical University of Athens, Nuclear Engineering Section

List of Intercomparison Participants (2)

GREECE
University of Athens,
Medical Physics Dept.

ITALY
Universita Cattolica del Sacro Cuore di Roma

POLAND
Central Mining Institute,
Radiometry Lab.

ROMANIA
Babes-Bolyai University,
Physics Dept.

ITALY
ANPA Environmental
Radioactivity Sector

POLAND
Central Laboratory for
Radiological Protection,
Radon Research Group

PORTUGAL
Instituto Teclologico e Nuclear,
Departamento de Protecca e
Seguranca Radiologica

ROMANIA
Public Health Institute,
Radiohygiene Laboratory,
Cluj-Napoca

List of Intercomparison Participants (3)

ROMANIA
ICPMRR
Research Laboratory for
Radiation Protection

SPAIN
University of Cantabria,
Faculty of Medicine, Medical
Physics Lab.

THE NETHERLANDS
Kernfysisch Versneller Instituut,
Nuclear Geophysics Division

SLOVENIA
Occupational Safety Institute,
Ecology Toxicology and
Radiation Protection Dept.

SWITZERLAND
Swiss Federal Office for Public
Health,
Radioactivity Surveillance
Section

- The intercomparison started in June 1998 and it was concluded in February 1999.
- Each participant was allowed for a 20-25 days measurement time.
- All participants reported back their results in March 1999.
- Two of the participating Laboratories (“H” & “K”) evaluated **all** the concrete slab specimens (3) used in the exercise, for reference purposes.

Concrete Slab specimens composition
(& ^{226}Ra concentration of the components)

- 28% sand (4 ± 0.2 Bqkg^{-1})
- 21% cement (131 ± 7 Bqkg^{-1})
- 21% gravel (3 ± 0.2 Bqkg^{-1})
- 19% water (0 Bqkg^{-1})
- 11% fly ash (1003 ± 50 Bqkg^{-1})

Estimated mean ^{226}Ra concentration of the specimens

140 ± 6 Bqkg^{-1}

Measured ^{226}Ra concentration of the aggregate

107 ± 5 Bqkg^{-1}

SPECIMEN DISPATCH SCHEME

Specimen "X":

GREECE > GERMANY > POLAND1 > POLAND2 > SWITZERLAND > SLOVENIA > ROMANIA1 > ROMANIA2 > ROMANIA3 > BULGARIA > GREECE

Specimen "Y":

GREECE1 > GREECE2 > GREECE3 >

GREECE4 > GREECE1

Specimen "Z":

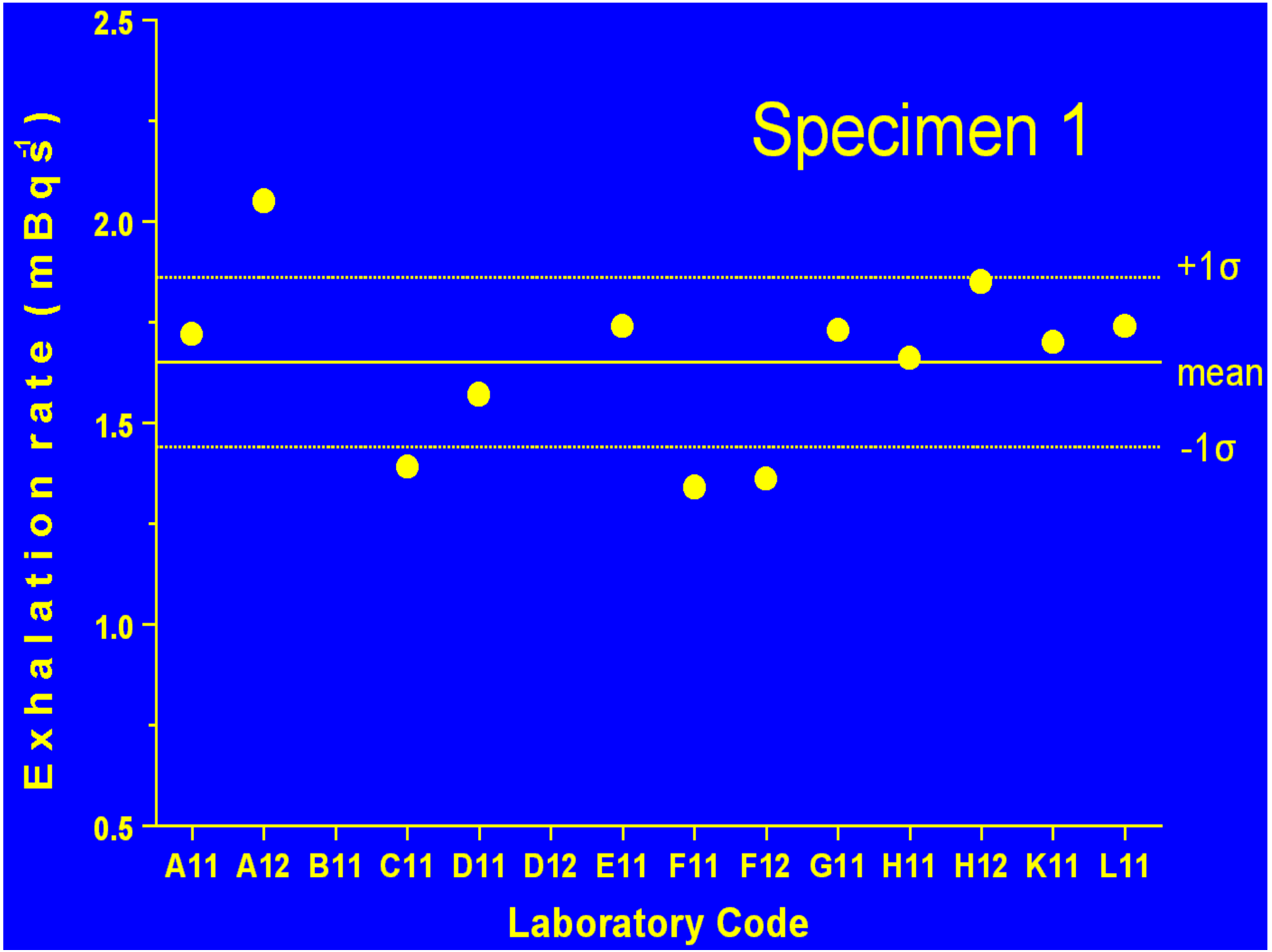
GREECE > DENMARK > THE NETHERLANDS > AUSTRIA1 > AUSTRIA2 > ITALY > SPAIN > PORTUGAL > GREECE

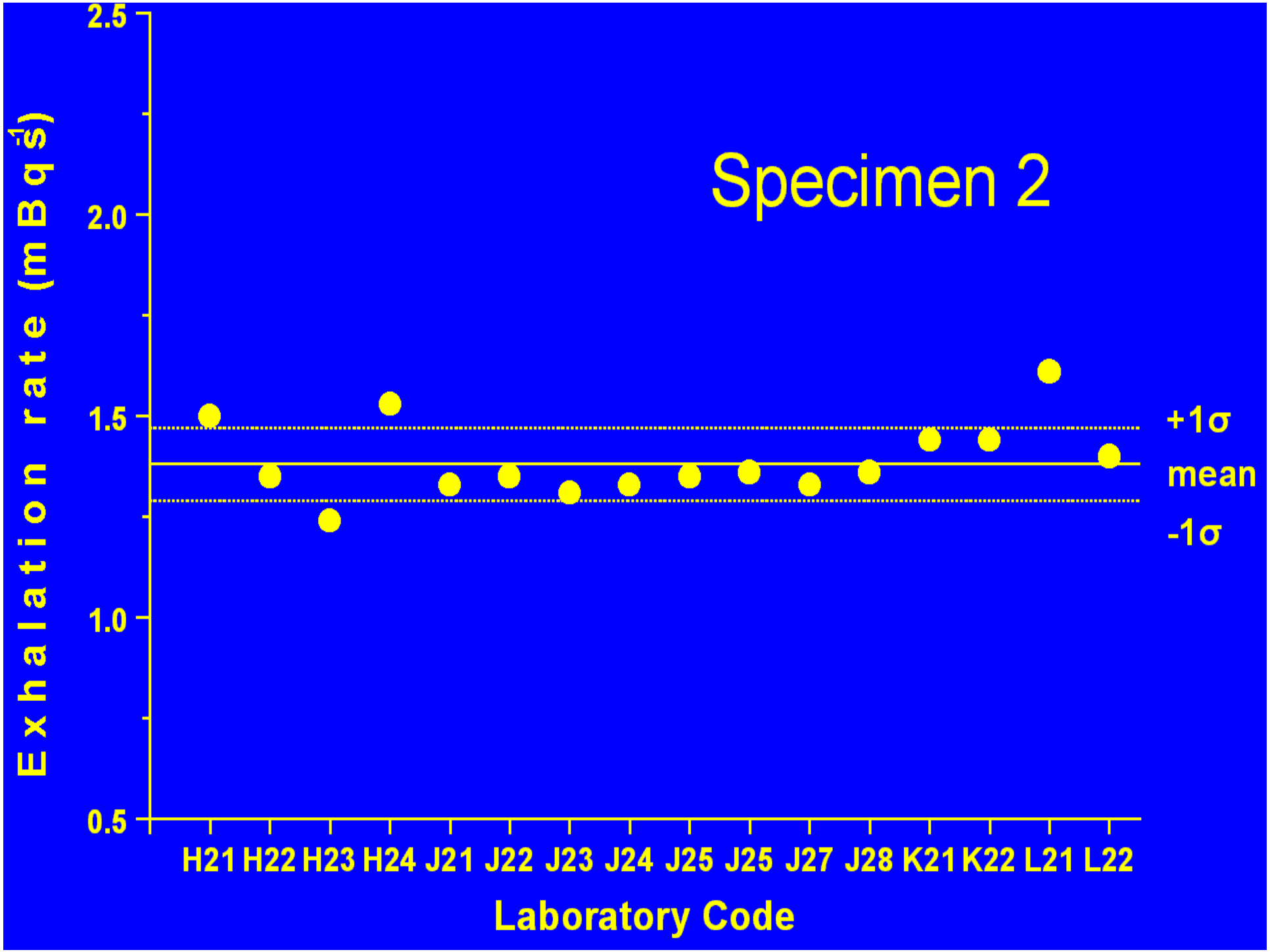
THE MOST IMPORTANT PROBLEM:

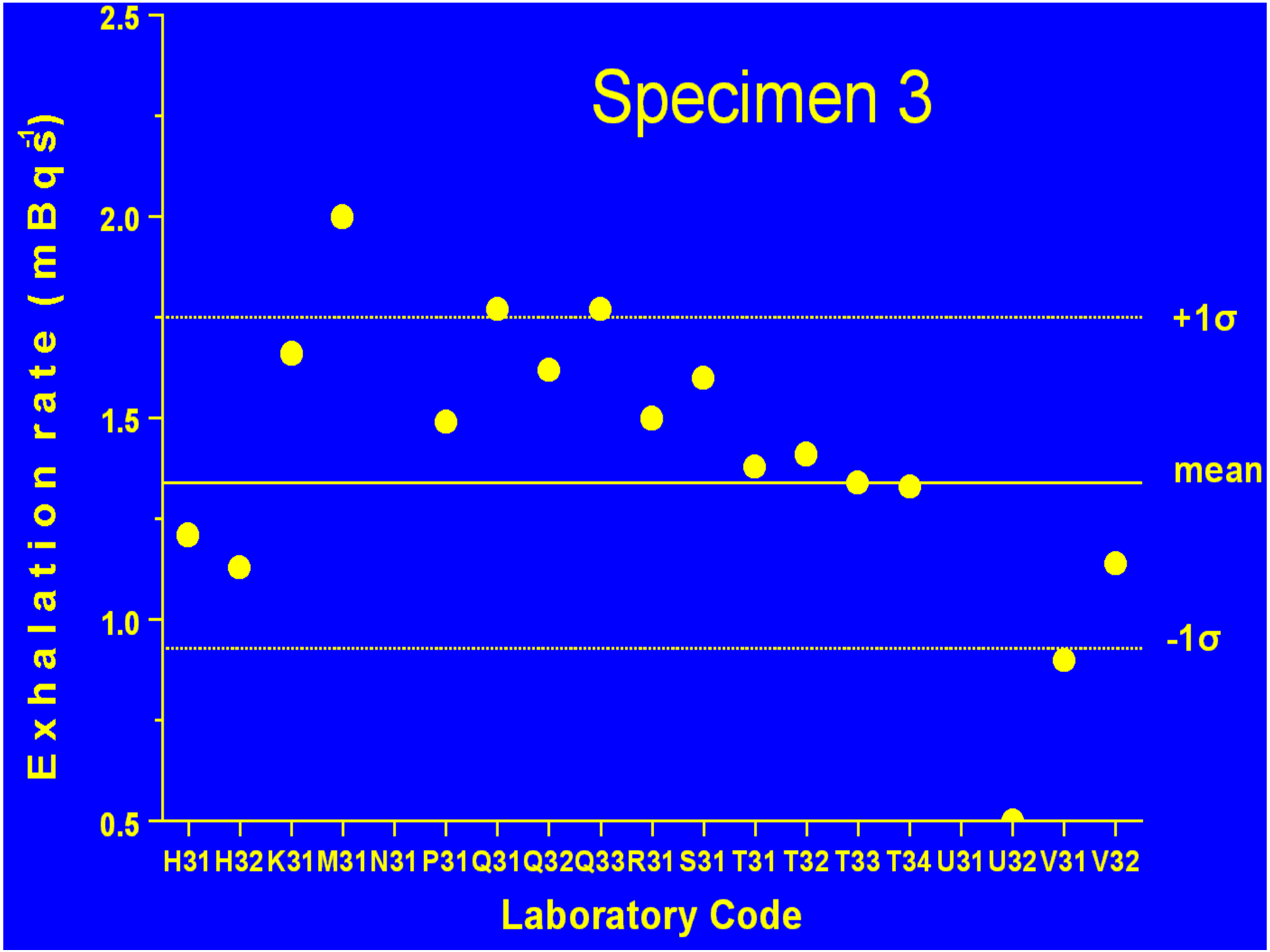
To efficiently organise

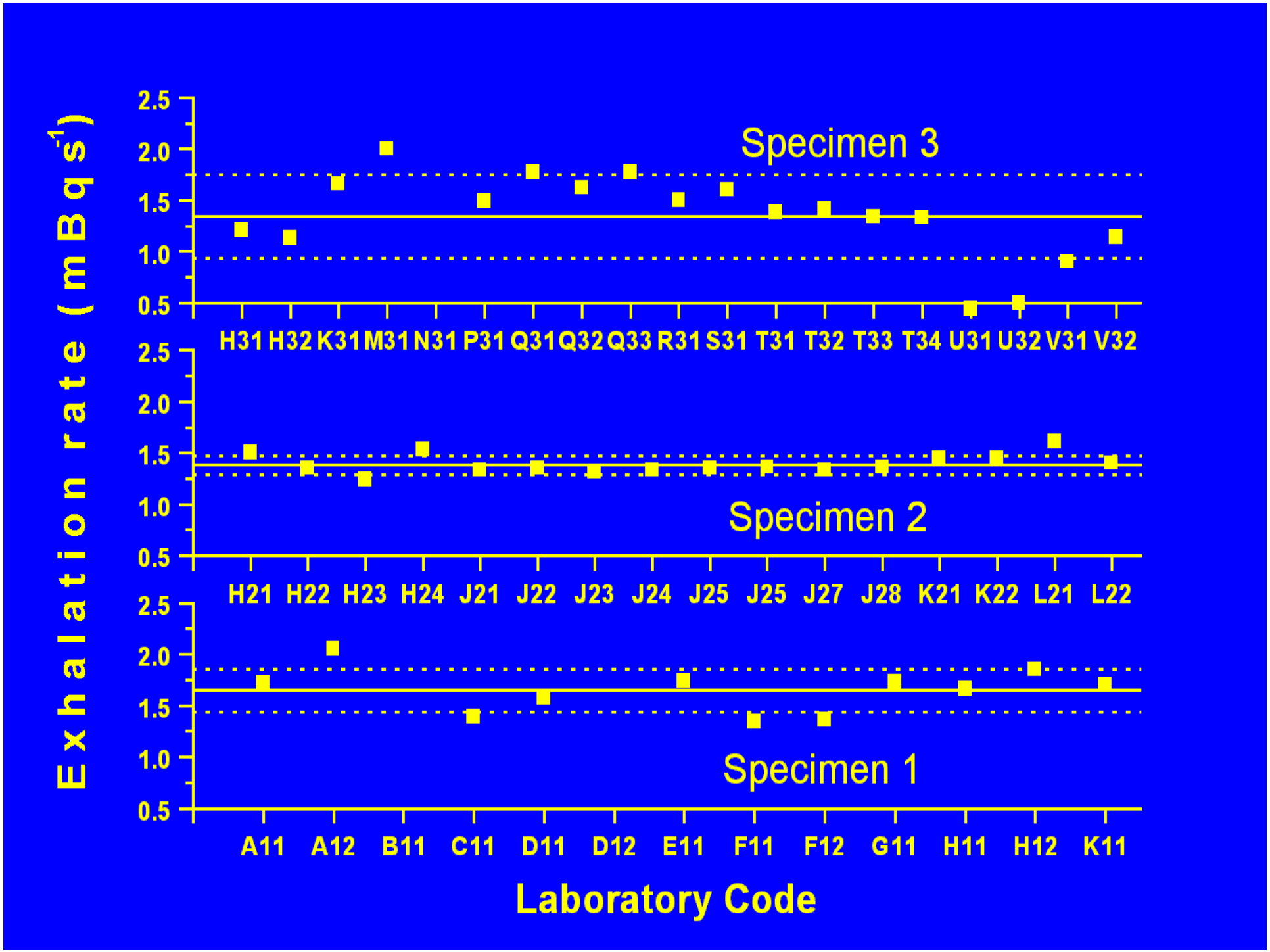
specimen dispatch

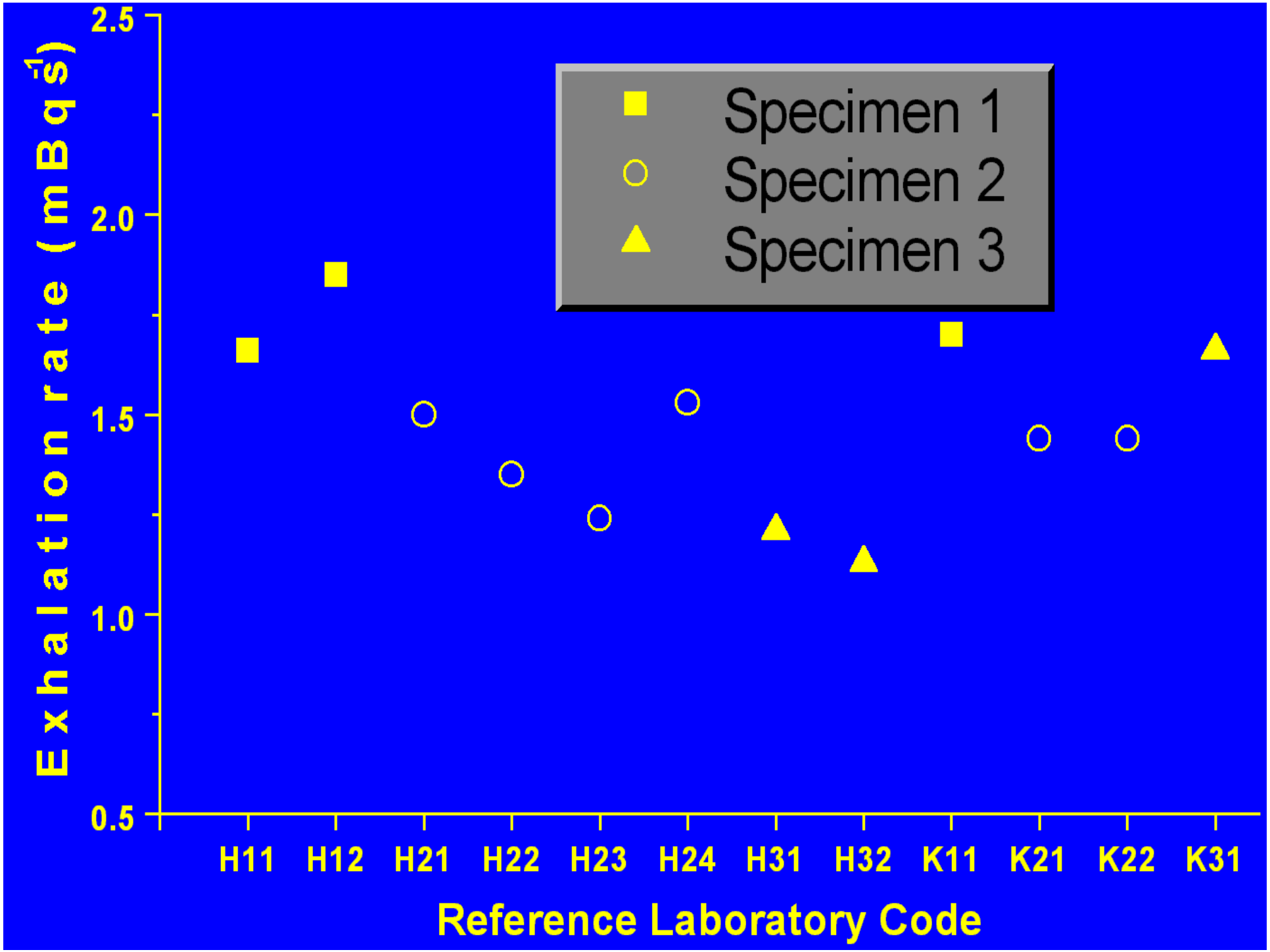
from one participant to the next


Specimen 1
Exhalation rate (mBqs^{-1})
2.5
2.0
1.5
1.0
0.5
+1σ
mean
-1σ
A11 A12 B11 C11 D11 D12 E11 F11 F12 G11 H11 H12 K11 L11
Laboratory Code


Specimen 2
Exhalation rate (mBqs-1)
2.5
2.0
1.5
1.0
0.5
+1σ
mean
-1σ
H21 H22 H23 H24 J21 J22 J23 J24 J25 J25 J27 J28 K21 K22 L21 L22
Laboratory Code


Specimen 3
Exhalation rate (mBq s-1)
2.5
2.0
1.5
1.0
0.5
+1σ
mean
-1σ
H31 H32 K31 M31 N31 P31 Q31 Q32 Q33 R31 S31 T31 T32 T33 T34 U31 U32 V31 V32
Laboratory Code


Exhalation rate (mBqs-1)
2.5
2.0
1.5
1.0
0.5
Specimen 3
H31 H32 K31 M31 N31 P31 Q31 Q32 Q33 R31 S31 T31 T32 T33 T34 U31 U32 V31 V32
Specimen 2
H21 H22 H23 H24 J21 J22 J23 J24 J25 J25 J27 J28 K21 K22 L21 L22
Specimen 1
A11 A12 B11 C11 D11 D12 E11 F11 F12 G11 H11 H12 K11
Laboratory Code

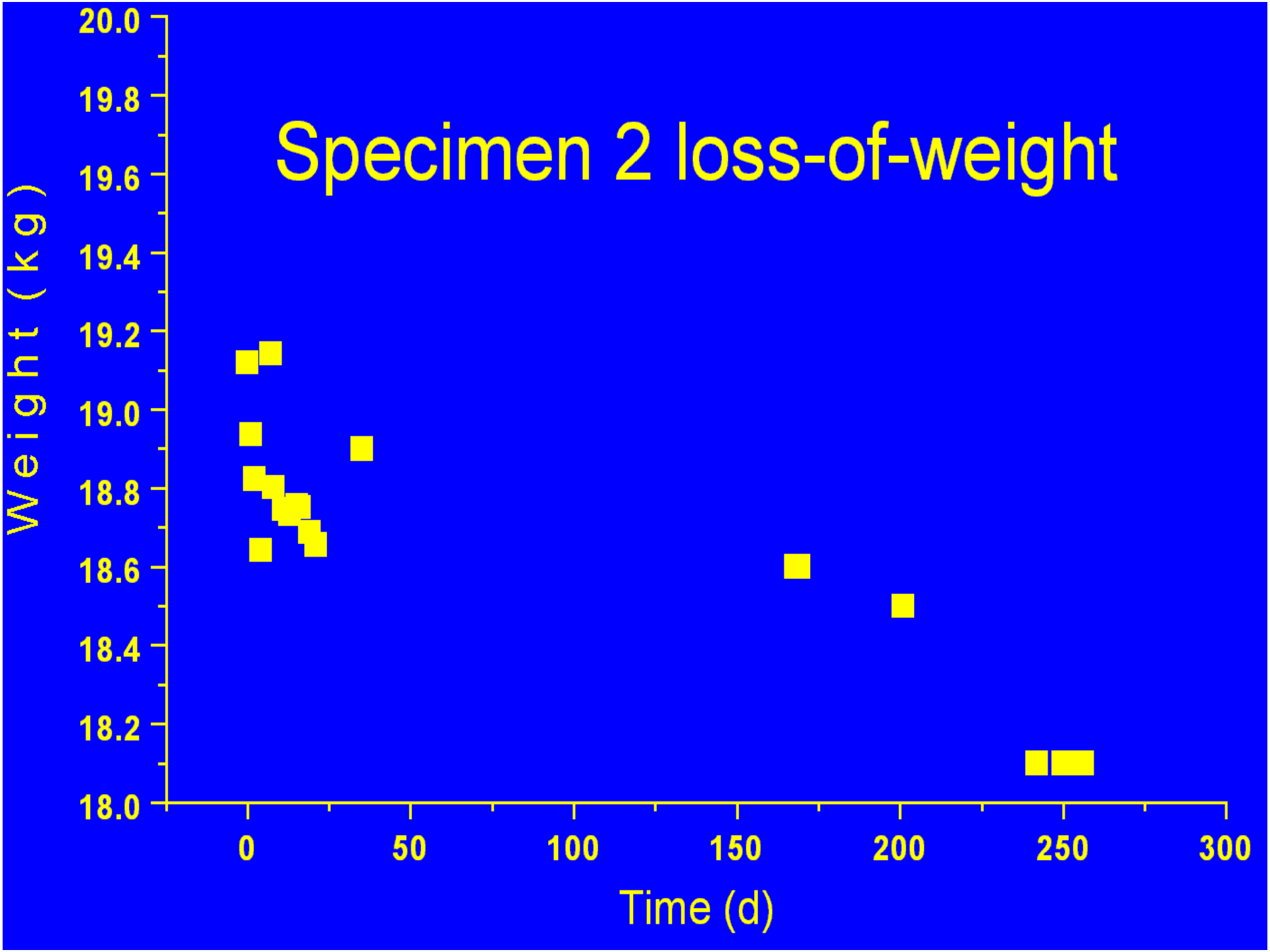

Exhalation rate (mBqs-1)
2.5
2.0
1.5
1.0
0.5
Specimen 1
Specimen 2
Specimen 3
H11
H12
H21
H22
H23
H24
H31
H32
K11
K21
K22
K31
Reference Laboratory Code

SHORT DISCUSSION

- **Specimen 1 presents a statistically significant higher radon exhalation rate than the other two specimens.**

- **Furthermore, none of the specimens presented any systematic aging effect during the cycle of the follow-up measurement procedure. However, a small loss–of–weight effect (~1 kg, 5%) was observed.**

- **Reported results outside the graph range were excluded.**


Specimen 2 loss-of-weight
Weight (kg)
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
0
50
100
150
200
250
300
Time (d)

CONCLUSION

The majority of the participating Laboratories reported results within the accuracy expected for such measurements.

On the other hand:

The participants dit not associate the reported results with the same type of uncertainty; an effort to achieve standardisation is under way.

Should we further discuss ?

For purposes of uncertainty standardisation all intercomparison participants were asked to calculate the uncertainty u of their results as:

$$u=(a^2+b^2+c^2)^{0.5}$$

where:

a **is the counting (random) error at the 1σ confidence level**

b **is the systematic error (due to instruments used, techniques, calibration etc.), and**

c **is the computation error (due to any algorithm applied to the raw data, i.e. least square fittings).**

WHAT IS NEXT??

This intercomparison may help to:

- get a better overview of the demands which should be met by the radon exhalation measuring methods (including sample preparation)
- evaluate measuring procedures from both practical and scientific point of view taking into account cost effectiveness, practical performance and reliability, and
- influence future recommendations for standard radon exhalation rate measurements procedures.

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