Natural and man-made gamma emitters in Gulf of Eilat / Aqaba sediments

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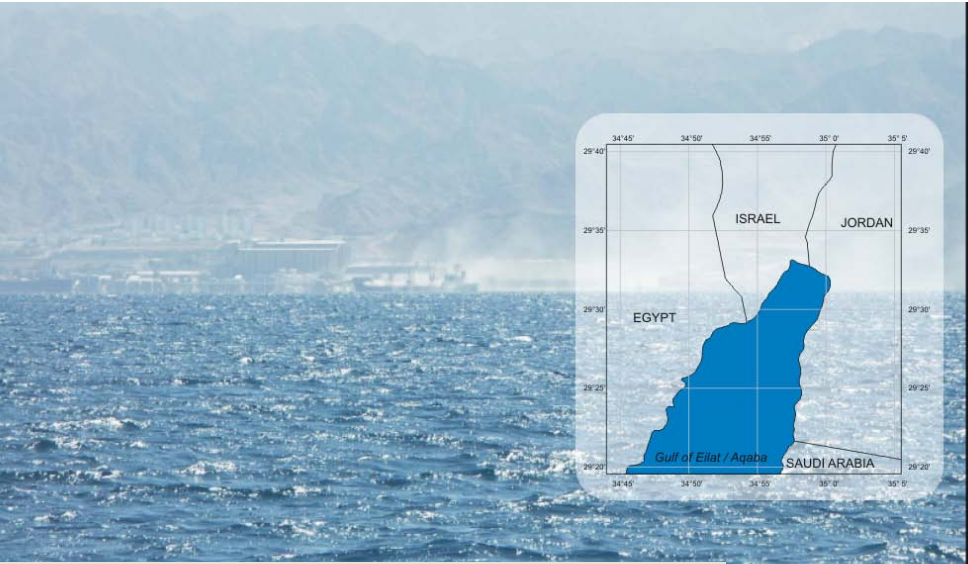
Table of contents

Gulf of Eilat

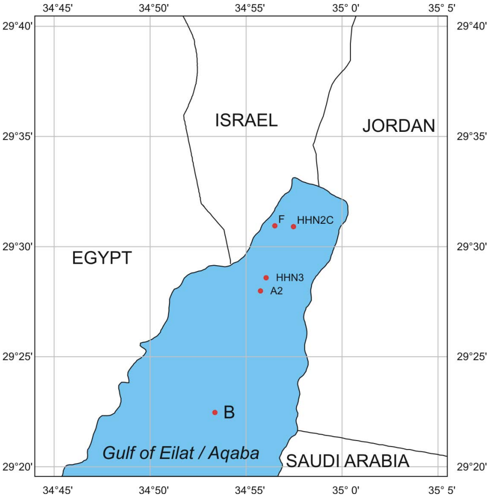


Motivation

- Last century's accelerated anthropogenic pollution and input of nutrients $\rightarrow$ negative effect on marine environment in Gulf of Eilat / Aqaba (GOE) - coral reefs and marine life biodiversity.
- Gamma emitting radionuclides in sediment cores analyzed within a study of sources and effects of particulate phosphorous in GOE.
- Particulate phosphorous sources: mariculture, sewage and phosphate ore dust from industrial ports in Aqaba and Eilat.
- Estimated P release from the port of Eilat: $\geq 8 \cdot 10^6$ mol P, Aqaba port approximately 10-fold higher.
- No previous publications on radionuclides in sediment profiles, sedimentation rates and radionuclide inventories from the studied area.

Sampling: sediments

- Five short sediment cores taken during 2007-2008
- St. F and HHN2C: shallow (240-316 m)
- St. A2 and HHN3: deeper part of Eilat subbasin (600-700 m)
- St. B: further south in Eilat deep (800 m), a reduced effect of anthropogenic pollution expected



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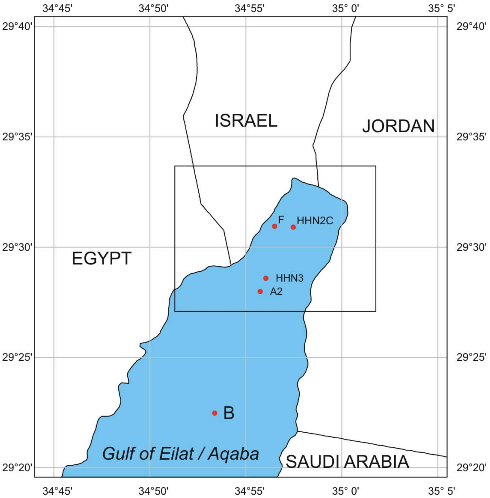

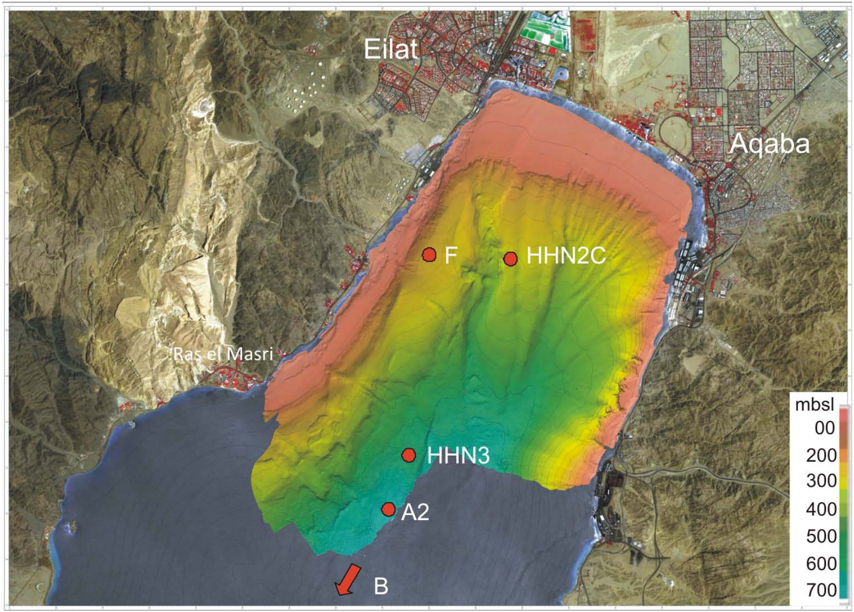
Eilat
Aqaba
F
HHN2C
Ras el Masri
HHN3
A2
B
mbsl
00
200
300
400
500
600
700

Measurements

Gamma spectrometry

- Samples hermetically sealed - waited for equilibrium for ^{226}Ra determination
- Low-level low-background $\gamma-$spec., 50% HPGe coaxial detector
- LabSOCS for a characterized detector used for efficiency calculations - variable geometries
- Cascade summing corrections applied
- Samples: 1-10 g
- Counting times: 2-3 days for small samples, 1-2 days for larger samples
- Gamma emitters: ^{210}Pb, ^{226}Ra (^{214}Pb, ^{214}Bi), ^{40}K, ^{228}Ra (^{228}Ac), ^{228}Th (^{212}Pb, ^{208}Tl), ^{137}Cs

Age models

$^{210}Pb_{xs}$

- Constant flux - constant sedimentation (CF-CS) model
- Variations in depth profile likely to be caused by other factors than changes of sedimentation rate

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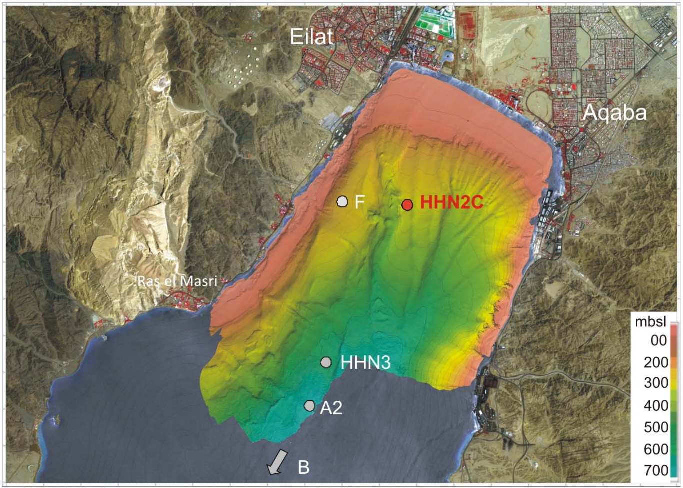
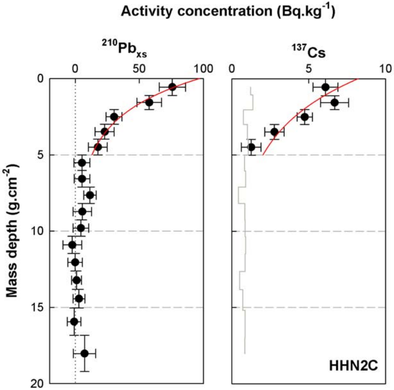
^{137}Cs

- Additional tracer
- Main source: global weapon test fallout, minimal effect of Chernobyl fallout
- No clear 1963 maxima in profiles
- Instead, “exponential” decay in some profiles: attempt to use the same CF-CS model

Shallow core HHN2C



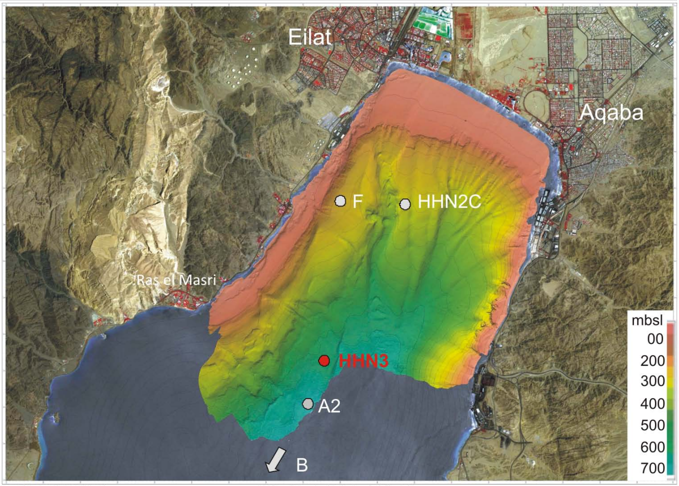
Shallow core HHN2C



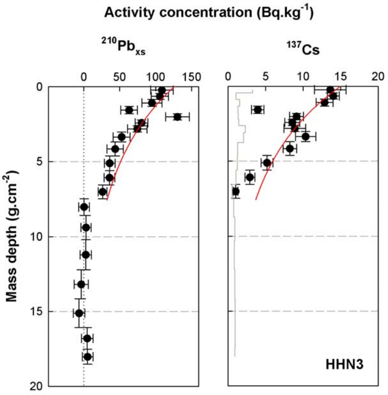
$r\ (^{210}Pb_{xs})$
$0.076 \pm 0.008\ g \cdot cm^{-2} yr^{-1}$

$r\ (^{137}Cs)$
$0.082 \pm 0.030\ g \cdot cm^{-2} yr^{-1}$

Deep core HHN3



Deep core HHN3



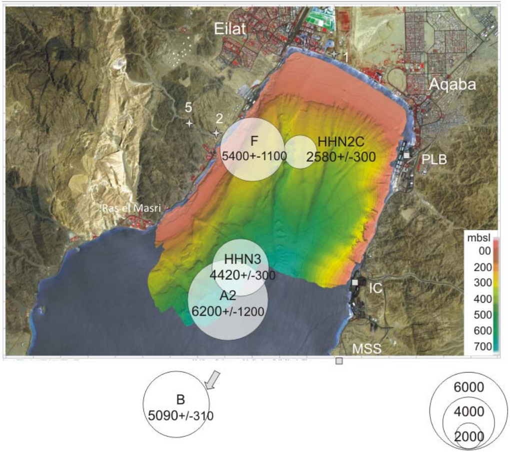
r ($^{210}Pb_{xs}$)

$0.16 \pm 0.04\ g \cdot cm^{-2} yr^{-1}$

r (^{137}Cs)

$0.11 \pm 0.03\ g \cdot cm^{-2} yr^{-1}$

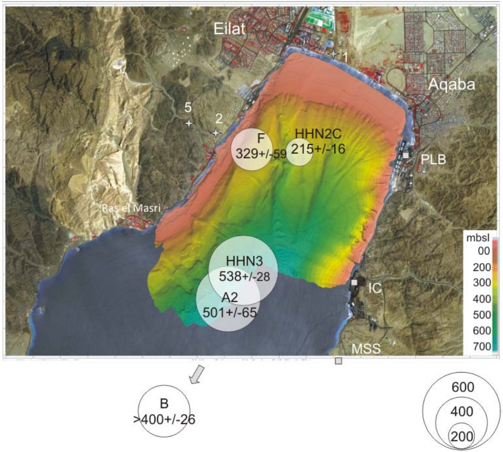
Inventories of $^{210}Pb_{xs}$ $(Bq \cdot m^{-2})$



Core	$^{210}Pb_{xs}$ Inventory $Bq \cdot m^{-2}$	Flux $Bq \cdot m^{-2} yr^{-1}$
F	5400±1100	167±33
HHN2C	2580±300	80.6±9.5
HHN3	4420±300	138.1±9.5
A2	6200±1200	195±35
B	5090±310	–

A mean atmospheric flux over continents in latitudal band 10°–30° N: 160 $Bq \cdot m^{-2} yr^{-1}$ (global compilation, Preiss et al. 1996).

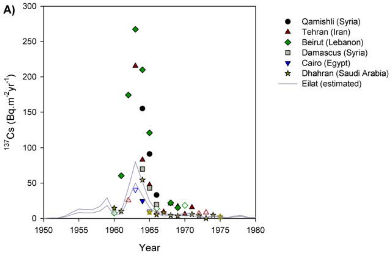
Inventories of ^{137}Cs ($Bq \cdot m^{-2}$)

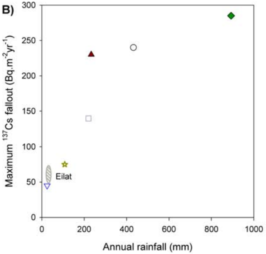


Core	Inventory $Bq \cdot m^{-2}$
F	$\geq$329$\pm$59
HHN2C	215$\pm$16
HHN3	538$\pm$28
A2	501$\pm$65
B	$\geq$400$\pm$26

ADDITIONAL: Global weapon test fallout, Middle East: ^{137}Cs

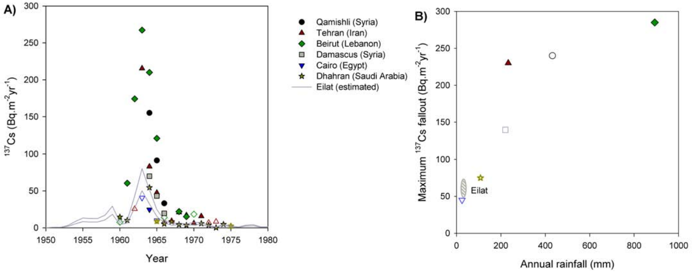
- Data: Environmental Measurements Laboratory Global Fallout Deposition program (on-line database). The measurement series not continuous (full / empty symbols).
- $^{90}Sr \rightarrow {}^{137}Cs$: constant ratio Cs/Sr=1.5 assumed
- Solid line: an estimate of fallout in GOE based on UNSCEAR (2000) deposition history scaled to maximal yearly fallout estimate.





ADDITIONAL: Global weapon test fallout, Middle East: ^{137}Cs

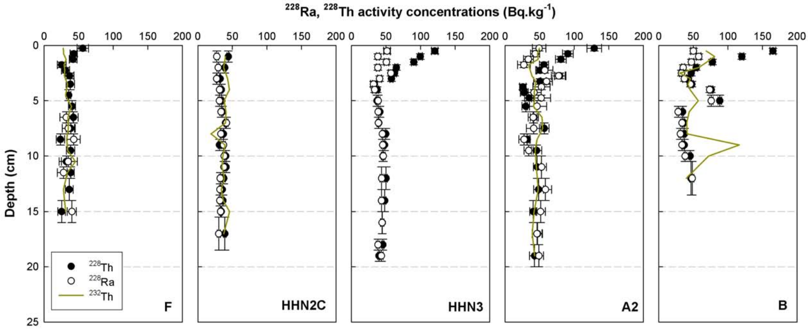
- Fallout varies with latitude and rainfall.
- Maximum ^{137}Cs yearly fallout (in 1963) vs. annual rainfall. Full symbols represent actual measured values, empty symbols extrapolation when 1963 value was not available.
- The maximum (1963) at GOE estimated 50–75 $Bq \cdot m^{-2} yr^{-1}$.
- Total fallout: 240–360 $Bq \cdot m^{-2}$ (decay corrected to 2007).



Global weapon test fallout, Middle East: ^{137}Cs

- Compilation of data: Environmental Measurements Laboratory Global Fallout Deposition program (on-line database) - 6 stations in Syria, Iran, Lebanon, Egypt and Saudi Arabia.
- Fallout varies with latitude and rainfall.
- Total fallout in Eilat: 240–360 $Bq \cdot m^{-2}$ (decay corrected to 2007).
- Inventories measured within the study: up to 540 $Bq \cdot m^{-2}$
- 33–56% ^{137}Cs not deposited directly, rather erosion derived

Th series radionuclides

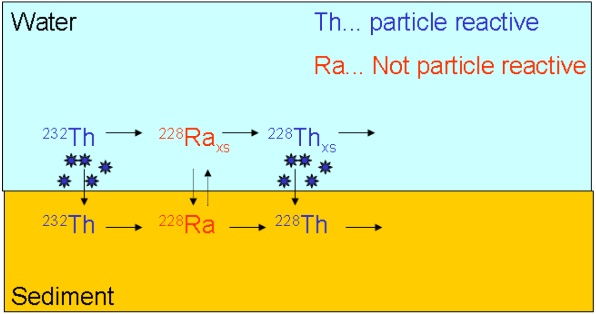


- Gamma emitters: ^{228}Ra and ^{228}Th
- ^{232}Th measured by ICP-MS

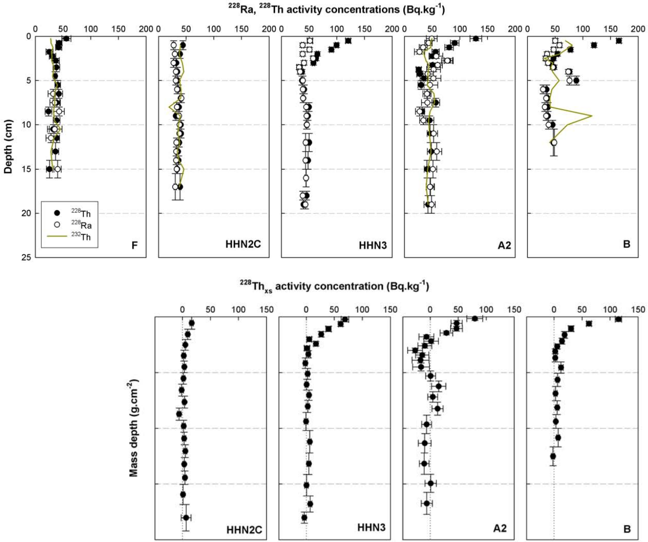
Th series radionuclides

$$^{228}Ra(t) = ^{232}Th(0) \cdot (1 - e^{-\lambda_2 t}) + ^{228}Ra(0) \cdot e^{-\lambda_2 t}$$

$$^{228}Th(t) = \lambda_3 \cdot \lambda_2 \cdot ^{232}Th(0) \cdot (\frac{1}{\lambda_2 \cdot \lambda_3} - \frac{e^{-\lambda_2 t}}{\lambda_2(\lambda_3 - \lambda_2)} - \frac{e^{-\lambda_3 t}}{\lambda_3(\lambda_2 - \lambda_3)}) +$$
$$+ \frac{\lambda_3}{\lambda_3 - \lambda_2} \cdot ^{228}Ra(0) \cdot (e^{-\lambda_2 t} - e^{-\lambda_3 t}) + ^{228}Th(0) \cdot e^{-\lambda_3 t}$$



Th series radionuclides - excess ^{228}Th



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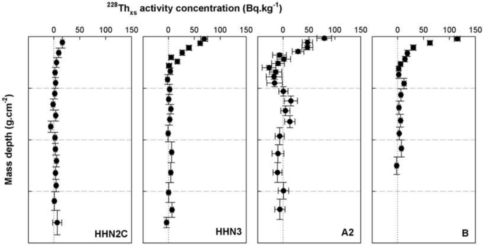
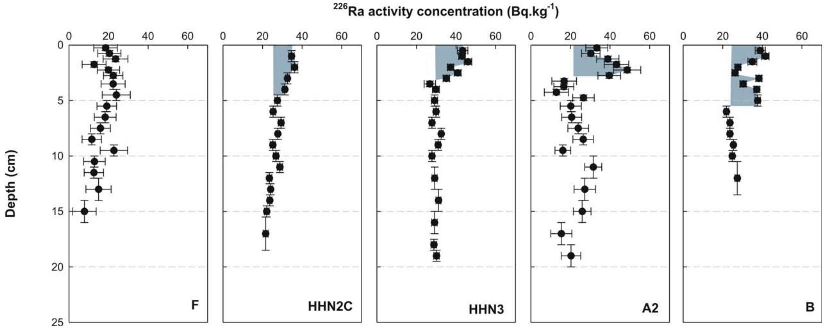


- Valuable additional information: the core tops were deposited very recently - $T_{1/2}$ (^{228}Th)=1.9 yr.
- Application of a simple CF-CS model leads to several times higher accumulation rates (0.3–0.7 $g \cdot cm^{-2} yr^{-1}$) than ^{210}Pb and ^{137}Cs model.
- Reasons: Bioturbation? Ra diffusion? Recent sedimentation rate acceleration? Recent reduction of $^{228}Th_{xs}$ flux? Postdepositional redistribution?

^{226}Ra - increase in upper parts of the profiles



$^{226}Ra_{“xs”}$ inventories

Core	Top interval cm	μ_{top} $Bq \cdot kg^{-1}$	μ_{bottom} $Bq \cdot kg^{-1}$	t-value	P-value	Inventory of $^{226}Ra_{“xs”}$ $Bq \cdot m^{-2}$
HHN2C	4.5	33.7	25.4	6.242	0.0004	320 ± 30
HHN3	3.5	40.9	29.5	6.627	0.0004	300 ± 30
A2	3.0	39.0	21.5	5.670	0.0002	410 ± 90
B	5.5	34.8	24.5	5.273	0.0001	440 ± 30

- Increase of ^{226}Ra in the top sections (3–5.5 cm) of 4 cores is statistically significant.
- Phosphate: 1200 $Bq \cdot kg^{-1}$ ^{226}Ra
- Estimated phosphate dust release since 1965: $17 \cdot 10^3$ t

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If phosphate dust responsible for ^{226}Ra increase:

- 300–440 $Bq \cdot kg^{-1} \rightarrow$ 0.25–0.36 $kg \cdot m^{-2}$ of phosphate accumulated on the seabed
- Over the area of 40 $km^2 \rightarrow (10.0 - 14.4) \cdot 10^3$ t of phosphate

Summary

Accumulation rates, inventories

- Based on ^{210}Pb and ^{137}Cs CF-CS model: 0.076–0.22 $g \cdot cm^{-2} yr^{-1}$
- ^{137}Cs: rather continuous erosion supported input, instead of direct fallout

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Th series radionuclides

- $^{228}Th_{xs}$ found in core tops: very fresh sediment
- Common dating model (CF-CS) not applicable

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- Common dating model (CF-CS) not applicable

^{226}Ra

- Increased ^{226}Ra activities in core tops: likely to be caused by contribution of phosphate dust from Eilat and Aqaba industrial ports.
- $(10.0 - 14.4) \cdot 10^3$ t of phosphate material deposited at a seabed of studied area.

Acknowledgments

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Bundesministerium für Bildung und Forschung

pip
physics international postgraduate

Thank you for your attention!