γ-ray spectrometry practices in the deep ocean

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Outline

- Study/Criteria
- KATERINA-Deep detection system
- Pressure tests and selection materials
- Simulations (MCNP-CP)
- Methodology (Quantification and MDA)
- Results (γ spectrum and MDA)
- Conclusions
Study / Criteria (in situ detection)

Detection crystal selection

✓ Low consumption
✓ Low cost
✓ High efficiency
✓ Without cooling

Enclosure material selection (housing)

✓ Minimum absorption of gamma rays
✓ Robustness
✓ Tolerant for deep sea deployment
✓ Easy to manage (appropriate dimensions, light weight)
KATERINA-Deep System
Patent INT.CL: G01T 7/00 [Commercialised]

Specifications

- Crystal: 3x3" NaI
- **Consumption:** <1 W
- Resolution at 662keV: < 6.5 %
- Variable energy range
- Adjustable spectroscopy and HV
- Operating temperature: 0°C-50°C
- Output voltage stability
- Autonomy (without PC connect)
- Continuous monitoring in autonomy mode
- Adjustable amplifier gain, PZC, BLR and shaping time
- Option for real time (software independent)
Pressure test and on going work

- Upgrade towards integration in deep sea observatories (up to 4500 m)
- Project RADIOSCOPIO: Research and development of an in-situ underwater gamma-ray spectrometer for low-level radioactivity measurements. Bilateral R&T Greece-China collaboration 2012-2014 [Funded by the Hellenic General Secretariat for R & T]
- Project LEVECO (task: monitoring gases in mud volcanoes)
Crystal and housing material

Detection crystal selection:
minimum dimensions of the crystal NaI: 3x3 inches

Enclosure material selection (housing):
Candidate materials: Stainless Steel, Borosilicate Glass, Carbon Fiber, Aluminium, Titanium

Comments: Al is not tolerant for deployments at 4500m, Ti is not cost-effective

Selected material: Stainless Steel, Borosilicate Glass, Carbon Fiber
Stainless steel configuration (up to 4500 m depth)

Al₂O₃-reflector: density = 0.55 gr/cm³, 1.6 mm

Al-window: density = 2.94 gr/cm³, 0.5 mm
Threshold energy of the deep system

$^{137}$Cs normalized simulation spectra

$^{137}$Cs Stainless Steel spectrum
$^{137}$Cs Acetal spectrum
FEPE comparison of housing materials

![Graph showing comparison of housing materials across different energies. The graph plots energy (keV) on the x-axis and ξ (m^3) on the y-axis. Different materials are represented by distinct line styles and markers: Acetal, Carbon fiber, Borosilicate, and Stainless Steel.](image)

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Deployments (deep sea)
Study area

Background station
Background measurement, Depth: 2070 m

YELEDZHIK station
Gas emission of mud volcano, Depth: 1685 m
$\gamma$-ray spectra (~ 2070 m)
experimental & simulation
MDA calculation (after $^{40}$K subtraction)

$MDA = \frac{L_D}{*V*I*T}$
Conclusions

• Stainless Steel is a robust enclosure material for high pressures (> 450 atm).

• Deep sea is the optimum environment for radioactive gas monitoring at volcanic areas. A background γ spectrum is recorded for 2 hours at 2070 m depth.

• The MDA of the system is very low (~ 3 Bq/m³ for thoron progenies, ~ 5 Bq/m³ for radon progenies).

• The MDA of the system is drastically reduced for the low gamma-ray emitters after subtraction of $^{40}\text{K}$ contribution.
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