A baseline study of radon in groundwater prior to unconventional shale gas development in the Karoo Basin (South Africa)

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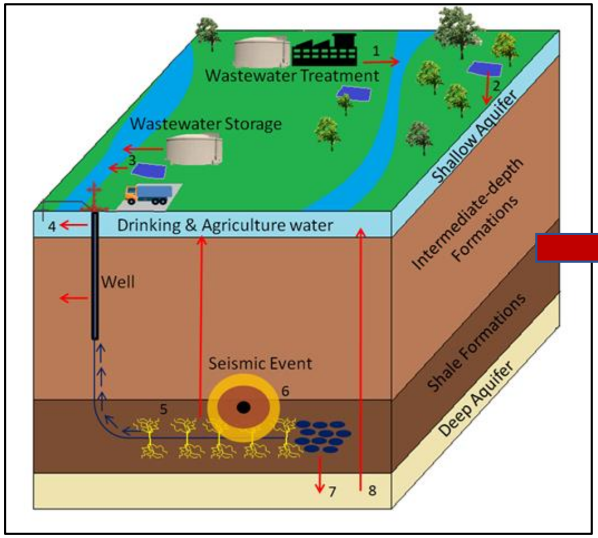
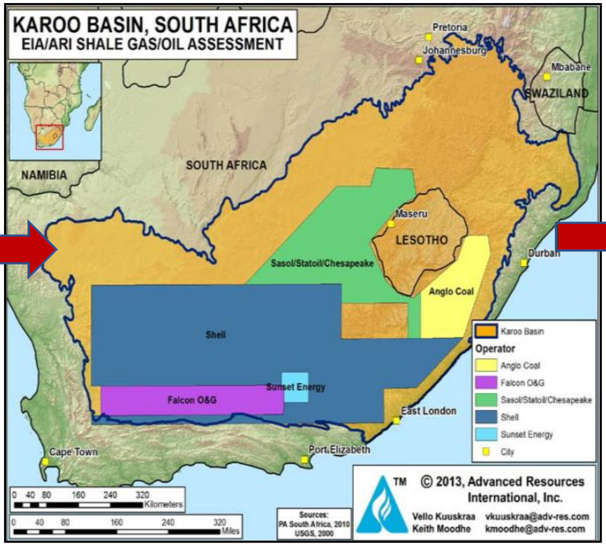
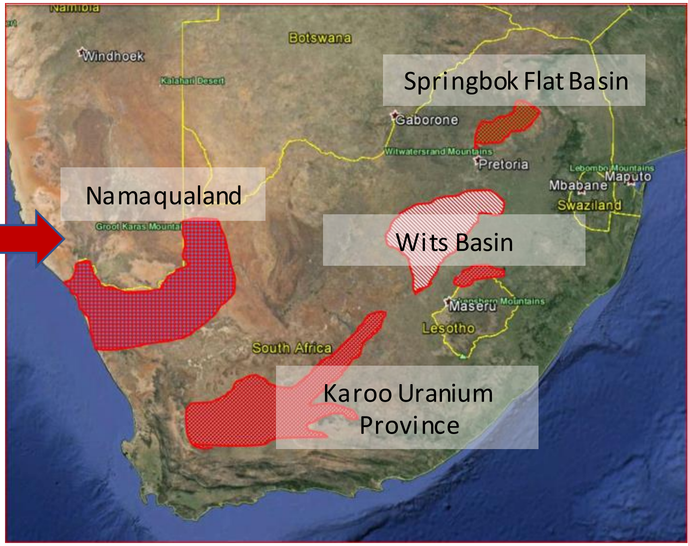
Introduction



(Botha et al., 2019)



(EIA, 2013)



(Kenan, 2014)

Radiological Groundwater Database (Baseline) – **Water Quality**

NORM: ^{222}Rn, ^{226}Ra, and ^{228}Ra and ^{238}U

Aim: Study Potential TENORM (^{222}Rn, ^{226}Ra) contamination in groundwater due to Shale Gas Developments

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Study Area

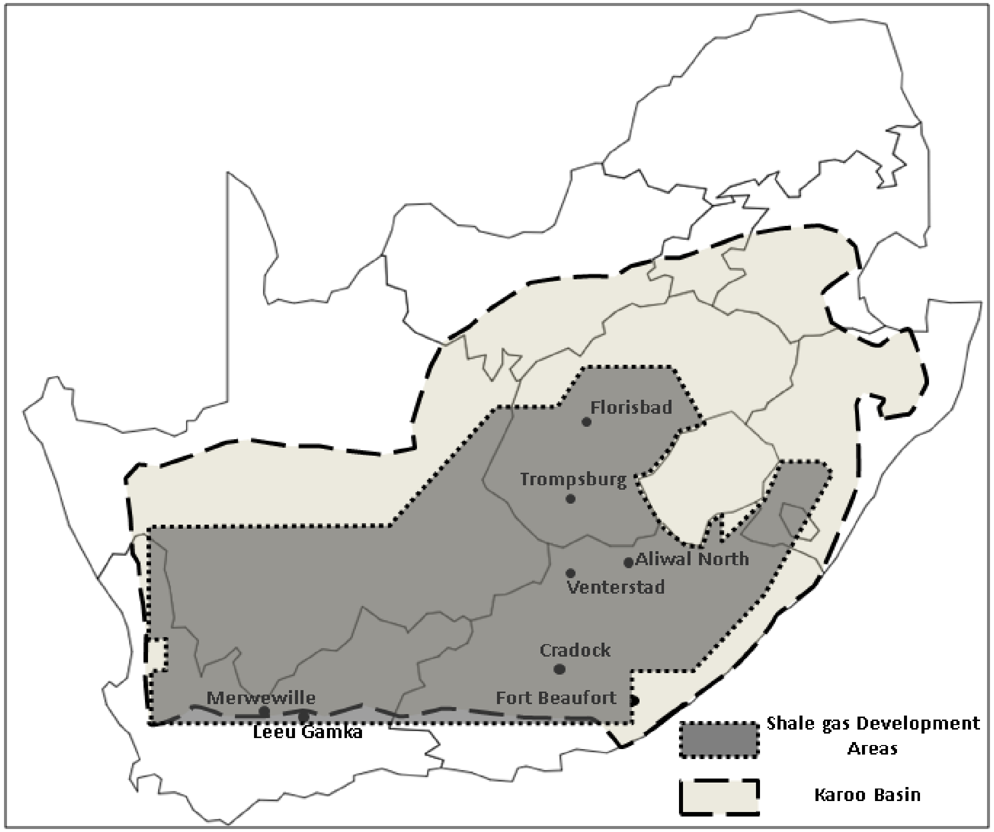

Figure 1: Provincial map of South Africa and associated shale gas development areas; eight major sampling regions (towns) and the Karoo Basin (Botha et al., 2019).

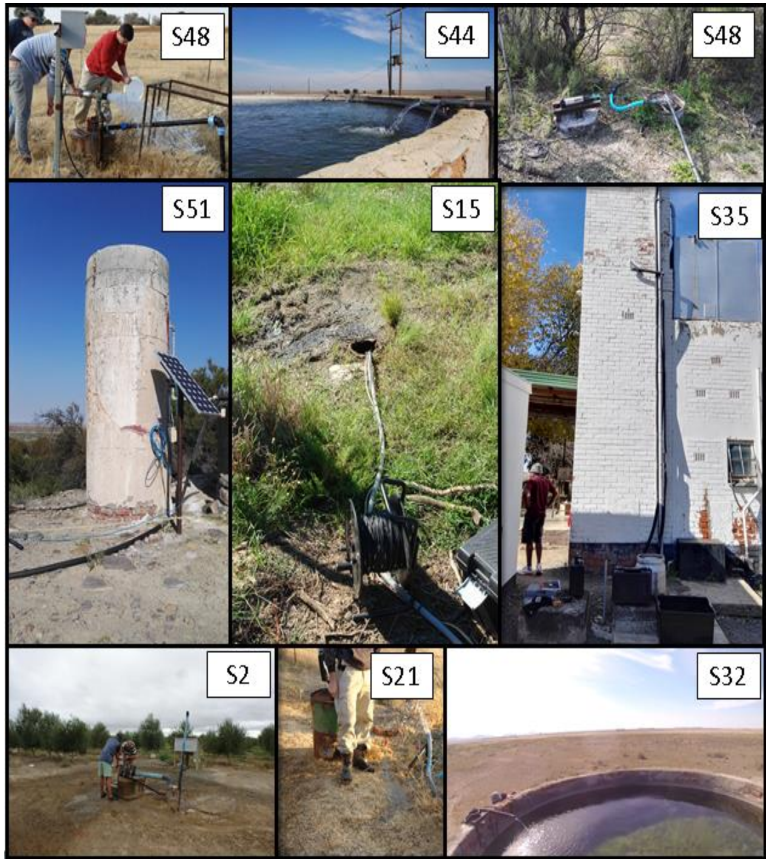

Figure 2: Various groundwater sampling sites, boreholes (S2, S21, S48), solar pumps (S51), drinking wells (S35) and dam (S32).

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Study Area

Site number, [S]	Region	Sampling Site Description	Aquifer Type	Measurement Series
1	Prins Albert	Borehole	-	F1, F2
2	Leeu Gamka	Borehole	Shallow	F1
3	Leeu Gamka	Borehole	Shallow	F1
4	Leeu Gamka	Borehole	Mixed	F1, F2
5	Leeu Gamka	Borehole	Shallow	F1
6	Leeu Gamka	Borehole	Shallow	F1
7	Leeu Gamka	Borehole	Shallow	F1, F2
8	Leeu Gamka	Borehole	Mixed	F1, F2
9	Cradock	Spa outdoor pool,hot spring	Deep	F1, F2
10	Cradock	Borehole	Shallow	F1
11	Cradock	Artesian	-	F1
12	Cradock	Artesian	Shallow	F1
13	Cradock	Stream	Shallow	F1
14	Cradock	Borehole	Shallow	F1, F2, F3
15	Fort Beaufort	Artesian,hot spring	Deep	F1, F2
16	Fort Beaufort	Artesian	Mixed	F1, F2
17	Aliwal North	Spa outdoor pool, hot spring	Deep	F1
18	Aliwal North	Spa indoor pool, hot spring	Deep	F1, F2
19	Aliwal North	Spa outdoor Olympic pool	Deep	F1
20	Aliwal North	Spa, source, hot spring	Deep	F1
21	Aliwal North	Borehole	Deep	F1, F2
22	Venterstad	Borehole	Shallow	F1
23	Venterstad	Borehole	Shallow	F1
24	Venterstad	Borehole	Shallow	F1
25	Venterstad	Borehole	Shallow	F1, F2, F3
26	Venterstad	Borehole, hot spring	Mixed	F1, F2
27	Venterstad	Borehole	Mixed	F1
28	Venterstad	Borehole	Mixed	F1, F2
29	Venterstad	Borehole	Shallow	F1, F3
30	Venterstad	Borehole	Deep	F1, F2
31	Venterstad	Borehole	Shallow	F1, F2, F3
32	Trompsburg	Artesian, hot spring	Deep	F1, F2, F3
33	Trompsburg	Borehole	Shallow	F1, F2, F3
34	Trompsburg	Borehole	Shallow	F1
35	Trompsburg	Borehole	Shallow	F1, F2, F3
37	Florisbad	Spa indoor pool, source, hot spring	Deep	F1, F2
38	Florisbad	Spa outdoor pool	Deep	F1, F2
39	Florisbad	Indoor pool (surface)	Deep	F1, F2
40	Florisbad	Borehole	Deep	F1
41	Merweville	Borehole	Shallow	F1
42	Merweville	Borehole	Shallow	F1, F2
43	Soutpan	Tap Water	-	F2
44	Soutpan	Borehole	-	F2, F3
45	Soutpan	Borehole	-	F2, F3
46	Soutpan	Borehole	-	F2, F3
47	Soutpan	Borehole	-	F2
48	Soutpan	Borehole	-	F2, F3
49	Cradock	-	Shallow	F2
50	Aliwal North	Borehole	Deep	F3
51	Merweville	Borehole	-	F3
52	Merweville	Borehole	-	F3
53	Merweville	Tap Water	-	F3

Table 1: A site descriptions of where radon-in-water measurements were performed in the Karoo Basin (Eilers et al., 2015; Murray et al., 2015; Swana, 2016).

Measurement Methods

- **Real-time α-spectrometry radon and thoron detector (RAD7 Detectors, Drystick, H2O kit)**
- **Passivated ion-implanted planar silicon detection technology**
- **Mobile System, Customized Measurement Protocol, Operational RH < 10 %**
- **Measurement accuracy: ± 5% (absolute)**
- **Split Samples – Two Detectors**

DURRIDGE
Radon Capture & Analytics

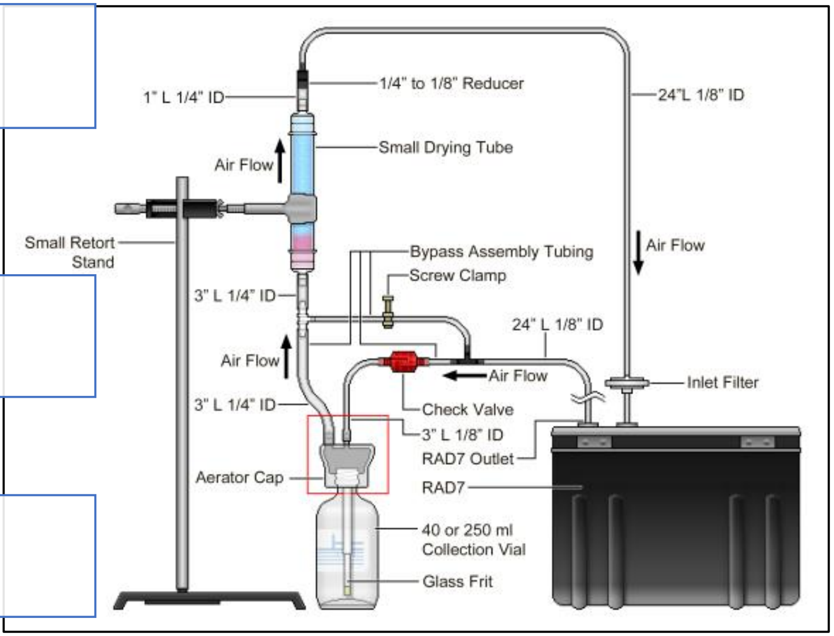

Figure 3: Illustration of experimental radon-in-water levels measurement setup making use of a closed-loop configuration, RAD7 detection system (DURRIDGE, 2018).

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Measurement Methods

Figure 4: Radon-in-water measurement mobile station making use of two RAD7 detectors, Drystick ADS-3R and H2O kit manufactured by DURRIDGE.

Results and Discussion

^{222}Rn activity levels within groundwater of the Karoo Basin from 2014 to 2016

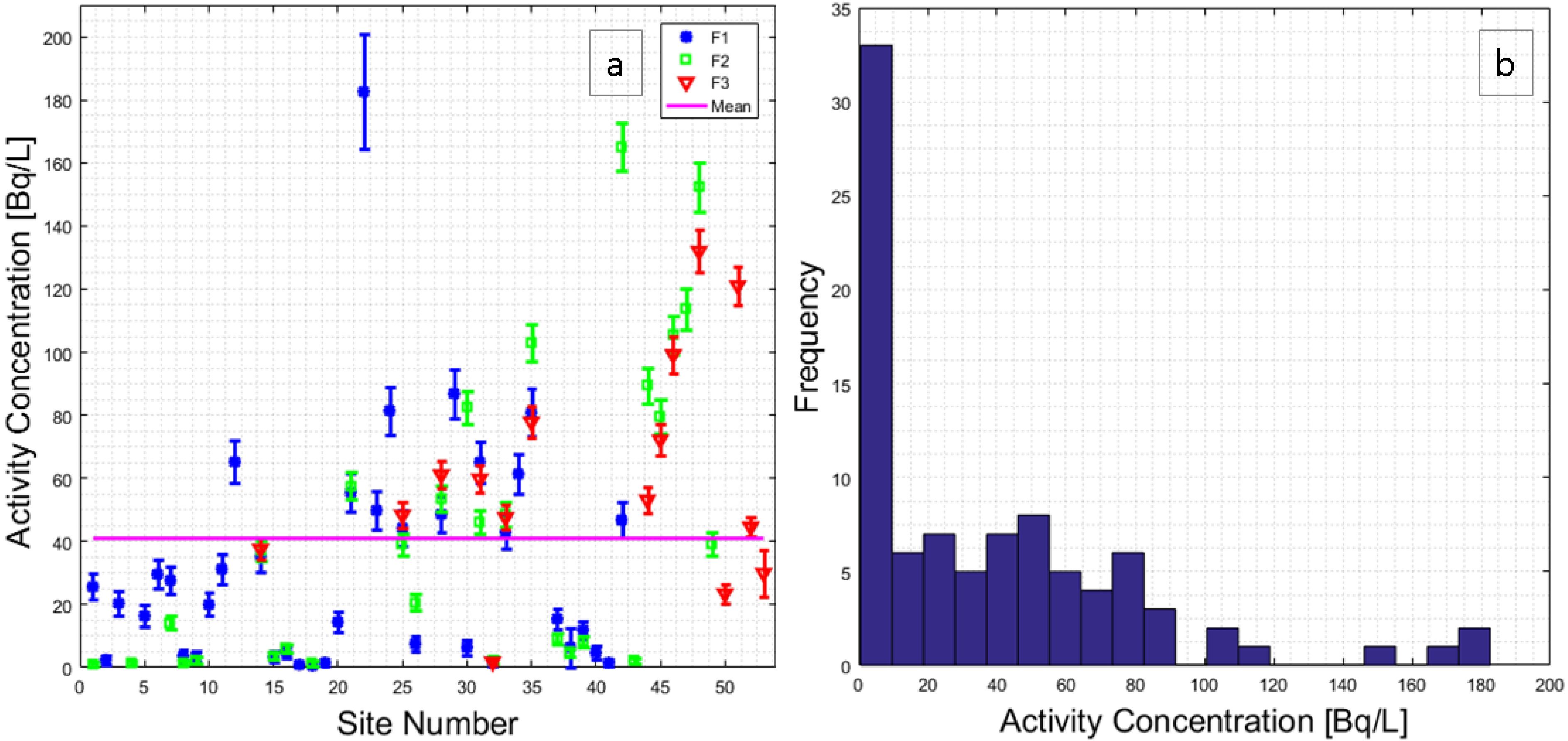

Figure 5: (a) Collective radon-in-water results according to the three measurements series, F1 (2014, summer, *), F2 (2014, winter, □) and F3 (2016, winter,∇); (b) histogram of the radon-in-water levels from (a) (Botha et al., 2019).

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Results and Discussion

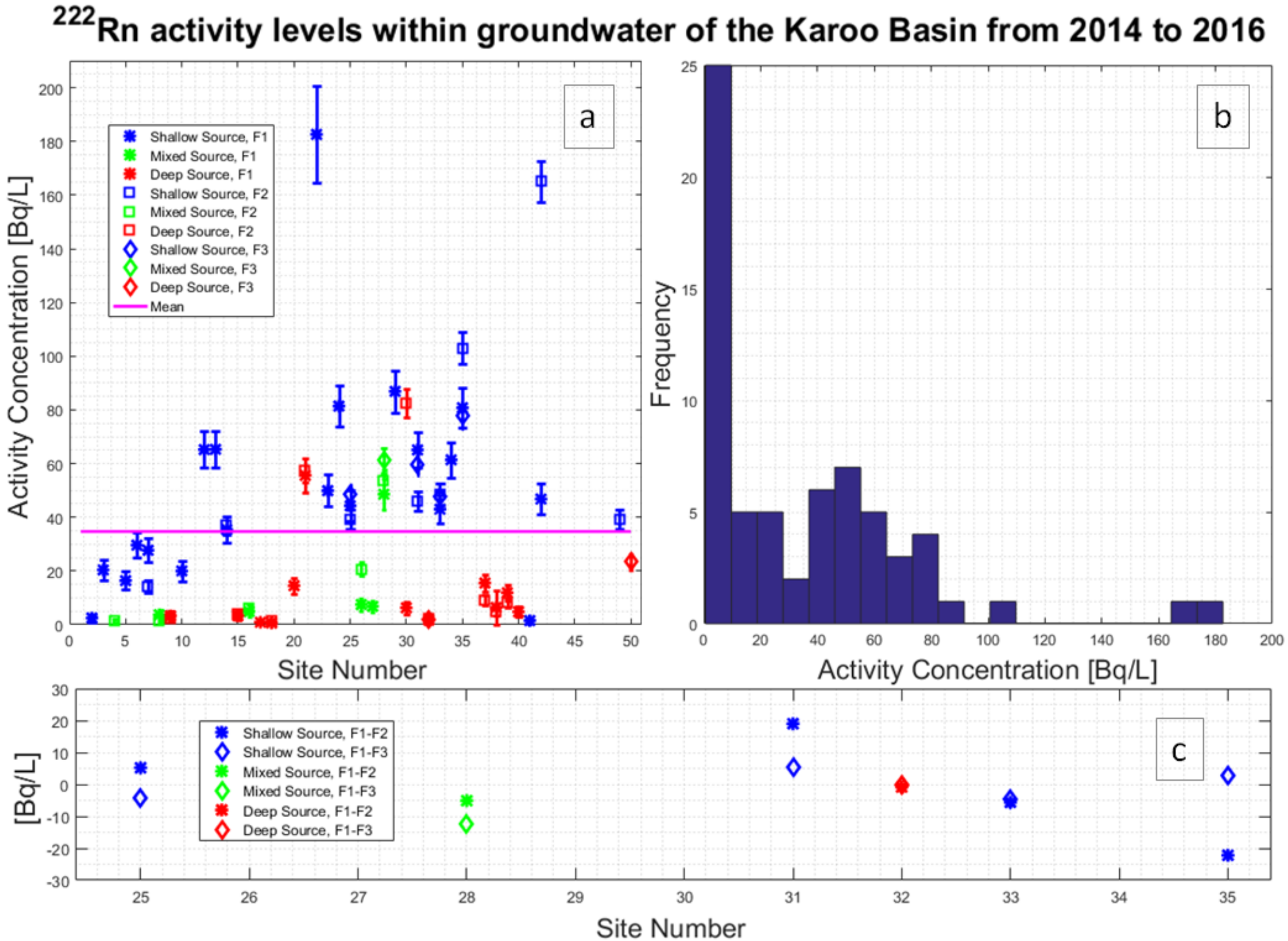

Figure 6: (a) results of radon-in-water according to the different aquifer type for three measurements series, F1 (2014, summer, *), F2 (2014, winter, □) and F3 (2016, winter, ◊); (b) histogram of the radon-in-water activities from (a); (c) change in radon-in-water levels from F1 to F2 and F3, respectively (Botha et al., 2019).

Results and Discussion

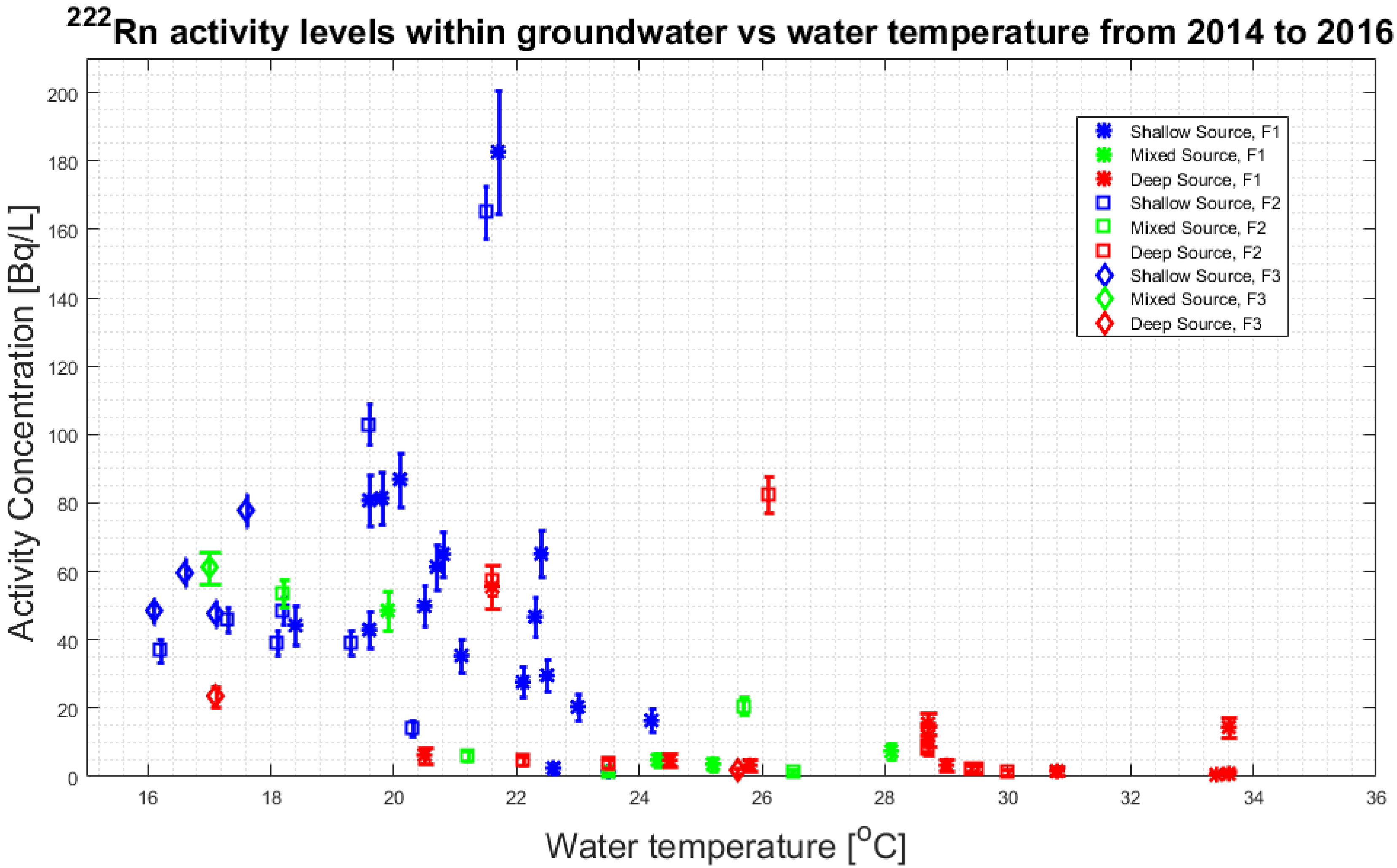

Figure 7: Results of radon-in-water levels according to water temperature and aquifer type for the three measurements series (F1 to F3) (Botha et al., 2019).

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Results and Discussion

Mean radon-in-water activity to the different measurement series, [Bq/L]			
Aquifer type	F1	F2	F3
Shallow	51 ± 11	62 ± 22	58 ± 29
Mixed	24 ± 12	17 ± 7	-
Deep	10 ± 3	19 ± 6	12 ± 9
Combined	32 ± 5	44 ± 8	61 ± 16

Table 2: Mean radon-in-water results according to different measurement series (F1 to F3) (Botha et al., 2019)

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Aquifer type	Minimum radon-in-water activity, [Bq/L]	Maximum radon-in-water activity, [Bq/L]	Mean radon-in-water activity, [Bq/L]	Median radon-in-water activity, [Bq/L]	Data points
Shallow	2 ± 1	183 ± 18	55 ± 10	47	32
Mixed	2 ± 1	61 ± 5	20 ± 6	7	11
Deep	1 ± 1	82 ± 5	14 ± 3	5	26
Collective	1 ± 1	183 ± 18	41 ± 5	28	85

Table 3: Statistical results of radon-in-water according to the type of aquifer (F1 to F3)(Botha et al., 2019).

Quality of Drinking Water (NORM-Radiological): seven sites radon-in-water activity concentration were above the recommended WHO of 100 Bq/L (WHO, 2011; EU, 2001), one site was above the 30 µg/L uranium-in-water concentration recommended as a drinking water guideline (WHO, 2011).

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Conclusion

Most comprehensive Karoo Basin Groundwater NORM (radon) database to date – **Water Quality (WRC, CSIR)**

Characterise ^{222}Rn in the Karoo Basin groundwater: minimum of 1 ± 1 Bq/L, a maximum of 183 ± 18 Bq/L and mean of 41 ± 5 Bq/L. Mean radon-in-water levels for shallow aquifers were systematically higher (55 ± 10 Bq/L) relative to deep (14 ± 3 Bq/L) or mixed aquifers (20 ± 6 Bq/L)

A seasonal mean radon-in-water increase from the winter of 2014 (44 ± 8 Bq/L) to winter of 2016 (61 ± 16 Bq/L) was observed which could be related to the extreme national drought experienced in 2015

The majority (78%) of the aquifers had relatively low radon-in-water levels (< 60 Bq/L). Seven sites had levels radon-in-drinking water above the EU and WHO reference level of 100 Bq/L

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References

Botha, R., Lindsay, R., Newman, R.T., Maleka, P.P., Chimba, G., 2019. Radon in groundwater baseline study prior to unconventional shale gas development and hydraulic fracturing in the Karoo Basin (South Africa). Appl. Radiat. Isot. https://doi.org/10.1016/J.APRADISO.2019.02.006

DURRIDGE, 2018. RAD H2O Radon in Water Accessory for the RAD7 User Manual.

EIA, 2013. Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States.

Eilers, A., Miller, J., Swana, K., Botha, R., Talma, S., Newman, R., Murray, R., Vengosh, A., 2015. Characterisation of Radon Concentrations in Karoo Groundwater, South Africa, as a Prelude to Potential Shale-gas Development. Procedia Earth Planet. Sci. 13, 269–272. https://doi.org/10.1016/J.PROEPS.2015.07.063

EU, 2001. European Union Commission Recommendation on the protection of the public against exposure to radon in drinking water supplies. J. Eur. Community 85–88.

Kenan, A.O., 2014. WORKSHOP ON APPLICATION OF UNITED NATIONS FRAMEWORK CLASSIFICATION, AN OVERVIEW OF URANIUM IN SOUTH AFRICA. South Africa Council for GeoScience, Johannesburg.

Murray, R., Swana, K., Miller, J., Talma, S., Tredoux, G., Vengosh, A., Darrah, T., 2015. The Use of Chemistry, Isotopes and Gases as Indicators of Deeper Circulating Groundwater in the Main Karoo Basin Report to the Water Research Commission. Water Research Commission.

Swana, K., 2016. Application of hydrochemistry and residence time constraints to distinguish groundwater systems in the Karoo Basin prior to shale-gas exploration.

WHO, 2011. Guidelines for Drinking-water Quality FOURTH EDITION WHO Library Cataloguing-in-Publication Data Guidelines for drinking-water quality-4th ed.

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Q&A Session

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