MATH MODEL OF GRAIN SIZE DISTRIBUTION VERSUS RADON CONTENT OF WADI ARAR, KINGDOM OF SAUDI ARABIA

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Abstract- Comparing to other fractions, Coarse and fine sand is highly correlated with radon content with correlation coefficients of - 0.79 and 0.80 respectively. A polynomial of 3rd degree is the best math model representing the relation between the grain size content and it is correlated with radon content. At Coefficient of Determination, R^2 equal to 82%, the relation between grain size of coarse and fine sand and radon contents is fitted with polynomials of 3rd degree. Radon content can be deduced depending on the grain size distribution instead of direct measurement using the polynomial model that created. At the radon point of view and for safety purpose, gravel, coarse and medium sand and silt and clay are the best material for construction because of the negative or very weak correlation between them.

Keywords- grain size distribution, CR-39, Radon, soil classification, polynomial.

I. INTRODUCTION

Reference [1] wrote the name radon was assigned in 1923. Radon is a noble gas and is a progeny product of ^{226}Ra, which is one of the nuclides due to disintegration of ^{238}U series [2]. It is the second leading cause of lung cancer and a serious public health problem [3]. Reference [4] wrote that the high soil radon anomalies are connected with the presence of tectonic faults or fissures and earthquakes. Reference [5] published the first model of the effect of grain size on radon emanation. Reference [6] found weak correlations between the raw values of radon concentration, soil particle size fractions and elevation. Reference [7] observed that radon exhalation rate increases with an increase in grain size. Reference [2] found that the exhalation rate of radon increases with grain size of samples of stone dust and natural dust. Reference [8] found that soil composition and grain size have the strongest concentration of radon measured and he found both techniques that he used yield similar radon concentrations in well-sorted sands, but do not correlate as well for poorly sorted Soils and clays. Reference [9] used LR-115 type II solid-state nuclear track detectors (SSNTDs) and found that radon diffusion through some building materials, viz., soil, sand, fly ash, cement, etc. decreases with grain size. Based on the ‘‘macroscopic’’ soil models, the radon emanation fraction is markedly increased with grain sizes ranging from 10 to 100 mm and reaches a constant value of 50% when moisture content is 0% [10]. Reference [11] Found that evident enhancing of the radon exhalation rate with the decreasing dimension of the grains of volcanic sand. Reference [12] found that deposits of wadi Arar were silty sand (SM) according to the unified soil classification system. Reference [13] measured the radon content in silty sand soil using rad7 and Cr-39 techniques at Wadi Arar, Saudi Arabia.

The purpose of this work concerning to the creation of a math model for the disturbed and bulk samples that reflect the relations between grain sizes and radon contents in Wadi Arar, Saudi Arabia. Fig.1 show simple and organized diagram of the purpose and scope of this work.

II. METHODOLOGY

Thirty five disturbed samples were collected from seven locations in Wadi Arar, five from each location. The profiles of the location are denoted by A, B, C, D, E, F and G. Profile A is located in North East direction of Wadi Arar, which facing Arar city while Profile G located in South West direction which facing Aljouf city. The remaining five profiles B, C, D, E and F are located between A and G respectively (Alghamdi and Hejazy 2013). Fig. 1.

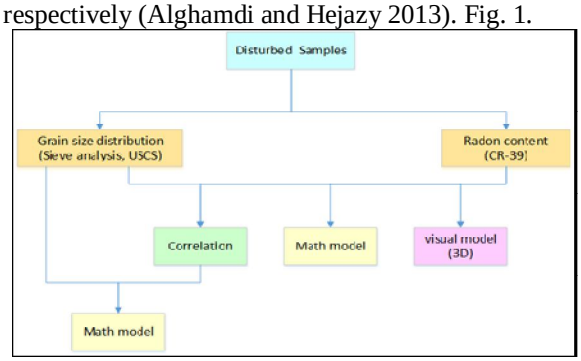


Fig. 1 Illustration diagram of the scope and purpose of the work.



Fig. 2 The locations of the seven profiles A, B, C, D, E, F and G along Wadi Arar (after Alghamdi and Hejazy, 2013).

III. DATA

The data of grain size distribution were extracted from Alghamdi and Hejazy, 2013 while the data of the radon content were extracted from Alghamdi and Diab 2016.

According to the available grain size data, the quantity percentages of gravel (G), coarse sand (CS), medium sand (MS), fine sand (FS) and silt and clay (SC) were calculated according to the unified soil classification system and tabulated in Table I.

Radon contents were measured in the bulk disturbed samples without sifting (i.e. Not in the fraction of each sieve) using the CR-39 technique (Alghamdi and Diab, 2016). For safety purpose the data of the maximum readings of radon contents were selected.

To increase the accuracy readings of standard deviation, σ and coefficient of variation, CV%, the maximum reading of radon content (Rn) Bq/m^3, was recalculated using harmonic means while grain size content was calculated using geometric means Table I.

Geometric means reflect that silt& clay represents the most fraction content percentage while coarse sand represent the lowest fraction content percentage with values of 28.73 and 12.17 respectively. According to the result of σ & CV% The fine sand reflects the best equality of distribution through the study area while gravel reflect the most fluctuated distribution with values of 1.62 and 8.0 and 7.68 and 47.14 respectively.

Fig. 3 show 3D plotting of grain content %, radon content Bq/m^3 for each fraction at different locations. The most easily discriminated concerning to the positive relation between radon content and location, which increase from A to G or 1 to 7.

Table 1: Max radon content, (Rn) "Bq/m^3", grain content % for gravel (G), coarse sand (CS), medium sand (MS), fine sand (FS) and silt and clay(SC), Mean, standard deviation (σ) and coefficient of variation (CV%).

Profiles	Max Rn	G	CS	MS	FS	SC
A	32	19.23	13.82	22.55	19.63	24.77
B	35	10.57	14.63	27.91	18.98	27.91
C	37	16.20	15.49	22.56	18.01	27.74
D	40	13.13	13.10	20.71	19.88	33.18
E	41	9.77	10.98	17.29	20.56	41.40
F	44	31.62	7.57	20.56	20.45	19.80
G	48	11.22	9.91	24.68	23.20	30.99
Mean	38.93	16.29	12.17	22.49	20.32	28.73
σ	5.44	7.68	2.84	3.37	1.62	6.82
CV%	13.98	47.14	23.33	14.97	8.00	23.74

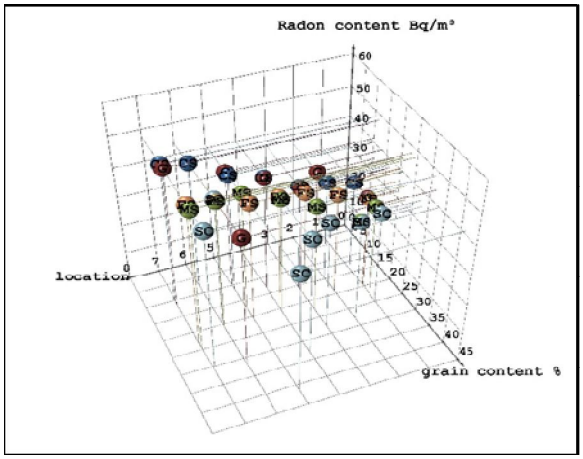


Fig. 3 3D plotting of Radon content, grain content and location

IV. CORRELATION

To detect and compare the strength and direction of the linear relationship between grain size distributions and radon content, the correlation coefficients (r), were calculated and plotted in Fig. 4.

It was observed a strong negative correlation coarse sand and strong positive with fine sand, with values of -0.79 and 0.80 respectively. Otherwise It was found a weak correlation with gravel, medium sand and silt and clay. At coefficient of determination, R^2 equal to 0.99, a polynomial relation of 3rd degree between grain size fraction and their correlations as shown in Fig. 4. According to the strong correlation results, a plotting of 3D was created to show another vision of the relation, which observed that a coarse sand reflect a negative relation with radon content and fine sand while the fine sand reflect the positive relation with radon content.

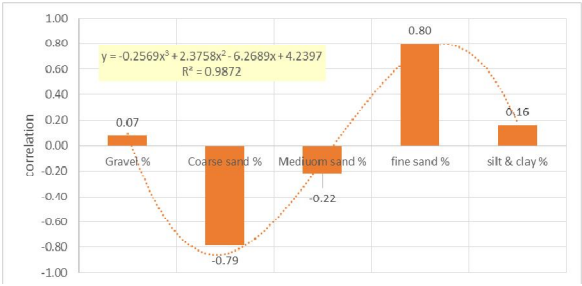


Fig. 4 Correlation between radon content and different fraction of grain size.

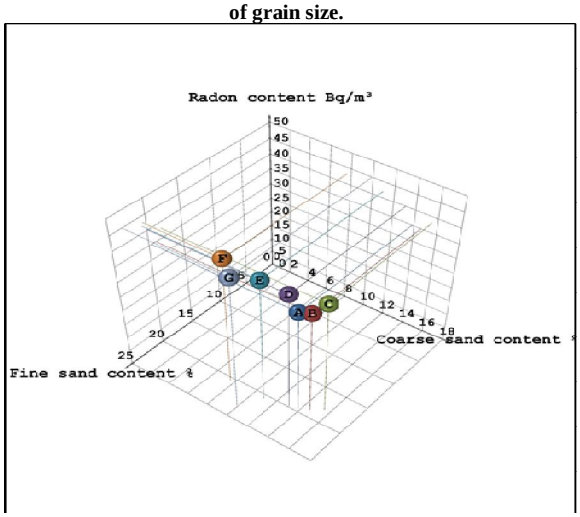


Fig. 5 3D plotting of Radon content, coarse sand and fine sand.

In case of using the cumulative percent finer curve instead of the content of each fraction, it was found the relation between grain size distribution and its correlation with radon contents reflects a 4th degree polynomial in the grain size as shown in Fig. 6.

V. REGRESSION

The data that represent the relation between radon content and each fraction of grain size was plotted, then the trendline that represent the best fit of the data was formatted at different type of functions such as linear, logarithmic, power and polynomial. According to the values of the coefficient of determination (R^2), the relations between radon content and grain size classified into three clusters of polynomial relations Table II and Fig. 7.

Good relation that include coarse and fine sand which have the highest values of R^2 at different polynomial degrees. Medium relation that includes medium sand and silt and clay which reflect high R^2 values at 4^{th} or higher degree of polynomial. Weak relation that include gravel fraction only which include the lowest values of R^2.

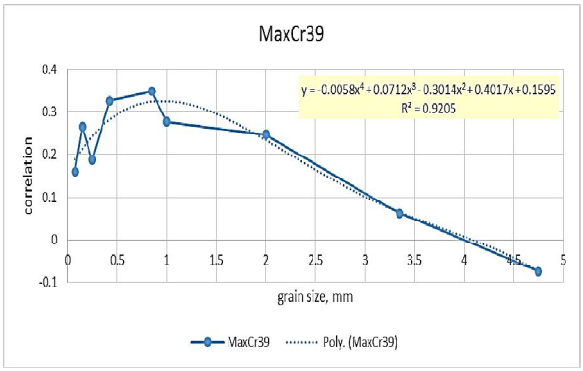


Fig. 6 Correlation between radon content and grain size.

Table II Coefficient of determination (R^2) at different degree of polynomial.

Degree	1	2	3	4	5
gravel	5.3	37.7	54.1	55	55
coarse sar	62.1	63.2	82.8	82.9	88.2
medium s	4.6	5.1	14.3	90.9	93.4
fine sand	63.5	65	82.2	82.5	99.2
silt & clay	2.6	7	57.1	75.9	97.9

Figs 8-13 represent the plotting of relation of some polynomial degrees for different fractions, totally or separated. While the equations 1-5 represent the best selected equation to represent the relation between radon content and grain size content for each fraction type as follow:

Gravel:

$$y = 0.0161x^3 - 0.8893x^2 + 14.402x - 30.85 \quad (1)$$

Coarse sand:

$$y = 0.1728x^3 - 6.0451x^2 + 66.862x - 190.54 \quad (2)$$

Medium sand:

$$y = -0.1015x^4 + 9.0967x^3 - 302.85x^2 + 4436.2x - 24077 \quad (3)$$

Fine sand:

$$y = -0.9022x^3 + 55.683x^2 - 1137.4x + 7731.2 \quad (4)$$

Silt and clay:

$$y = 0.0035x^4 - 0.4337x^3 + 19.854x^2 - 394.81x + 2909.8 \quad (5)$$

Where

Y represent radon contents in Bq/m^3

X Grain size fraction percentage.

Finally and according to the polynomial relation, it can deduce the radon content in Wadi Arar depending on that plotted graphs or that deduced equation instead of measure radon directly. Otherwise and according to correlations It can select the material of construction that include negative or weak correlation, such as gravel, coarse and medium sand and silt and clay.

VI. CONCLUSIONS

1- A polynomial is the best model to simulate the relation between grain size and radon content.

2- Coarse sand has a highly negative correlation with radon content.

3- Fine sand has a highly positive correlation with radon content.

4- The relation between gravel and radon content is the least representative of a relation using a polynomial math model.

5- At 5^{th} degree polynomial, the coefficient of determination (R^2) equal to 99, 98, 93, 88 and 55 for fine sand, silt and clay, medium sand, coarse sand and gravel respectively.

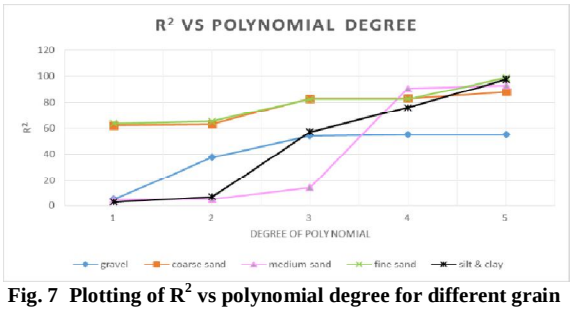


Fig. 7 Plotting of R^2 vs polynomial degree for different grain fraction

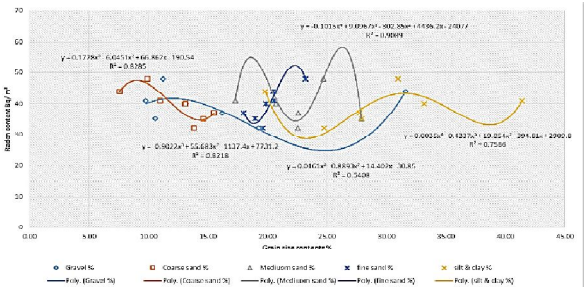


Fig. 8 Nonlinear relationship between radon content and grain size content for different fraction.

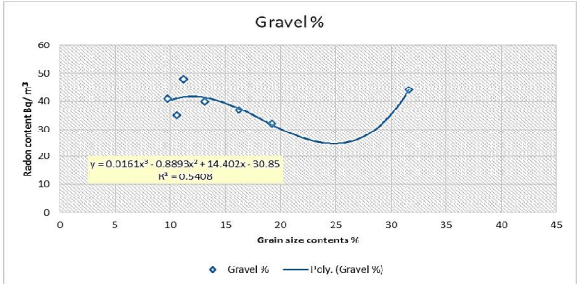


Fig. 9 Polynomial relation of radon content and grain size content for gravel fraction.

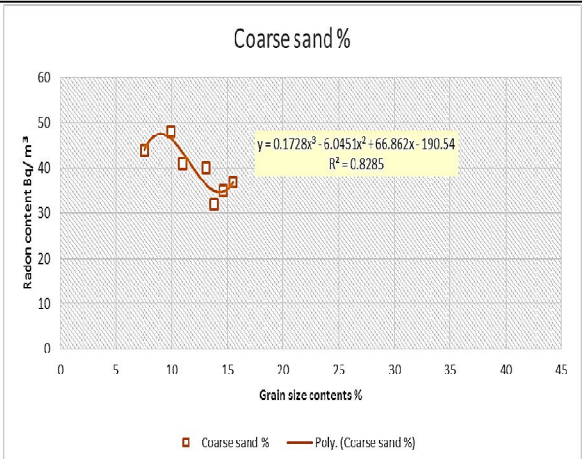


Fig. 10 Polynomial relation of radon content and grain size content for coarse sand fraction.

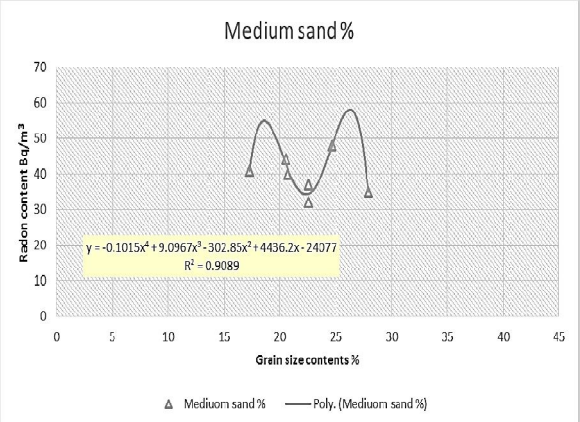


Fig. 11 Polynomial relation of radon content and grain size content for medium sand fraction.

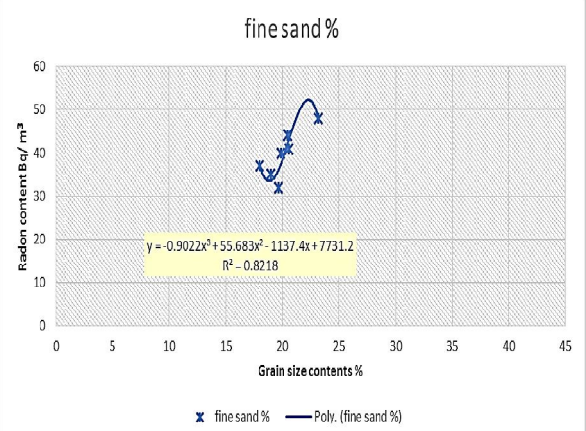


Fig. 12 Polynomial relation of radon content and grain size content for fine sand fraction.

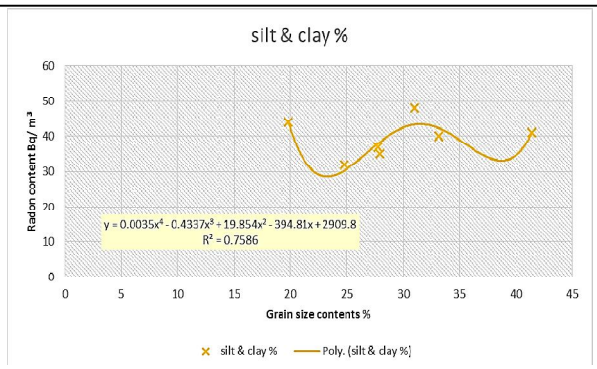


Fig. 13 Polynomial relation of radon content and grain size content for silt & clay fraction.

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