RADON CONCENTRATIONS IN DIFFERENT TYPES OF WATER RESOURCES IN HISA VALLEY - JORDAN

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This study presents the results of Radon (^{222}Rn) concentrations for different water resources in Hisa Valley in Jordan. The results were taken directly in twenty locations of water resources, every two weeks for the year (1998), using the Pylon AB-5 Portable Radon Radiation Monitor. The activity density of ^{222}Rn ranged from 304.67 KBq/m^3 (Afra hot water spring), 178.83 kBq/m^3 (well water in Phosphate mines region) 118.29 KBq/m^3 (Tanour hot water spring), 91.42 kBq/m^3 (Tanour well), 31.46 kBq/m^3 (Borbata cool spring), 11.62k kBq/m^3 (Cistern in Phosphate mines region), and 1.21 kBq/m^3 (Aina Pool). These averages were samples of the substantial variation of Radon concentrations in water resources in this small size watershed in Jordan. The rainfall season has apparently limited impact on Radon concentrations in pools, cisterns and shallow springs and wells, and no impact on deep wells and hot springs, because they are far from direct recharge. This study is the first step for Radon (^{222}Rn) mapping of Hisa Valley from the water resources perspective.

تعرض هذه الدراسة و تحلل بالمقارنة نتائج تراكيز الرادون في مصادر المياه في وادي الحسا في الاردن . وقد أخذت تلك النتائج مباشرة من عشرين موقعا لمصادر المياه في الوادي بشكل دوري ، كل أسبوعين طيلة عام ١٩٩٨ ، باستعمال جهاز (Pylon AB-5 Portable Radon Radiation Monitor) وقد تفاوت معدل تراكيز الرادون (^{222}Rn) من ٣٠٤,٦٧ كيلو بكريل لكل متر مكعب (ك ب/م٣) في أحد ينابيع عفرا الحارة ، الى ١٧٨,٨٣(ك ب/م٣) في بئر في منطقة مناجم الفوسفات ، الى ١١٨,٢٩ (ك ب/م٣) ، في أحد ينابيع التنور الحارة ، الى ٩١,٤٢ (ك ب/م٣) في بئر في منطقة التنور ، الى ٣١,٤٦ (ك ب/م٣) في ينبوع غير حار في منطقة البربيطة ، الى ١١.٦٢ (ك ب/م٣) في بئر جمع في منطقة مناجم الفوسفات ، الى ١,٢١ (ك ب/م٣) في بركة ري في منطقة العيناء . هذه المعدلات نماذج على التفاوت الكبير في تركيز غاز الرادون في مصادر المياه في حوض الحسا المائي المحدود الاتساع نسبيا . ولقد كان لفترة الشتاء الرطبة تأثير واضح في تخفيف تركيز الرادون في البرك وآبار الجمع والينابيع والآبار التي تستمد مياهها من تكوينات صخرية قريبة . ولم يكن لتلك الفترة أي تأثير يذكر في الآبار العميقة والينابيع الحارة لأن تغذيتها المائية غير مباشرة . وهذه الدراسة هي الخطوة الأولى لعمل خارطة لتوزيع الرادون في مصادر المياه في وادي الحسا .

Keywords: Radon concentrations, Radiation in groundwater resources, Natural radioactivity.

INTRODUCTION

Radon gas exists everywhere in air, soil, and water. Its concentration could be as high as hundreds of thousands of kBq/m^3 or so low in the media to an undetectable level. Radon gas is an intermediate product of the decay of Uranium-238, which can be found in most rocks, including those serving commonly as aquifers [1]. Radon is chemically inert but radioactive gas which decays to other radioactive elements. Its mobility in natural water is affected by physical rather than chemical processes. Radon as a noble gas is not ionized in solution. Also, it does not precipitate in solid phase but readily degases from water exposed to air because its ambient partial pressure is extremely low. Therefore, the radon concentrations in groundwater are commonly more than hundred times its concentrations in surface water [1] This study focused on ground water sources in Hisa valley. The studied pools and cisterns were mainly supported by ground water sources of wells and springs hot or cool Table 1. The wide variability of radon content in ground water of Hisa watershed may be related to several factors. The main factors would be the residence time in the aquifer rock, distance from recharging source, and rock characteristics. These characteristics include Uranium content, porosity, grain size and whether inter granular or fissure form predominates the aquifer structure [2] Exploring the real effects these factors thoroughly in Hisa valley would need several other studies. This study concentrated on the temporal and spatial variability of radon content in water sources in Hisa watershed (Table 1 and Table 2). The results gave good indications of radon distribution geographically and geologically. Comprehensive radon distribution mapping would need more sites and longer monitoring.

Table 1 Notation of investigated water sources in Hisa watershed

1	Ph1-Well	Well number 1 in the Hisa phosphate mines region.
2	Ph2-Well	Well number 2 in the Hisa phosphate mines region.
3	Ph3-Well	Well number 3 in the Hisa phosphate mines region.
4	TA1-Well	Well number 1 in Tanour region.
5	TA2-Well	Well number 2 in Tanour region.
6	AF1-Hot spring	Hot spring number 1 in Afra region.
7	AF2-Hot spring	Hot spring number 2 in Afra region.
8	BO1-Hot spring	Hot spring number 1 in Borbata region.
9	BO2-Hot spring	Hot spring number 2 in Borbata region.
10	TA-Hot spring	Hot spring in Tanour region.
11	AI-1 spring	Spring number 1 in Aina region.
12	AI-2 spring	Spring number 2 in Aina region.
13	TA-1 spring	Cool spring number 1 in Tanour region.
14	TA-2 spring	Cool spring number 2 in Tanour region.
15	BO spring	The main cool spring in Borbata.
16	Ph-1 cistern	Cistern number 1 in the Hisa Phosphate mines region. Depth = 6m Volume = 72m^3 (New cistern)
17	Ph-2 cistern	Cistern number 2 in the Hisa Phosphate mines region. Depth = 8m Volume =100 m^3 (Old cistern)
18	AI-1 pool	Irrigation open pool number 2 in Aina region. Depth=4m Volume =80 m^3
19	AI-2 pool	Irrigation open pool number 2 in Aina region. Depth=2m Volume =50 m^3
20	BO pool	Irrigation open pool in Borbata region. Depth= 3 m Volume =60 m^3

It is worth mentioning here that direct ingestion of ^{222}Rn from drinking water is not as serious as radon inhalation from air. But ^{222}Rn could be introduced into indoor air through domestic water supplies, if the degassing through aeration process was not performed in the water treatment process [3,4] and Prichard, 1987). ^{222}Rn and its α-emitting daughters may deposit on the lung tissue with up to three α- decays per ^{222}Rn atom [1]. The unit used in this study for radon concentration is kBq/m^3. Knowing that one Bq equal one decay per second.

The basic danger of the high radon content in hot springs is bathing in caves and closed chambers where radon escapes from hot water to the confined air. In Afra resort, people prefer to use confined areas not the open pools, regardless of radon dangers. These confined areas should be ventilated mechanically to reduce the radon content in the confined areas.

Table 2 Location and elevation of the studied sites in Hisa watershed

No.	Site	Elev. (M)	LAT. N		LONG. E	
			°	'	°	'
1	Ph1-well	842	30	55	36	04
2	Ph2-well	811	30	57	36	08
3	Ph3-well	760	31	02	36	10
4	TA1-well	435	31	00	35	43
5	TA2-well	413	31	01	35	44
6	AF1-Hot spring	321	30	53	35	32
7	AF2-Hot spring	328	30	56	35	33
8	BO1-Hot spring	362	30	58	35	40
9	BO2-Hot spring	374	30	58	35	40
10	TA-Hot spring	402	31	01	35	38
11	AI-1 spring	571	31	02	35	56
12	AI-2 spring	587	31	02	35	57
13	TA-1 spring	420	31	00	35	40
14	TA-2 spring	423	31	00	35	41
15	BO spring	392	30	57	35	38
16	Ph-1 cistern	832	30	56	36	04
17	Ph-2 cistern	815	30	56	36	08
18	AI-1 pool	567	31	02	35	56
19	AI-2 pool	580	31	02	35	57
20	BO pool	370	30	58	35	40

HISA WATERSHED CHARACTERISTICS

Hisa valley watershed has an area of 2520 km^2 with average precipitation of 140 mm/yr. Precipitation varies from 50 mm/yr in the east side of the watershed to 300 mm/yr in the high lands south and north of the valley. The potential evaporation is variable too. It ranges from 2800 mm/yr around the Dead Sea area to 3900 in the desert parts of the watershed.

These characteristics of the watershed rendered the water resources of this watershed to be mainly groundwater either as springs, wells or other ways of tapping ground water. Generally, groundwater has more radon content than surface water due to its routes through radiating rocks, and due to limited aeration process under ground. This description is supported by the fact that the average valley discharge is 34 MCM/yr with 32 MCM/yr as ground water and 2 MCM/yr as floods [5].

FIELD MEASUREMENTS

Radon concentrations in water sources in Hisa watershed were measured by Pylon AB-5 portable Radon Radiation Monitor in water [6]. Using the direct reading equipment in the same day needed strict preplanning to cover all the sites. To minimize the required time for the experiment, the working group was divided into three subgroups: one subgroup with the equipment was to explore Afra, Borbata, and Tanour; second subgroup was to take water samples from the Aina area. The third subgroup was to take water samples from the Hisa mines area. The tested water in springs, cisterns, and pools was taken from 50 cm below water surface to avoid water layer in contact with air where radon would escape.

The tested water of wells was held in plastic canisters, tightly closed to prevent leakage, and carried gently to prevent disturbance, which enhances degassing. The carried water was tested not more than six hours later in the afternoon. Each site was tested with five samples in the same day. The recorded number was the average of the five tests, which lowered the mean standard error, Table A-1 in the Appendix. All the sites were covered in a single day.

The experiment was done twice each month, at the first day and at the fifteenth of the month. The time series of the results were intended to explore the seasonal effects, especially the wet season effects of water recharge on radon concentrations in the water sources (Figures 1 to 8).

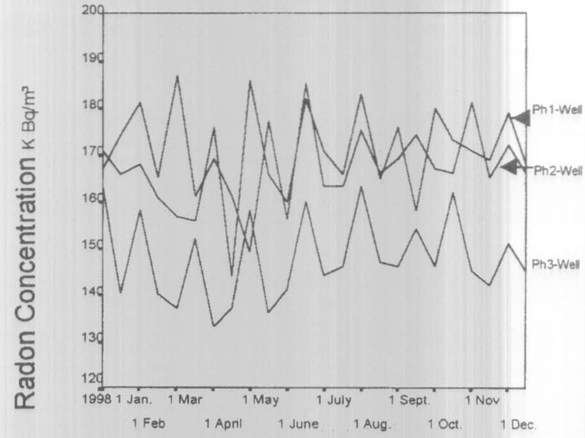


Figure 1 ph-well

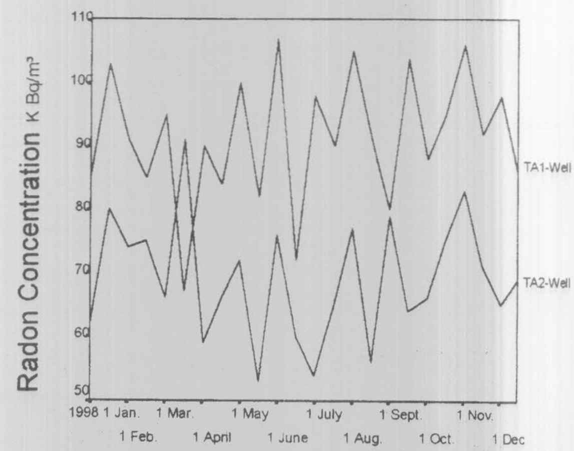


Figure 2 TA-well

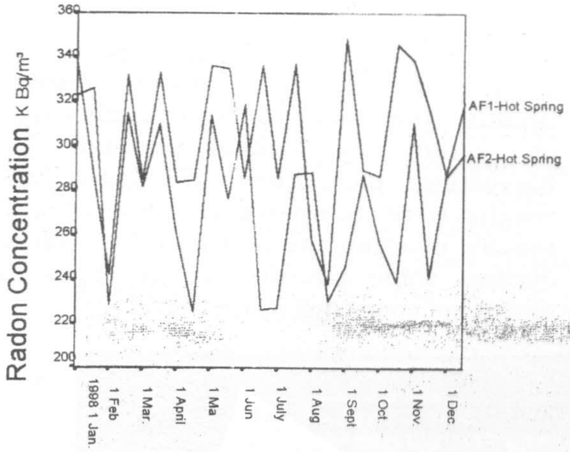


Figure 3 AF-Hot Sprig

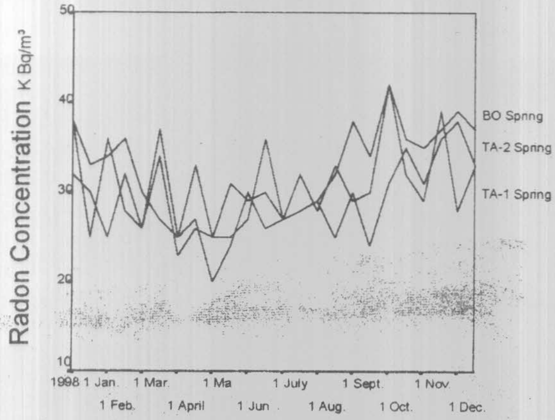


Figure 6 Spring

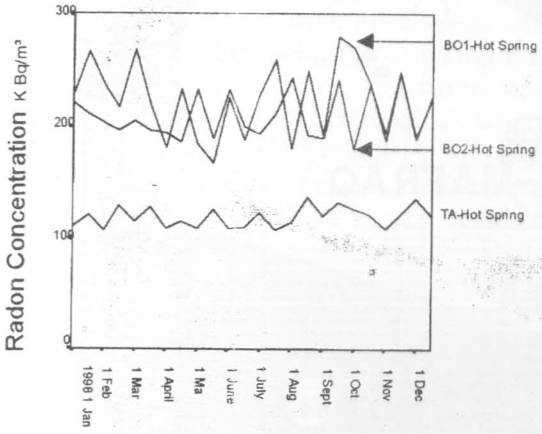


Figure 4 Hot Spring

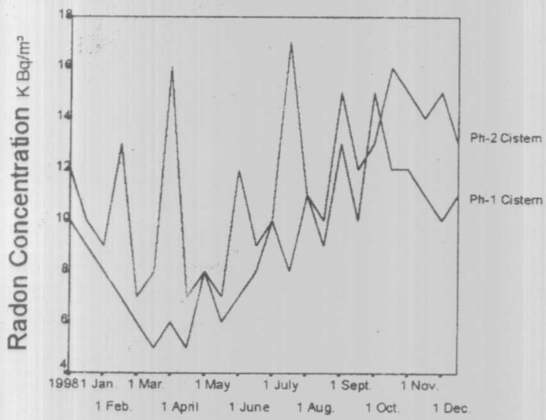


Figure 7 Ph Cistern

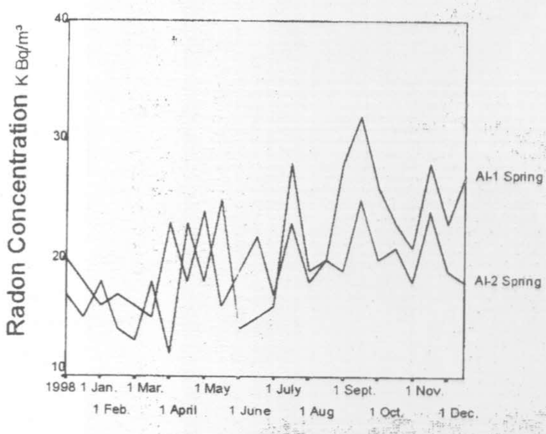


Figure 5 Al Spring

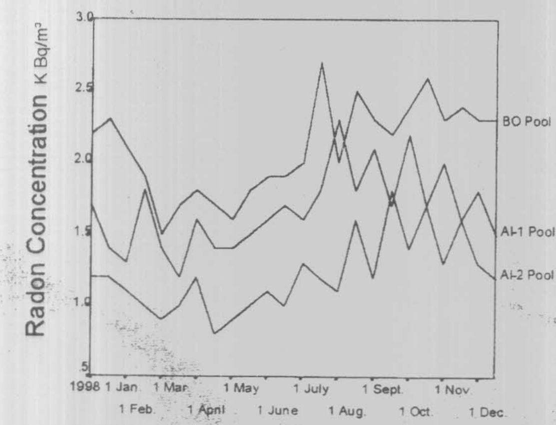
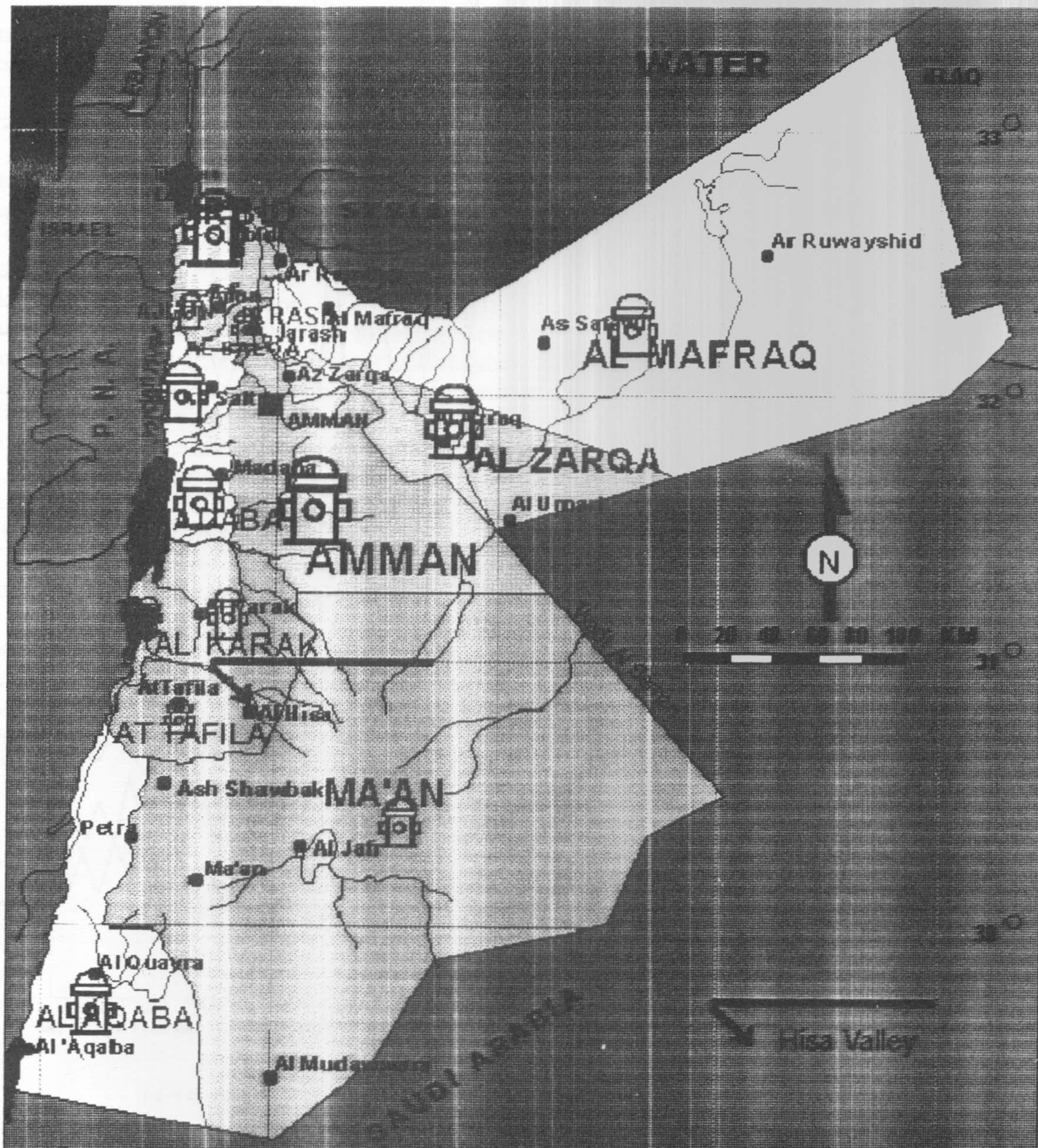


Figure 8 Pool

DISCUSSION

General

Results of any experiment should be put in perspective internally and externally to assess their worthiness and advancement. Internally, this study was wide enough to explore radon concentrations in four types of water resources in Hisa watershed: water wells, hot springs, cool springs, and cisterns and pools. Cisterns and pools were considered separate water resources because they were filled regularly partially or totally by rainfall through water harvesting techniques. Externally these results were compared and contrasted with results of other studies in other valleys in Jordan, some countries in the Middle East, and some countries in the world.



In Jordan, the radon content in water resources is variable. It could be as low as 0.776 kBq/m^3 for Mu'tah University well and 0.924 kBq/m^3 for Sultani well. Also it could be negligible like Wadi Sir well from upper cretaceous. On the other hand it could be as high as 1000 kBq/m^3 in Mukheiba well, 790 kBq/m^3 in Wadi El-Arab well, and 420 kBq/m^3 for Rama Well of Zarqa area of lower cretaceous aquifer [5].

The variability of radon concentration in water resources in Syria is not as wide as it is in Jordan for geologic reasons. Concentration in springs varies from 13-133 kBq/m^3. Wells regularly have lower concentration except for phosphate mine wells where radon concentration could go as high as 180 kBq/m^3, with an average of 123 kBq/m^3 [8]. In Saudi Arabia drinking water, the reported radon concentration varied from 1.25 kBq/m^2 to 3.25 kBq/m^2, which is lower than Jordan and Syria [9].

In Nigeria, radon concentration ranged from 17-161 kBq/m^3 in water resources, [9]., in Poland from 1-29 kBqlm^3 [10]. In Finland it reached 4800 kBq/m^3 (Asikainen et al, 1996), in Arkansas (USA) hot springs, it reached 100,000 kBq/m^3 (Wanty et al, 1987 and [11]

In perspective of these regional and global figures, the results of this study were not too low nor too high. They were in the expected range with the expected variability due to the geologic and geographic variability in Hisa watershed like most of Jordan. Most of water sources in Hisa valley had radon content higher than the suggested allowable level of USEPA of (300 pci/l) which is equivalent to (12 kBq/m^3 [12]).

SPATIAL VARIATION

The sites were selected to be as representative as possible of the valley geographical and geological variability. The spatial distribution was not for mapping purposes but its results could help any mapping project of radon concentration in water resources in Hisa valley. The average concentrations ranged from 1.21+0.53 kBq/m^3 for Aina pool number two to 304.67+6.75 kBq/m^3 for Afra spring number one (See Appendix Table A-2). Mostly hot springs had the highest concentration except for Tanour hot spring. There is an apparent correlation between water temperature and the level of radon concentration except for phosphate region wells, (Table 3 correlation = 0.79). Temperature was an indicator of the depth of the aquifer formation, which issues the concerned spring.

The phosphate region wells came after the hot spring in radon concentration level. Their highest was well number one (178.83+2.02 KBq/m^3) which had the shallowest depth and the lowest temperature of the wells; and the lowest was well number three (147.75+1.87) which had the deepest depth and the highest temperature of the wells. These results could appear paradoxical, but this may be explained by the fact that Uranium concentrations in the phosphate mines in Jordan decrease as we go deeper due to upward migration of Uranium compounds which is associated with groundwater upward gradient [13].

Tanour wells were lower than phosphate region wells in radon concentration. Tanour well number one was (91.42+2.13 kBq/m3 and Tanour well number two (69.08+1.94 kBq/m^3). Water of Tanour wells was warmer than other wells but cooler than Tanour hot spring (11 and 29+1.91), which gave us an indication of the source geologic formation (Table 3).

Cool water springs were comparable in temperature and in radon concentrations: in Borbata (31.46+1.11 kBq/m^3), in Tanour (29.58+0.81, 31.33+1.06 kBq/m^3), and in Aina (21.25+0.93, 18.71+0.83 kBq/m^3) (Table A-2). They are issuing from the hillsides of the limestone aquifer [5]. Their time series relative to the wet period was comparable due to rainfall recharging.

As expected the cisterns and pools had the lowest radon concentration due to their renewal and atmospheric exposure. Pools were lower than the cisterns due to the increased air-water interface. Cisterns in phosphate region (9.04+0.53 kBq/m^3, 11.62+ 0.64 kBq/m3) were partially exposed to air movement and radon migration from rock formation to water and air above cistern water Radon levels in these cisterns were higher than pools. Aina pools were filled mostly by Aina cool springs for irrigation purposes, and in the wet season partially by rainfall. The radon concentrations in the pools were less than 7 percent of the level of source spring. This large difference gave us a good method for radon reduction in critical regions. Aeration method would be the cheapest to reduce radon concentration levels by continuous degassing.

Table 3 Radon Concentration means and temperatures

	MEAN	TEMP
Ph1-Well	178.83	18
Ph2-Well	169.13	19
Ph3-Well	147.75	21
TA1-Well	91.42	36
TA2-Well	69.08	32
AF1-Hot Spring	304.67	62
AF2-Hot Spring	276.25	57
BO1-Hot Spring	223.04	49
BO2-Hot Spring	208.46	42
TA-Hot Spring	118.29	40
AI-1 Spring	21.25	17
AI-2 Spring	18.71	18
TA-1 Spring	31.33	22
TA-2 Spring	29.58	21
BO Spring	31.46	19
Ph-1 Cistern	9.04	16
Ph-2 Cistern	11.62	17
AI-1 Pool	1.671	21
AI-2 Pool	1.212	23
BO Pool	2.1	26
Correlation: 0.79		

Periodicity

Several researchers have stressed recently on periodicity or seasonality of radon gas concentration [14]. They found out that one-time sampling of water supplies might not produce a representative sample for the water source due to expected temporal variations in the source.

The expected periodicity would be due to water recharge in the wet season by rainfall, which has less radon content. This effect was not direct in all cases due to variable directions and velocities of different ground water movements, which obscured the responses.

Wet season in Hisa watershed comes normally in rainfall form, but snowfall occurs once yearly in the average above the highlands north and south of watershed. The wet season starts mostly in October and extends to April. Most of the precipitation comes in January, February and March. The ground water recharge in October, November, and December is mostly minimal due to the required wetting and the high surface evaporation.

The variation of precipitation amounts spatially are substantial, from a round 300 mm/yr along the highlands to about 100 mm/yr by the dead sea area, and 50 mm/yr at the eastern desert boundaries of the Hisa watershed [5].

The temporal and spatial variations of rainfall had variable effects on the time series of radon content of each water source. Some effects were pronounced and apparent, some were moderate, and some were negligible or nonexistent, depending on the depth of the strata where water issues.

The time series of the three wells in the region of phosphate mines were different. The time series of radon content of well number one showed some variation during the wet season from January to May (Figure 1). The rainfall around this well is about 120mm and its depth is about 180m, which indicated moderate recharge. On the other hand, for well number two with rainfall around 75mm and depth 300m, time series showed relatively little depression from March to June. The water recharging was negligible and was being lagged by two months. Well number three of the phosphate region is far in the desert with negligible direct rainfall recharging because of its depth (35om) and the little rain of 50 mm.

Tanour wells, number one and number two had negligible seasonal variation in radon content due to their depths of (220,270m) which tape from the upper sandstone aquifer (Figure 2). This aquifer had little direct recharging from rainfall. The ground level of these wells is about 370 m below the surface level of phosphate mines wells.

Hot springs mostly didn't show periodicity or variation in radon content due to the wet season. This fact was apparent in Afra and Tanour hot spring, which are issuing from the sandstone aquifer. The hot springs of Borbata showed some variation due to mixing of hot springs with upper level springs which were affected by the wet season for a certain degree (Figures 3 and 4).

Aina springs had apparent variation due to the effect of the wet season. Spring number one was affected from January to August. Spring number two was affected from January to April (Figure 5). The prolonged effects on spring number one was due to the complex geologic formation draining to it, which made its average outflow four times that of spring number two.

Cool water springs of Tanour and Borbata were issuing from the same aquifer of Aina springs, but the first one of Tanour cool springs had almost no variation (Figure 6). This could be due to multi-seasonal, or multi-yearly lag of recharge due to the hard rock over laying the spring and the peculiar direction of water recharge. The second had a depression in the time series from April to September. On the other hand, the Borbata cool spring had a depression in its time series from March to September. The recharging of the aquifer where these springs originated was higher in the west closer to Borbata, and lower in the east closer to Tanour.

For all the pools and cisterns, the wet season effects on the radon content time series were apparent as expected (Figure 7 and 8). They had similar performances, except for cistern number two in the region of phosphate mine because of its depth, continuous closure, and being old with rock cracks. The other cistern and the pools had definite depression in radon content from January to May. In cistern number one in the phosphate region and Aina pool number two the depression was extended to August, due to continuous usage and radon degassing.

CONCLUSION

Radon concentration in water resources of Hisa valley watershed was widely variable. In Aina pool, it was (1.21 kBq/m^3), in phosphate region well (178.83 kBq/m^3), in Borbata hot spring (304.67 kB1/m^3). This variability was due to geographic and geologic variability of the valley like most of side valleys, which drain to the rift valley of Jordan.

The correlations between radon concentrations in each water source in Hisa watershed were generally low due to the differences of the geologic formation. Only the pools and the cisterns had some tangible correlations due to their similar conditions of storage, usage, and aeration.

The periodicity of the data time series for each water source was not the same. The effects of wet season were apparent for pools, cisterns, cool springs, and shallow wells, because of the short recharging routes of groundwater and the direct water harvesting effects on pools and cisterns. But no real effect was for hot springs and deep wells because the recharging routes were not direct or they need more than a season.

All springs and wells in Hisa valley watershed had radon content higher than 12 kBq/m^3, the standard suggested by USEPA, while the cisterns and pools were lower than the standard. The water of springs and wells of this valley should be aerated before domestic usage. Ventilation of closed chambers and caves is necessary to reduce the radon concentration in air above hot springs' pools.

Radon concentration mapping needs more sites and comprehensive monitoring, while this study gave indications and landmarks for further comprehensive studies in this watershed and other similar ones.

Table A-1 Data of radon concentrations in water sources in Hisa valley

Date	Ph1-Well	Ph2-Well	Ph3-Well	TA1-Well	TA2-Well	AF1-Hot Spring	AF2-Hot Spring	BO1-Hot Spring	BO2-Hot Spring	TA-Hot Spring	AI-1 Spring	AI-2 Spring	TA-1 Spring	TA-2 Spring	BO Spring	Ph-1 Cistern	Ph-2 Cistern	AI-1 Pool	AI-2 Pool	BO Pool
1998	181	167	163	85	62	338	323	227	221	110	20	17	38	32	38	10	12	1.7	1.2	2.2
15 Jan	176	174	140	103	80	289	326	266	211	120	18	15	25	30	33	9	10	1.4	1.2	2.3
1 Feb.	178	181	158	91	74	242	228	237	202	106	16	18	36	25	34	8	9	1.3	1.1	2.1
15 Feb.	171	165	140	85	75	332	315	216	196	129	17	14	28	32	36	7	13	1.8	1.0	1.9
1 Mar.	167	187	137	95	66	285	282	268	204	115	16	13	26	26	30	6	7	1.4	.9	1.5
15 Mar.	166	161	152	67	91	333	310	219	196	128	15	18	37	34	27	5	8	1.2	1.0	1.7
1 April	186	169	133	90	59	284	261	181	194	108	23	12	25	23	25	6	16	1.6	1.2	1.8
15 April	154	161	137	84	66	285	225	233	185	115	18	23	33	26	27	5	7	1.4	.8	1.7
1 May	196	149	158	100	72	336	314	184	232	108	24	18	25	25	20	8	8	1.4	.9	1.6
15 May	176	177	136	82	53	335	276	166	188	125	16	25	25	31	24	6	7	1.5	1.0	1.8
1 June	170	156	141	107	76	286	319	225	232	108	19	14	27	29	30	7	12	1.6	1.1	1.9
15 June	192	185	160	72	60	336	226	187	199	109	22	15	36	30	26	8	9	1.7	1.0	1.9
1 July	181	163	144	98	54	286	227	228	193	122	17	16	27	27	27	10	10	1.6	1.3	2.0
15 July	176	163	146	90	65	337	288	259	211	107	23	28	28	28	32	8	17	1.8	1.2	2.7
1 Aug.	193	175	163	105	77	258	289	180	243	114	18	19	29	29	28	11	11	2.3	1.1	2.0
15 Aug.	175	166	147	91	56	238	230	249	192	136	20	20	32	25	33	9	10	1.8	1.6	2.5
1 Sept.	186	169	146	80	79	349	246	192	189	119	28	19	38	30	29	13	15	2.1	1.2	2.3
15 Sept.	168	174	154	104	64	290	288	280	241	132	32	25	34	24	30	10	12	1.7	1.8	2.2
1 Oct.	190	167	146	88	66	287	257	270	180	126	26	20	42	31	42	15	13	2.2	1.4	2.4
15 Oct.	183	166	162	95	75	346	239	238	237	120	23	21	32	35	36	12	16	1.7	1.7	2.6
1 Nov.	181	181	145	106	83	339	311	186	194	108	21	18	29	31	35	12	15	2.0	1.3	2.3
15 Nov.	179	165	142	92	71	317	241	247	248	120	28	24	39	36	37	11	14	1.6	1.6	2.4
1 Dec.	189	172	151	98	65	287	289	188	190	135	23	19	28	38	39	10	15	1.8	1.3	2.3
15 Dec.	178	166	145	86	69	297	320	227	225	119	27	18	33	33	37	11	13	1.5	1.2	2.3

Table A-2 Descriptive Statistics of radon Concentration in Water Sources in Hisa Valley in (K Bq/m³).

Water Source	Range	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Ph1-Well	42	178.83	2.02	9.89	-.401	.472	.344	.918
Ph2-Well	38	169.13	1.84	9.00	.118	.472	.162	.918
Ph3-Well	30	147.75	1.87	9.14	.341	.472	-1.007	.918
TA1-Well	40	91.42	2.13	10.41	-.467	.472	.026	.918
TA2-Well	38	69.08	1.94	9.53	.251	.472	-.210	.918
AF1-Hot Spring	111	304.67	6.75	33.09	-.387	.472	-.824	.918
AF2-Hot Spring	101	276.25	7.43	36.42	-.136	.472	-1.551	.918
BO1-Hot Spring	114	223.04	6.83	33.47	-.034	.472	-1.144	.918
BO2-Hot Spring	68	208.46	4.27	20.92	.600	.472	-1.068	.918
TA-Hot Spring	30	118.29	1.91	9.36	.381	.472	-.962	.918
AI-1 Spring	17	21.25	.93	4.57	.620	.472	-.327	.918
AI-2 Spring	16	18.71	.83	4.08	.502	.472	-.124	.918
TA-1 Spring	17	31.33	1.06	5.20	.407	.472	-1.054	.918
TA-2 Spring	15	29.58	.81	3.98	.242	.472	-.563	.918
BO Spring	22	31.46	1.11	5.44	-.061	.472	-.547	.918
Ph-1 Cistern	10	9.04	.53	2.61	.302	.472	-.360	.918
Ph-2 Cistern	10	11.62	.64	3.13	.028	.472	-1.186	.918
AI-1 Pool	1.1	1.671	.057	.277	.610	.472	.125	.918
AI-2 Pool	1.0	1.212	.053	.258	.748	.472	.140	.918
BO Pool	1.2	2.100	.066	.324	-.067	.472	-.851	.918

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