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GIS Approach to Radioactive Contamination Around Seyitömer Thermic Powerhouse

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ABSTRACT

Researching radiometric elements such as uranium(U), thorium(Th), potassium's(K) and their decay products distribution in nature; are an important subject to protect environment. Around the lignite-fired thermic powerhouse, Seyitömer settlement regions pollution was studied on account of radionuclide element distribution. Samples were taken from an area of 25 km2 in the vicinity of Seyitömer Thermic Powerhouse. Alpha, beta activity levels of soil and rock samples were measured with Handecount scintillation device. U, Th, K element concentrations of elements were analyzed by means of Spectro X-LAB 2000 PED X-LAB 2000 PED XRF device. U, Th and K are known as main alpha and beta sources in nature. Distribution of radioactive element concentrations was analyzed and mapped using Geostatistical Tools of ArcGIS software. Risky element's intensity maps were prepared; risky areas were also determined with intensity distribution maps. For evaluation of region; alpha, beta activities were compared with natural radioactive sources U, Th, K. Thus side affects of Seyitömer Thermic Powerhouse ashes as regards of radioactive ingredients were investigated.

Key Words: Seyitömer Thermic Powerhouse, Radioactive Elements, Soil, Rock, Pollution, Geostatistical Analysis.

1. INTRODUCTION

Thermic powerhouses in Turkey use mine coal, lignite, fuel oil, diesel fuel, natural gas and liquid petrol gas sources for electric production process (Sedat A, 2005). Turkey's thermic powerhouses electric power production share was 67 percent in 2008. Seyitömer Thermic Powerhouse is one of the biggest electric production foundations which were established in interior western Anatolia. This facility was located near Seyitömer region at northeast of Kütahya. Thermic powerhouse has got four central units which were opened in 1973, 1974, 1977, 1989 years. Each unit has 150MW capacity; thermic powerhouse total electric production power capacity is 600 MW. For electric production process lignite coal is used. Turkey lignites as average include 36,5% moisture, 21% ash and 2,1% sulphur. Also varying amounts of radioactive materials were determined in coals (Sedat A, 2005). Thermic powerhouse wastes consist of solid, liquid, gas and radioactive components relating to burned coal ingredients. However much of solid wastes keep by the chimney of powerhouse; flying ash sized components arrive to agriculture areas and living areas by air (Evyapan, F., 2007; Ilgari, R., 2008). As a result of flying ash's strewing over the soil; contamination both directly affects agriculture and soil components (H.Tsukadaa et al., 2002; Tuna, L.A.and Girgin, R.A, 2005). Food and fodder produced on soil are at the beginning of food chain and this situation also affects animals and people life directly (A.Dellantonio et al., 2007). This affect would be by exposed ionizing radiation from outside or inside the living body. By their nutrition behaviors also radioactive elements were absorbed by living organisms at different ratios (S.C. Sheppard et al., 2005). Radioactive element absorptions in aquatic habitat animals, radionuclide particle concentration ratios in animal bodies were prepared by A. Hosseini et al. (2008). Ionizing radiation damage to DNA is obvious. Radiation affect to DNA damage in

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nuclei of the root cells of allium cepa seeds germinated in the soil of high background radiation areas of Ramsar was researched by M. Saghirzadeh et al. (2008). In addition to food sources also water sources of region would be affected by radioactive decay chains. Heavy rains can bring the radioactive particles to the ground. Sorbent and complexing capacities of soil contribute to the immobilization of radionuclides with water in the underlying layers.

Afterwards radionuclides were displaced from complexes or adsorption layers (M.Gavrilescu et al., 2007; D.J. Ashworth et al., 2003). In a serious contamination, pollution affect would be increased by water sources (Baba, A., 2001). Humans expose to natural and artificial radiological hazards from earth's crust (Y.G. Zhu and G. Shaw, 2000). Uranium, thorium and potassium decay chain's members are most affective natural radioactive sources in human life (N.Damla et al., 2009). In this study extent soil and rock samples were used specially to determine uranium, thorium, and potassium levels. Alpha and beta activity of samples around thermic powerhouse, were measured to evaluate area by radioactive contamination. Uranium, thorium and potassium intensities were guided us to fix pollutions main source. Aim of this study is to settle whether there is a radioactive pollution by thermic powerhouse. Geostatistical Tools of ArcGIS software; a helpful interface was used to compare pollution maps.

2. Materials and methods

2.1. Description of area which is studied

Seyitömer lignite basin was formed during Pleistocene as an organic participation of lake. The basement of the study area is represented by ophiolitic rocks which are mainly composed of serpentinite, gabbro and diabase rocks. The basements of the study area are covers by conglomerate and layered claystone and marl. Two different coal bearing rock units are observed in the study area. These are "main" and "B" viens. Both of these veins are interlayered by clay and marl. The thicknesses of the coal reach upto 1.5m. Seyitömer district is in Kütahya city and exists in interior western Anatolia between 39^o 37' latitude and 29^o 27' longitude (Figure 1).

2.2. Sampling and analysis

All samples were collected from thermic powerhouse in September 2007. Totally 59 samples were collected consist of soil and rock from approximately 25 km2 area. Sample coordinates were determined by a Magellan model GPS device. Samples coordinates were plotted on a geographic map with a scale of 1/25000. One kilogram capacity black plastic bags were used to store samples. Systematically collected samples were also labeled with informative stickers. Sample number, sample type, coordinate data were written on a notebook. All samples were sieved until 200 mesh; samples were dried before pellet preparation. Prepared pellets were used in XRF measurement. Pellet ingredients were 0,9 g wax and 4 g soil. Wax and soil mixture was pressed until 20 kbar by means of pressing machine.

Detection of alpha and beta activities performed by means of the Handecount alpha and beta scintillation counter. Hand count system is controlling by a palm computer which was mounted on it, has touch screen capability. Device stores all measurement results in time and date order; it is easy to reach stored data after experiment. Before any measuring process background count is taken by device and subtracts it from the main count; as a result of calculation activity values of alpha and beta is given. Consequently gives result in any user ordered unit type. Device has got a 50,8 mm diameter sized drawer; which depth is adjustable between 0,76 mm -7,94 mm. Soil and rock samples were sieved until 20 micron size. By this operation alpha measuring efficiency was tried to increase (Aitken 1985). Also drawer space adjusted to possible minimum height, which performed alpha particle air absorption to minimum. Soil samples which were 20 micron size, stuck on aluminum discs by using paraffin oil. For sample preparation 0,7 mm thickness, 1cm diameter sized discs were used. Experiments with increased diameter sized discs were also done. But only 1 cm diameter sized discs were gave repeatable and maximum certainty results. With a result of series experiments repetition number and measuring periods designated. For each disc 10 minute measuring time and 3 repetition numbers were accepted. Aluminum discs beta backscatter value was calculated with using device's ^{90}Sr beta source. ^{90}Sr beta source activity was 0,0025 μCi. 1, 2, 3, 4, 5 mg KCl dusts were prepared to make a small correction with beta measurement results. 1gr natural potassium gives 750pCi activity; this knowledge was known (Gaylord 2005). Theoretical results and experimental results of KCl samples were found. Between two results very small difference were seen. This experimental result was performed to find a corrective equation; which were used to adjust beta measurement results. All the analyzed experimental data were showed in Table 1 and Table 2. Using the Geostatistical Tools of ArcGIS, and by the Kriging linear interpolation method, we have constructed contours for activity concentrations.

3. Results and discussion

All pollution maps were demonstrated with grids; from one to six numbered lines were intersected with A to E lettered columns. Each map consists of thirty cells. In the following lines every map's cells were defined with two characters. Firstly column character, secondly line number were used as like A1, E5 for defining place of a cell.

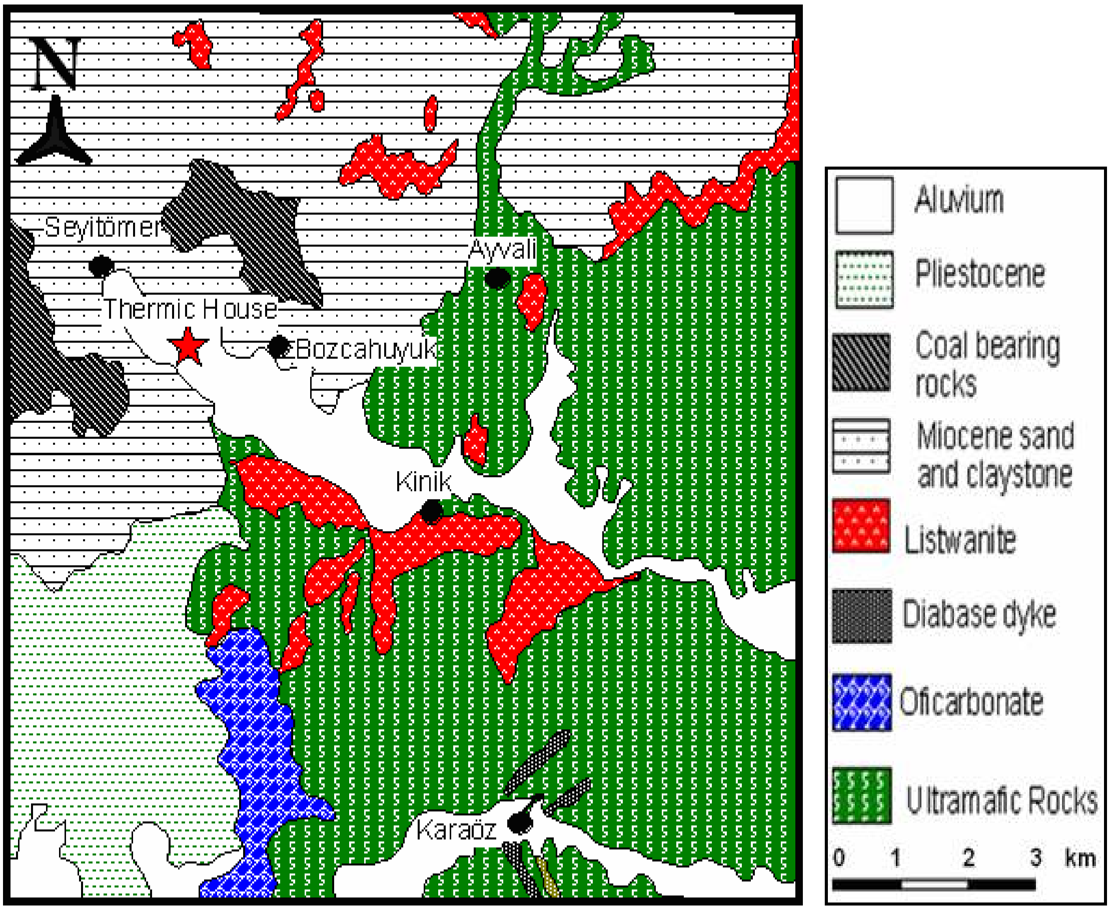

Figure 1. Geological and location map of Seyitömer Thermic Powerhouse (red star).

Table 1. Radioactive and heavy element concentrations around the Seyitömer Thermic Powerhouse.

Sample number	K(ppm)	U(ppm)	Th(ppm)	W(ppm)	Pb(ppm)
1	1.324	1.1	1.1	32900	23800
2	1.051	1.2	1.1	14300	23200
3	2.054	10,6	1.6	14000	73900
4	0.5148	8,2	0.7	8200	18600
5	1.277	17,4	1.3	179800	10500
6	0.2452	8,5	1.7	8600	13300
7	1.343	15,3	12.9	148300	23900
8	2.181	16,2	12.6	12000	80500
9	1.404	16,6	5.9	65700	27600
10	0.7388	7,7	1.2	13900	14000
11	0.8099	2	1.1	17600	17000
12	1.118	2.2	5.4	33000	25700
13	1.2	1	2.8	27900	16500
14	1.049	1.76	5.7	57800	31800
15	0.958	1.9	6.8	16300	31500
16	1.405	2	2.2	24900	26600
17	1.032	1.6	0.9	16300	20000
18	0.7208	8.2	1.2	11000	12800
19	1.499	13,2	0.7	32700	30900
20	0.9471	14,1	1.2	13500	21000
21	1.04	1	1.1	18800	13000
22	1.037	1.6	1.2	28100	11400
23	0.6801	1	1.2	12600	22300
24	0.7068	1.2	1.3	10000	23300
25	1.183	9,0	1.4	17300	21400
26	0.6621	7,0	1.2	12800	21900

27	0.5545	1.4	1.3	13000	12700
28	0.4408	1.3	1.5	16000	3800
29	1.24	1.9	1.1	17100	23300
30	0.5178	15,7	3.1	62200	30300
31	0.5511	1.5	1.3	12000	14600
32	0.7985	1.4	3	10000	32600
33	1.248	1	1.1	21900	24500
34	1.069	1.8	1	14900	19700
35	0.8859	1.4	9.2	25300	35800
36	0.8593	0.2	1.3	12300	17700
37	0.9507	1.2	3.3	33900	49000
38	0.94	0.8	11.3	9400	28800
39	0.4651	0.8	1.4	15000	3500
40	1.331	0.9	2.7	30500	24600
41	1.075	12,3	1.1	36600	22600
42	0.6857	0.7	1.1	11000	30800
43	0.6455	8,5	0.9	10000	26200
44	0.7648	7,3	8.9	14100	32500
45	0.7473	1.6	9.7	12300	29400
46	0.4964	1.8	2.4	12000	27200
47	0.5304	1.5	2.7	11000	29800
48	1.029	14,6	0.9	39300	21700
49	1.266	0,8	0.9	29200	22300
50	1.11	7,7	0.9	35300	22000
51	1.069	0,1	1.7	19800	20600
52	1.317	10.4	13.2	106700	23400
53	0.4384	13.3	1.1	26800	4600
54	0.3323	0.1	5.1	8600	18300
55	1.363	0.1	5.4	53200	28600
56	0.3804	20.7	1	8900	12600
57	0.6708	0.1	1.6	11000	24700
58	1.266	0.1	1.2	11000	26600
59	0.7922	0.1	6	11600	30200

Table 2. Alfa and Beta element concentrations around the Seyitömer Thermic Powerhouse.

Sample number	Alfa_rock (Bq/ kg)	Beta_rock (Bq/ kg)	Alfa_soil (Bq/ kg)	Beta_soil (Bq/ kg)
1	-	-	3693	0
2	0	24860	4135	4306
3	0	0	0	0
4	4937	0	4540	0
5	-	-	4171	26442
6	3183	0	5137	18679
7	4045	0	0	0
8	5268	6239	0	0
9	0	0	0	0
10	0	0	5817	28824
11	0	17596	0	0
12	0	25924	6526	0
13	5584	0	0	0
14	0	0	-	-
15	5516	0	0	0
16	3082	32185	0	42791
17	4771	0	3034	21712
18	0	0	3121	0
19	0	3858	0	0
20	0	0	-	-
21	5567	0	0	0
22	4315	0	-	-
23	5416	0	-	-
24	3341	5085	4668	0
25	6742	29905	0	5569
26	0	13326	-	-
27	3610	0	0	0
28	4450	0	-	-
29	3811	13901	-	-
30	3760	4578	-	-
31	0	0	0	0
32	4396	0	5315	0

33	2929	18947	-	-
34	7793	11486	3410	34794
35	5121	46040	-	-
36	0	0	-	-
37	0	28582	0	0
38	-	-	0	0
39	3799	0	0	19459

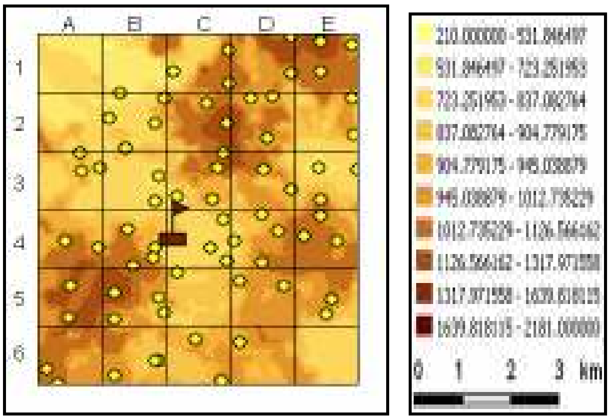

Figure 2. Potassium (K) concentrations (ppm) map around Seyitömer Thermic Powerhouse.

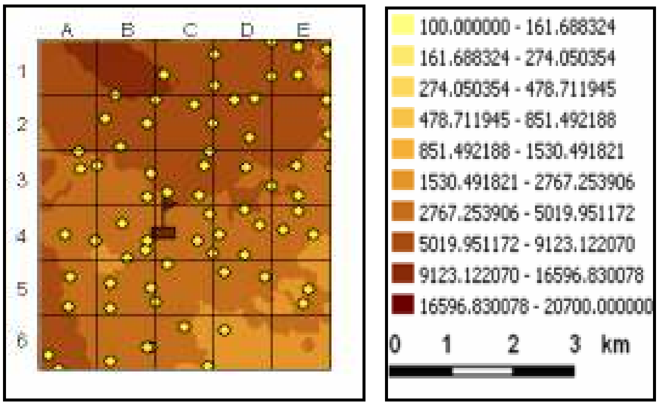

Figure 3. Uranium (U) concentrations (ppm) map around Seyitömer Thermic Powerhouse.

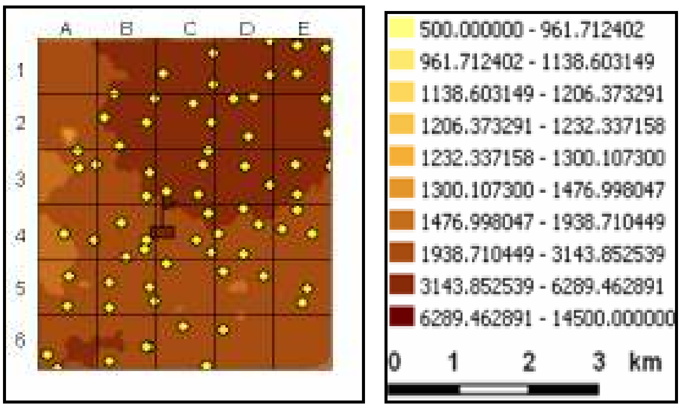

Figure 4. Thorium (Th) concentrations (ppm) map around Seyitömer Thermic Powerhouse.

Earth ground consists from rock and soil components. It is known that rock particles taken from area would sample regions main rock veins. Soil would be carried by external forces like wind, streams; but it's not subject for rock particles. Also soil components would be contaminated easily from air particles and polluted water streams. Rock parts of ground are unbroken and wouldn't be contaminated as a soil component. If thermic powerhouse weren't pollute the environment; alpha, beta soil pollution maps would resemble with U, Th, K pollution maps. In contrary thermic powerhouse pollution would be obvious on soil pollution maps.

Before alpha pollution maps were evaluated, alpha radiation was known to resemble uranium and thorium series. When uranium Figure 3 and thorium Figure 4 maps were compared with alpha rock pollution map Figure 7, similar regions are included. Thorium distribution map has got intense region over 4 line and right side of A column. These regions are harmonious at alpha rock pollution map Figure 7 at the same locations. But there are white regions on C1, D1 and E1 squares in alpha rock pollution map; this may be explained by absorption of alpha radiation with the high atomic numbered (Z) elements on C1, D1 and E1 squares. It would be probably difficult for alpha radiation to pass among high Z elements; which samples would contain these high Z elements at these regions. On C1 square tungsten element Figure 5 and on D1, E1 squares Figure 6 lead element levels were seen with an increased intensity. On lead pollution map there is an intense region like a diagonal through D3, C4, B5, A6 squares; on the same squares on alpha rock pollution map Figure 7 there are white intensity regions which supports this opinion. Potassium element Figure 2 distribution was expected to resemble with beta rock pollution map. Potassium element Figure 2 has got intense regions on C1-2, D2 and A4-6 B4 squares also E3-4, D4 squares have got light gray intensities. Beta rock pollution map Figure 8 has got dark gray intensities on D3, E3 squares and light gray intensities on E1-4, D1-4, C2-4 squares.

As it is expected there are common regions with potassium pollution map and beta rock pollution map on C2, D2, D4, E3-4 squares. Alpha and beta soil pollution maps were expected to show thermic powerhouse pollution affects. Alpha soil pollution map has got intensities on A1-4, B4, D5, D6, E6 squares. On alpha soil pollution map especially around thermic powerhouse there isn't a widespread intensity except B4, A1-4 regions, it is possible that these regions are polluted by thermic powerhouse. But B4, A1-4 regions also includes changing thorium and uranium intensities which refuses pollution was sourced by thermic powerhouse. Again on alpha soil pollution map 5^{th} and 6^{th} lines have got changing intensities at the bottom of map. Then these regions pollution source can be commented as thermic powerhouse but on these regions sampling number isn't enough to make a comment like this. Beta soil pollution map has got intensities on D2-4, E2-5 squares which these regions resemble with potassium pollution map. An exception from potassium pollution map on this beta soil pollution map is just A1-2 and B1 squares, only these squares shows us thermic powerhouse was polluted this region. Figure 11 and Figure 12 tell us mostly wind blow force took heavy particles to north region of thermic powerhouse, as a result region was polluted by thermic powerhouse.

4. Conclusion

Geostatistical Tools of ArcGIS software analyzed Seyitömer Thermic Powerhouse's pollution by element mapping. It was seen that alpha rock pollution map resembled with uranium, thorium pollution maps. Also beta rock pollution map resembled with potassium pollution map. These situations were expected before experiments done. When average soil radiation activity values of region compared with world soil radiation activity values Table 4. It would be seen that region's radiation activity values are very high as compared average radiation activity values of world. Rock radiation activity values of region are also high as compared to average values of world. This clue shows us natural geographic structure of region increases radioactive pollution affect in this site. There were some unexpected pollutions on A1, B1 squares for beta soil pollution. This was commented as; pollution was performed by thermic powerhouse. On subject of a real pollution, heavy air particles would be settled near thermic powerhouse on days without wind. Also it was assumed that pollution distribution would be close to zero at long distances. For evaluation of site wind values taken from 1996 (thermic powerhouse dust filters attached in 1995) to 2006 (soil samples collected from the region in 2007 year) by this way also tried to understand filters affect to decrease pollution. Significant numbers of windy days were seen between north and west-northwest directions for ten years period; pollution could be estimated by direction of wind approximately. Wind blow statistics of region showed us subject of A1 and B1 squares pollution was sourced by thermic powerhouse. ArcGIS software's distribution maps gave us a lot of clue to understand shape of pollution. Sampling number must be taken at probable maximum level to understand affects of pollution easily. For measuring alpha radiation high atomic numbered elements probable negative affects must be taken in consideration. Regarding these points to take definite and reliable results; in similar studies sampling number must be increased and nature's side affects to pollution should be investigated.

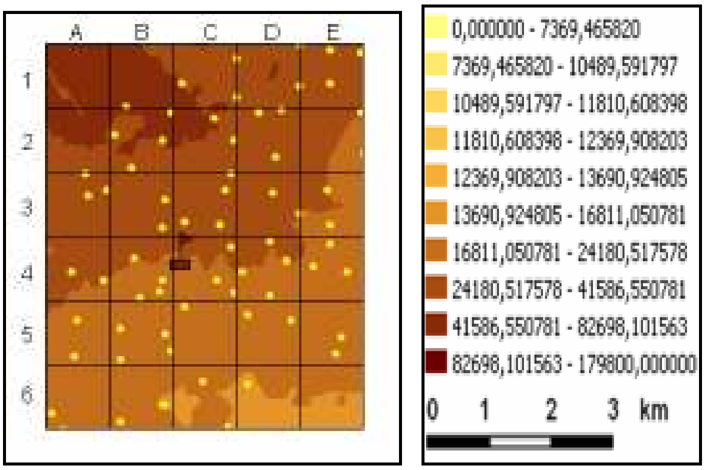

Figure 5. Tungsten (W) concentrations (ppm) map around Seyitömer Thermic Powerhouse.

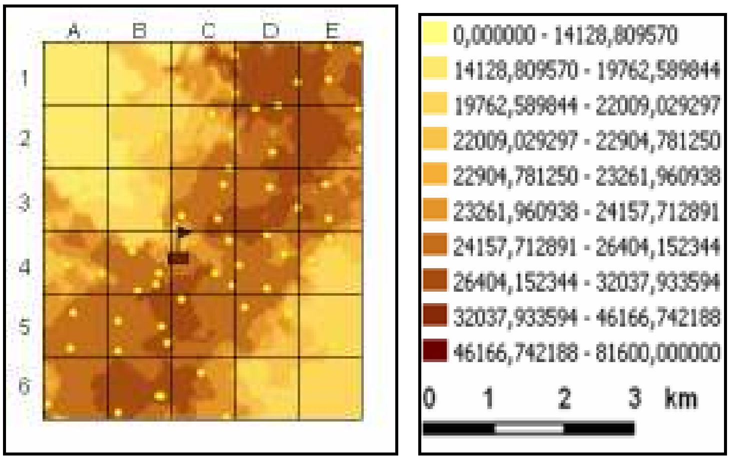

Figure 6. Lead (Pb) concentrations (ppm) map around Seyitömer Thermic Powerhouse.

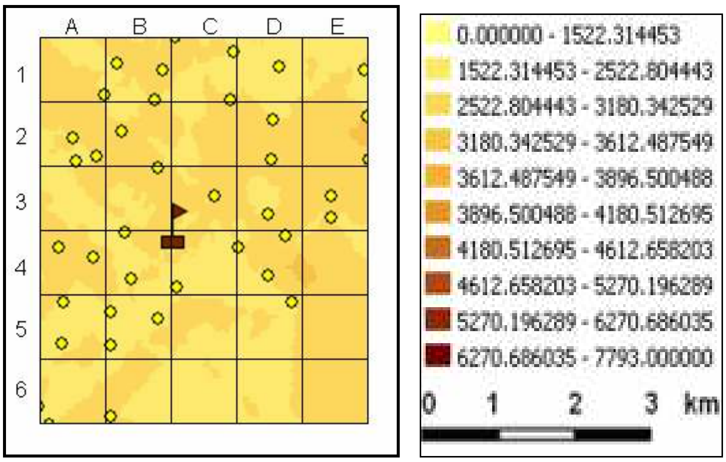

Figure 7. Alpha rock concentrations (Bq/kg) map around Seyitömer Thermic Powerhouse.

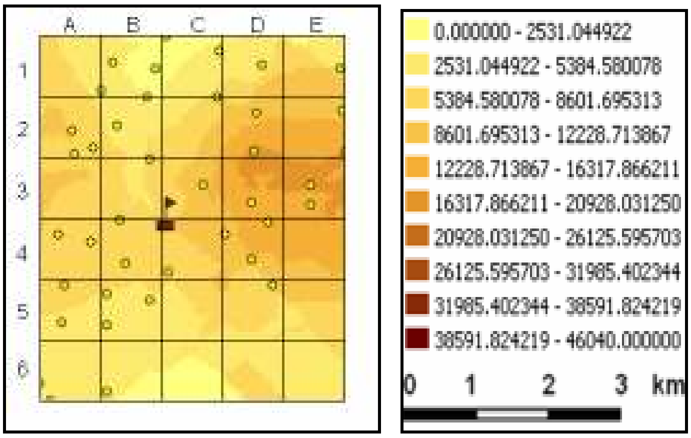

Figure 8. Beta rock concentrations (Bq/kg) map around Seyitömer Thermic Powerhouse.

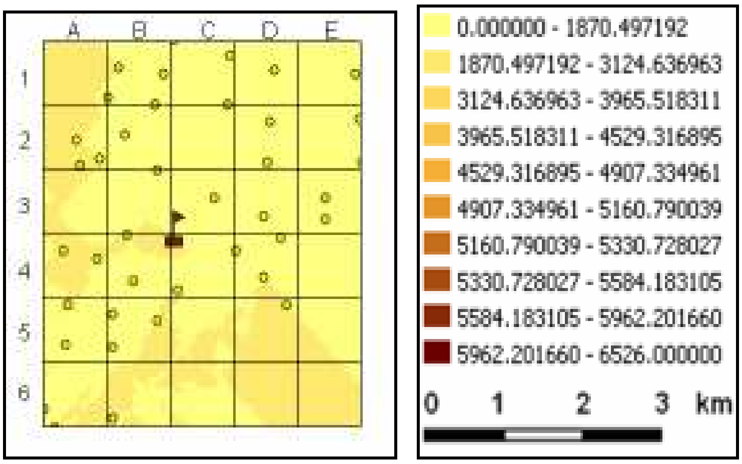

Figure 9. Alpha soil concentrations (Bq/kg) map around Seyitömer Thermic Powerhouse.

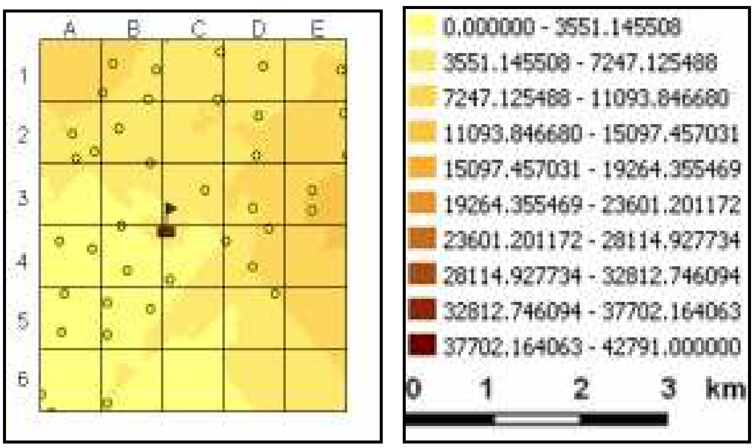

Figure 10. Beta soil concentrations (Bq/kg) map around Seyitömer Thermic Powerhouse.

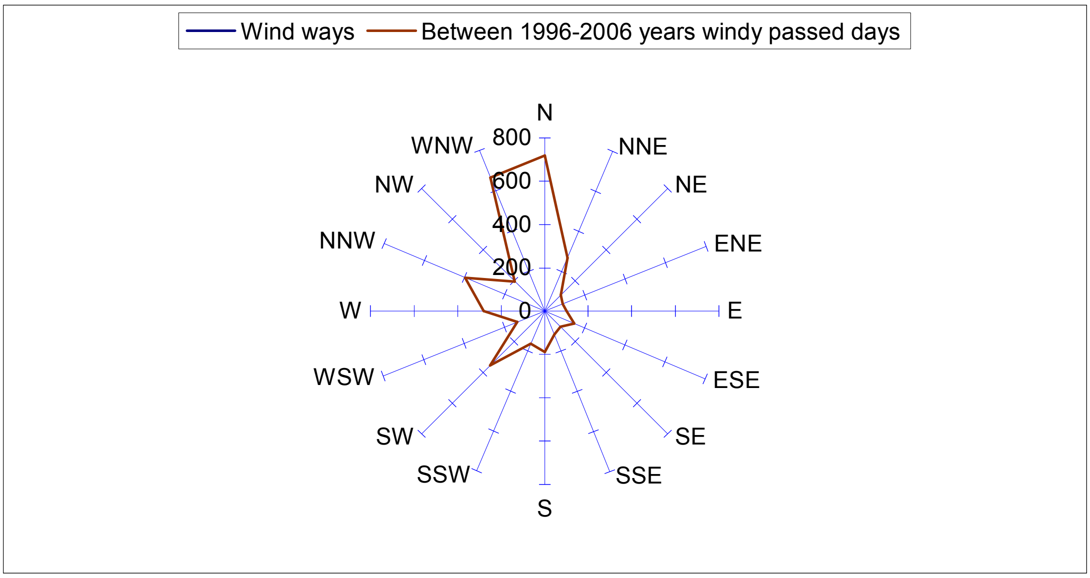

Figure 11. Graphic shows for ten years period time how many days wind blew to which way. Most of time wind blew between north and north-northwest directions.

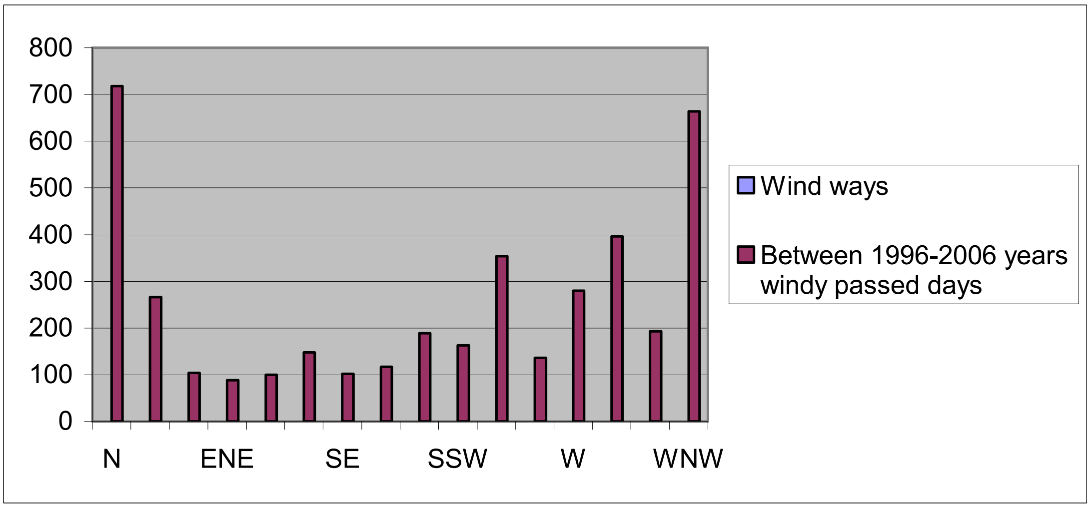

Figure 12. Bar graphic shows for ten years period time (1996-2006) how many days wind blew to which way.

Table 3. Between 1996 (first filters attached to thermic powerhouse) and 2006 years (samples collected from region in 2007 year) windy passed days.

Wind directions	Between 1996-2006 years windy passed days
N	718
NNE	266
NE	104
ENE	88
E	100
ESE	148
SE	102

SSE	117
S	189
SSW	163
SW	354
WSW	136
W	280
NNW	396
NW	193
WNW	664

Table 4. Natural radionuclide contents in soil in the world (UNSCEAR Survey of Natural Radiation Exposures).

Region / country	Population in 1996 (10^6)	Concentration in soil (Bq kg^{-1})							
		^{40}K		^{238}U		^{226}Ra		^{232}Th	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Africa									
Algeria	28.78	370	66–1 150	30	2–110	50	5–180	25	2–140
Egypt	63.27	320	29–650	37	6–120	17	5–64	18	2–96
North America									
Costa Rica	3.50	140	6–380	46	11–130	46	11–130	11	1–42
United States [M7]	269.4	370	100–700	35	4–140	40	8–160	35	4–130
South America									
Argentina	35.22	650	540–750						
East Asia									
Bangladesh	120.1	350	130–610			34	21–43		
China [P16, Z5]	1232	440	9–1 800	33	2–690	32	2–440	41	1–360
– Hong Kong SAR [W12]	6.19	530	80–1 100	84	25–130	59	20–110	95	16–200
India	944.6	400	38–760	29	7–81	29	7–81	64	14–160
Japan [M5]	125.4	310	15–990	29	2–59	33	6–98	28	2–88
Kazakstan	16.82	300	100–1 200	37	12–120	35	12–120	60	10–220
Korea, Rep. of	45.31	670	17–1 500						
Malaysia	20.58	310	170–430	66	49–86	67	38–94	82	63–110
Thailand	58.70	230	7–712	114	3–370	48	11–78	51	7–120
West Asia									
Armenia	3.64	360	310–420	46	20–78	51	32–77	30	29–60
Iran (Islamic Rep. of)	69.98	640	250–980			28	8–55	22	5–42
Syrian Arab Republic	14.57	270	87–780	23	10–64	20	13–32	20	10–32
North Europe									
Denmark [N5]	5.24	460	240–610			17	9–29	19	8–30
Estonia	1.47	510	140–1 120			35	6–310	27	5–59
Lithuania	3.73	600	350–850	16	3–30			25	9–46
Norway	4.35	850		50		50		45	
Sweden	8.82	780	560–1 150			42	12–170	42	14–94
West Europe									
Belgium	10.16	380	70–900			26	5–50	27	5–50
Germany	81.92		40–1 340		11–330		5–200		7–134
Ireland [M6]	3.55	350	40–800	37	8–120	60	10–200	26	3–60
Luxembourg	0.41	620	80–1 800			35	6–52	50	7–70
Netherlands [K2]	15.58		120–730		5–53	23	6–63		8–77
Switzerland	7.22	370	40–1 000	40	10–150	40	10–900	25	4–70
United Kingdom [B2]	58.14		0–3 200		2–330	37			1–180
East Europe									
Bulgaria	8.47	400	40–800	40	8–190	45	12–210	30	7–160
Hungary	10.05	370	79–570	29	12–66	33	14–76	28	12–45
Poland [F7]	38.60	410	110–970	26	5–120	26	5–120	21	4–77
Romania [I13]	22.66	490	250–1 100	32	8–60	32	8–60	38	11–75
Russian Federation	148.1	520	100–1 400	19	0–67	27	1–76	30	2–79
Slovakia	5.35	520	200–1 380	32	15–130	32	12–120	38	12–80
South Europe									
Albania	3.40	360	15–1 150	23	6–96			24	4–160
Croatia	4.50	490	140–710	110	83–180	54	21–77	45	12–65
Cyprus	0.76	140	0–670			17	0–120		
Greece	10.49	360	12–1 570	25	1–240	25	1–240	21	1–190
Portugal	9.81	840	220–1 230	49	26–82	44	8–65	51	22–100
Slovenia	1.92	370	15–1 410			41	2–210	55	2–90
Spain	39.67	470	25–1 650			32	6–250	33	2–210
Median		400	140–850	35	16–110	35	17–60	30	11–64
Population-weighted average		420		33		32		45	

Table 5. World natural radionuclide soil contents activity (Bq/kg) comparision with SeyitömerThermic Powerhouse region (UNSCEAR Survey of Natural Radiation Exposures).

Region	**Country**	**K-40 (Bq/kg)**		**U-238 + Th-232 (Bq/kg)**	
		Mean	Range	Mean	Range
Africa	Algeria	**370**	66-1150	**55**	4-250
	Egypt	**320**	29-650	**55**	8-216
North America	Costa Rica	**140**	6-380	**57**	12-172
	United States [M7]	**370**	100-700	**70**	8-270
South America	Argentina	**650**	540-750		
East Asia	Bangladesh	**350**	130-610		
	China [P16, Z5]	**440**	9-1800	**74**	3-1050
	– Hong Kong SAR [W12]	**530**	80-1100	**179**	41-330
	India	**400**	38-760	**93**	21-241
	Japan [M5]	**310**	15-990	**97**	4-147
	Kazakstan	**300**	100-1200	**97**	22-360
	Korea, Rep. of	**670**	17-1500		
	Malaysia	**310**	170-430	**148**	112-196
	Thailand	**230**	7-712	**165**	10-490
West Asia	Armenia	**360**	310-420	**76**	49-138
	Iran (Islamic Rep. of)	**640**	250-980	**22**	5-42
	Syrian Arab Republic	**270**	87-780	**43**	20-92
		Beta activity		**Alfa activity**	
West-Asia	Türkiye-Kütahya/Seyitömer	**7234**		**1913**	

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