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## Feasibility study of Improvement Experimental Measurement and Thermodynamic Modelling of Contaminants Effect on the Thermo-Mechanical Properties of Industrial Petroleum recycled plastics wastes

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### Article Info

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### Abstract

The recycled plastics (RHDPE and RLDPE) were exposed to environment conditions for many years. Also the chemical contaminants had effects on the thermo-mechanical and other properties of these wastes. Then a weathering effect data is examined for both Iraqi and Foreign wastes on the thermo-mechanical and chemical properties (Tensile strength, modulus, elongation, impact and permeability). The different mathematical software model were applied to analysis these weathering – properties data in order to estimate which one or several among these properties had more effective by these weathering conditions such as (concentration of contaminant, time, temperature, thickness of specimen, length of spectra, basic property).

The results shows that a multi-polynomial model has a best fit for most or several of properties to active weathering variables, also gave a vary residual and deviation than experimental analyzed data for both sources of wastes Iraqi and Foreign RHDPE and RLDPE.

Also the results for thermo-mechanical and chemical properties prove that both tensile strength and modulus of elasticity thermo-mechanical properties and permeability / length of spectra chemical property were given a high quality of correction and fitting factor from 93-99 %, with less deviation and residual function was produced.

And the results of RHDPE gave a best fit than RLDPE for most of checked analysis properties (thermo-mechanical and chemical properties).

**Keywords:** Tensile strength; Modulus; Elongation; Permeability; RHDPE; RLDPE

### Introduction

Recycling is an expanding area of chemical industry in general, plastic recycling and waste management in particular is being closely being examined in academic commercial organizations and governmental institutions. Finding suitable solutions could lead to the recycling of potentially hazardous materials on the other hand production of acceptable commercial products with little or no outlay in raw material. A precursor to recycling is to understand the effects of chemical contaminants on the properties of both RHDPE and RLDPE eventually how these effects can be overcome to successfully reuse contaminated RHDPE and RLDPE [1].

However in the regeneration process some questions have still not been resolved, such as: the sorting of the plastics with optimal purity over cost ratio, their cleaning, the characterization of the regenerated product before it is sold, and the market for the

recycled products. Both the sorting and characterization of the polymer are obligatory steps of the recycling process: the first because the recycling blends of polymer does not lead to satisfactory products and the second, because the final user of the regenerated material must be informed of the real quality of the product you buys [1]. All the more as it might be hazardous to re-use some blends such as PVC and PET blends [1,3].

RHDPE and RLDPE consumption continuous to grow annually, with products substitution and potential new applications increasing volume sales growth. Such as pipes segments, bottles of pipsi and milk. Where HDPE substitution into juice and milk packaging market is likely to continue as high density bottles replace glass and Tetra-Pak bricks. For replacing metals in automotive fuel tank, metal cans, large industrial container and house hold fuel tanks is also likely to support HDPE and LDPE demand in the coming years [1,2,4].

Some authors were studied the change in mechanical properties of R-polyethylene after exposure to artificial weathering [5-10]. Others were proposed a mathematical model to predict the behavior of Thermo-mechanical properties of LDPE [11]. In the other hand many of researchers were studied the effect of many stabilizers on the structure and thermo-mechanical properties of LDPE [12,13].

Apparently, studied of literature review indicated that many of inorganic pigments such as Iron oxides, Chromic oxides and Titanium oxide are widely used as stabilizer in plastic industry (HDPE and LDPE) [14,15,16].

### Aim of the Present Work

The use of recycled plastics in packaging is growing around 14 %, as year as a result of increased demand and collection growth of recycled materials is due to both legislative mandate and technology advancements.

An interesting sorting characterization data for this study was used to compare the effect of chemical contaminates and other weathering variables (time of aging, temperature, thickness of specimen, length of spectra, basic property) on the analyzing Thermo-mechanical and chemical properties (tensile strength, modulus of elasticity, impact strength, elongation, permeability) from both type of sources Iraqi and Foreign polyethylene wastes (RHDPE and RLDPE).

Also state which one or several of these sorting and characterization properties had more effects by the above weathering conditions. Then design a mathematical models for the analyzing properties with more economical, fitting and applicable, also with high quality for correction factor and less residual and deviation between experimental and theoretical one.

On the other hand state which one or several analysis properties were used to specify and modify these wastes in an industrial process applications.

### Theoretical background data

The Thermo-mechanical and chemical properties for both polyethylene wastes (RHDPE and RLDPE) data had been

studied at different weathering conditions (concentration of chemical contaminant, temperature, time of aging, thickness of specimen, length of spectra and basic property) with a great detail.

As a result, a variety of available software models were used to analysis and describe these properties / weather conditions (tensile strength, modulus of elasticity, Impact strength, and elongation) for Thermo-mechanical properties / concentration of contaminants, time, basic property and chemical properties / time, concentration of contaminates, thickness of specimen, length of spectra. By the use of experimental data produced from Iraqi and Foreign waste of RHDPE and RLDPE. In order to arrive an optimal software model with best fitting and less deviations between all properties data from both type of sources Iraqi and Foreign RHDPE and RLDPE.

Then related a comparison and mixing model between Iraqi and Foreign PE wastes to give an accurate, simplest and best fitting software model, also stated which of these sorting properties was the basic and specify property for modification these wastes and re-use them in different industrial process applications [17-23].

## Experimental Program

### Materials

The source data for Thermo-mechanical and chemical properties of both RHDPE and RLDPE wastes produced by Iraqi and Foreign researchers. Also the source of both RHDPE and RLDPE wastes were collected from local waste bottles for Iraqi and bottles of both Pipsi and milk for foreign one. Then a modern modeling software programming were use and updating continuously from a web site Internet system. To gave an economic and simples model to analysis these sorting properties / weathering condition from both sources of PE wastes Iraqi and Foreign.

### Procedures

The case problem was a negative effect of hazard polyethylene wastes on the environment and public-health than a theoretical software programs were used to study the effect of different weathering conditions (concentration of contaminate, temperature, time of aging, thickness of specimen, length of spectra, and basic property) on both Thermo-mechanical properties (tensile strength, modulus of elasticity, impact strength, and elongation) and chemical property of permeability to design an optimum software model collect and mixing these effects on both PE wastes (RHDPE and RLDPE) from both sources Iraqi and Foreign (Figures 1-4).

And this experimental program was achieved by several steps: firstly, classified a details data in two cases Thermo-mechanical and chemical properties for both Iraqi and Foreign PE waste (RHDPE and RLDPE). Secondly, sketched the experimental data details as a comparison between Iraqi and Foreign source data properties from both PE wastes (RHDPE and RLDPE) (Tables 1, 2, 3).

Table 1. shows the coefficients values for optimum model of tensile strength for both rhdppe and rldpe wastes.

Coefficient	Value	
	RHDPE	RLDPE
a	17.730	13.55
b	1.109	1.194
c	$1 \times 10^{11}$	$-1 \times 10^{11}$
d	$-5.109 \times 10^{-2}$	$-1.4 \times 10^{-2}$
e	$-1 \times 10^9$	$1 \times 10^9$
f	$9.254 \times 10^{-4}$	$1.73 \times 10^{-3}$
g	$1.736 \times 10^{-3}$	$6.07 \times 10^{-3}$
h	$2.7 \times 10^6$	$-4.07 \times 10^6$
i	$2.2 \times 10^{-6}$	$-1.14 \times 10^{-5}$
j	$-5.8 \times 10^{-6}$	$-6.98 \times 10^{-5}$
R <sup>2</sup>	0.9749	0.9559
V (%)	97.49	95.59

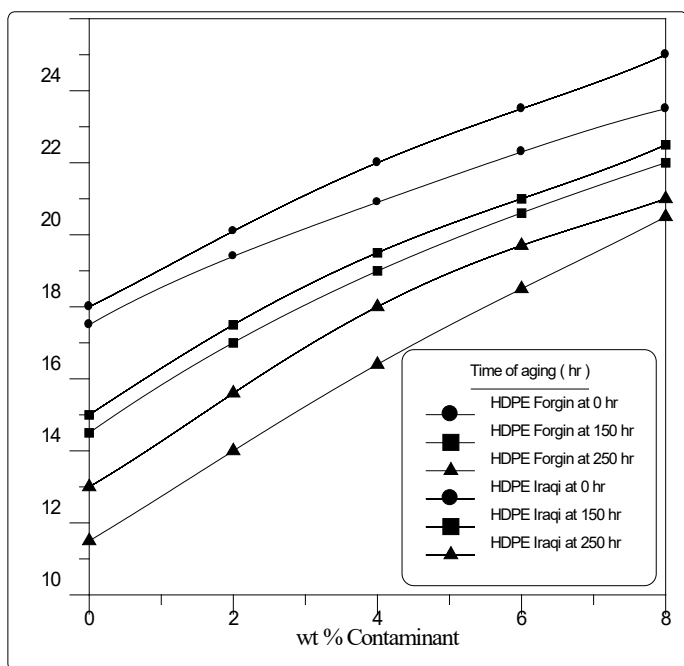


Figure 1. The Experimental Data for Tensile strength properties for RHDPE

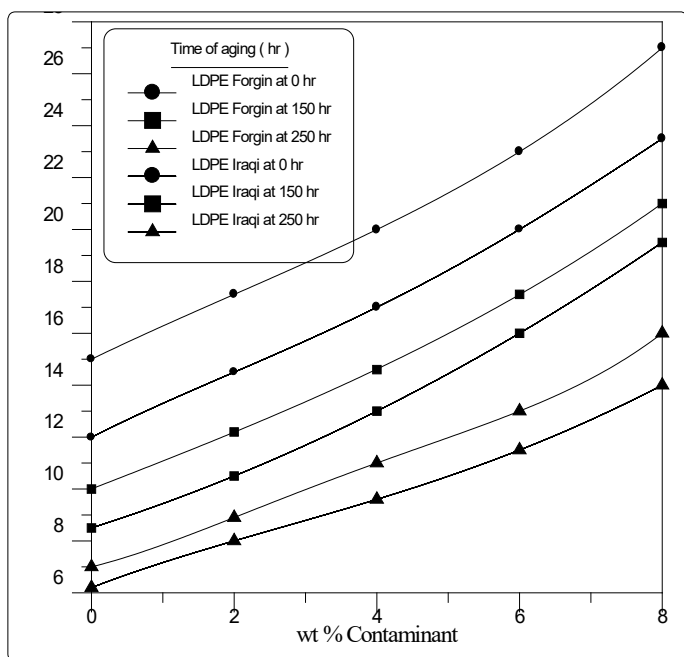


Figure 2. Shows the experimental data for RLDPE

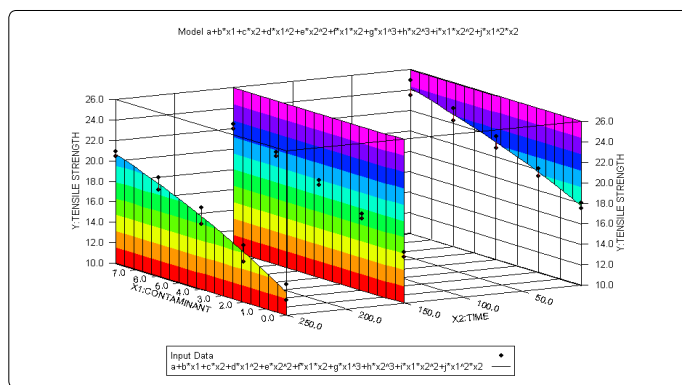


Figure 3. Indicate the theoretical fit model data for RHDPE

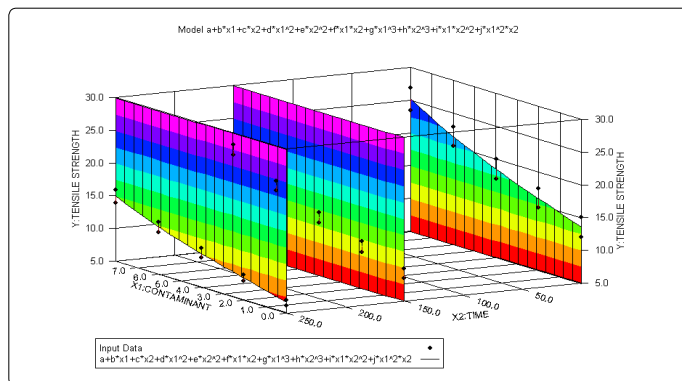


Figure 4. Indicate a theoretical model data for RLDPE of both Iraqi and Foreign waste

Table 2. Shows the results of fitting optimum model for tensile strength property of RHDPE.

X <sub>1</sub>	X <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
0	0	17.5	17.73121	-0.23121
2	0	19.4	19.75937	-0.35937
4	0	20.9	21.46209	-0.56209
6	0	22.3	22.9227	-0.6227
8	0	23.5	24.22458	-0.72458
0	150	14.5	14.8208	-0.3208
2	150	17	17.1949	-0.1949
4	150	19	19.17263	-0.17263
6	150	20.6	20.83811	-0.23811
8	150	22	22.27397	-0.27397
0	250	11.5	12.18408	-0.68408
2	250	14	14.90293	-0.90293
4	250	16.4	17.17996	-0.77996
6	250	18.5	19.09672	-0.59672
8	250	20.5	20.73719	-0.23719
0	0	18	17.73121	0.268791
2	0	20.1	19.75937	0.340629
4	0	22	21.46209	0.537913
6	0	23.5	22.9227	0.577295
8	0	25	24.22458	0.775423
0	150	15	14.8208	0.179199
2	150	17.5	17.1949	0.305102
4	150	19.5	19.17263	0.327369
6	150	21	20.83811	0.161892
8	150	22.5	22.27397	0.226029
0	250	13	12.18408	0.815918
2	250	15.6	14.90293	0.697072
4	250	18	17.17996	0.820041
6	250	19.7	19.09672	0.603282
8	250	21	20.73719	0.262809

Table 3. Shows the results of fitting optimum model for tensile strength property of RLDPE.

$x_1$	$x_2$	$Y_{prop.}$	$Y_{cal.}$	Res.
0	0	15	13.55244	1.44756
2	0	17.5	15.93111	1.568893
4	0	19.99	18.4831	1.506904
6	0	23	21.49993	1.500075
8	0	27	25.27311	1.726889
0	150	10	9.122803	0.877197
2	150	12.2	11.46615	0.733852
4	150	14.6	13.89906	0.700942
6	150	17.5	16.71353	0.786474
8	150	21	20.19984	0.800165
0	250	7	6.666016	0.333984
2	250	8.9	8.413554	0.486446
4	250	11	10.1953	0.804704
6	250	13	12.3003	0.699696
8	250	16	15.02252	0.977476
0	0	11.99	13.55244	-1.56244
2	0	14.5	15.93111	-1.43111
4	0	17	18.4831	-1.4831
6	0	20	21.49993	-1.49993
8	0	23.5	25.27311	-1.77311
0	150	8.5	9.122803	-0.6228
2	150	10.5	11.46615	-0.96615
4	150	13	13.89906	-0.89906
6	150	16	16.71353	-0.71353
8	150	19.5	20.19984	-0.69984
0	250	6.2	6.666016	-0.46602
2	250	8	8.413554	-0.41355
4	250	9.6	10.1953	-0.5953
6	250	11.5	12.3003	-0.8003
8	250	14	15.02252	-1.02252

Table 4. The coefficients values for fitted impact property model for both wastes (RHDPE and RLDPE).

Coefficient	Value	
	RHDPE	RLDPE
a	0.215	0.13
b	$-1.34 \times 10^{-2}$	$-5.6 \times 10^{-3}$
c	$-4.7 \times 10^8$	$-2.6 \times 10^9$
d	$5.6 \times 10^{-4}$	$-2.3 \times 10^{-4}$
e	$5 \times 10^6$	$2.7 \times 10^7$
f	$2.85 \times 10^{-5}$	$1.39 \times 10^{-5}$
g	-1.77	$1.37 \times 10^{-5}$
h	$-1.2 \times 10^4$	$-6.9 \times 10^9$
i	$7.95 \times 10^{-9}$	$-8.8 \times 10^{-8}$
j	$-1.59 \times 10^{-6}$	$2.56 \times 10^{-7}$
R <sup>2</sup>	0.97106	0.30047
V (%)	97.106	30.047

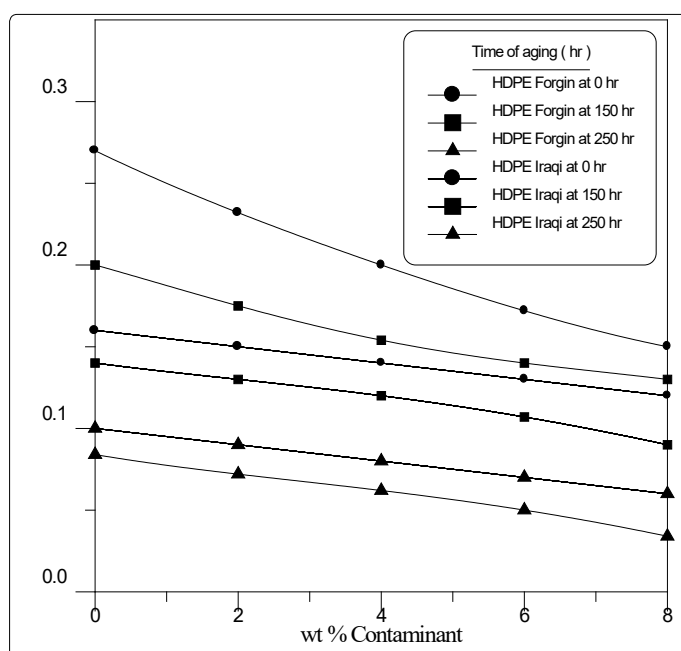


Figure 5. Indicate the Experimental data for both Iraqi and Foreign RHDPE wastes

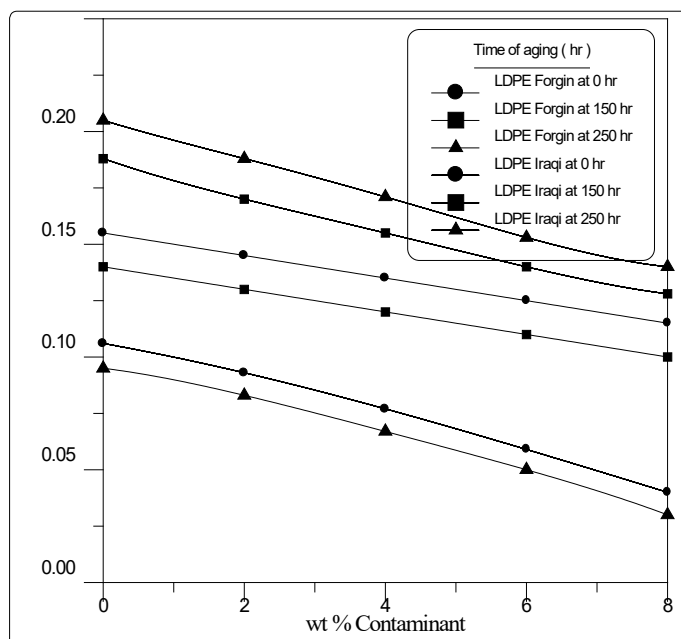


Figure 6. Indicate the Experimental available data for RHDPE both Iraqi and Foreign source for impact property.

### Thermo-mechanical Impact Strength Property

The experimental data for both PE wastes (RHDPE and RLDPE) indicated that an increasing in the concentration of contaminates cause a decreasing of impact strength values at different time of aging with higher deviation between result at 250 hr, also the values of this property was higher for Foreign source in RHDPE waste and Iraqi source for RLDPE one as shown in (Figures 5, 6).

Afterward an application of different software model program were achieved for both waste types (RHDPE and RLDPE) and sources (Iraqi and Foreign), which gave an optimum multi-polynomial software model of high correction factors for RHDPE 79% and low correction factor for RLDPE 30% and less deviation and residual for RHDPE and RLDPE at range (0.008-0.02) % as shown in (Figures 7, 8). The results of coefficients values and other fitting results were shown in (Tables 1, 2, 3). The modeling results indicated that large difference between two types of wastes (RHDPE and RLDPE) and had a same effect between two sources (Iraqi and Foreign) as in (Tables 4, 5, 6).

Table 5. Shows the fitting results data for RHDPE wastes.

x <sub>1</sub>	x <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
0	0	0.27	0.215364	0.054636
2	0	0.232	0.190663	0.041337
4	0	0.2	0.169607	0.030393
6	0	0.172	0.151343	0.020657
8	0	0.15	0.135022	0.014978
0	150	0.2	0.169453	0.030547
2	150	0.175	0.152717	0.022283
4	150	0.154	0.137716	0.016284
6	150	0.14	0.1236	0.0164
8	150	0.13	0.109517	0.020483
0	250	0.084	0.092186	-0.00819
2	250	0.072	0.081157	-0.00916
4	250	0.062	0.070594	-0.00859
6	250	0.05	0.059639	-0.00964
8	250	0.034	0.04744	-0.01344
0	0	0.16	0.215364	-0.05536
2	0	0.15	0.190663	-0.04066
4	0	0.14	0.169607	-0.02961
6	0	0.13	0.151343	-0.02134
8	0	0.12	0.135022	-0.01502
0	150	0.14	0.169453	-0.02945
2	150	0.13	0.152717	-0.02272
4	150	0.12	0.137716	-0.01772
6	150	0.107	0.1236	-0.0166
8	150	0.09	0.109517	-0.01952
0	250	0.1	0.092186	0.007814
2	250	0.09	0.081157	0.008843
4	250	0.08	0.070594	0.009406
6	250	0.07	0.059639	0.010361
8	250	0.06	0.04744	0.01256

Table 6. Shows the fitting results data for RLDPE wastes.

x <sub>1</sub>	x <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
0	0	0.155	0.130913	0.024087
2	0	0.145	0.118843	0.026157
4	0	0.135	0.105557	0.029443
6	0	0.125	0.091715	0.033285
8	0	0.115	0.077975	0.037025
0	150	0.14	0.16272	-0.02272
2	150	0.13	0.150982	-0.02098
4	150	0.12	0.138347	-0.01835
6	150	0.11	0.12546	-0.01546
8	150	0.1	0.112979	-0.01298
0	250	0.095	0.150803	-0.0558
2	250	0.083	0.134872	-0.05187
4	250	0.067	0.118249	-0.05125
6	250	0.05	0.101559	-0.05156
8	250	0.03	0.085474	-0.05547
0	0	0.106	0.130913	-0.02491
2	0	0.093	0.118843	-0.02584
4	0	0.077	0.105557	-0.02856
6	0	0.059	0.091715	-0.03272
8	0	0.04	0.077975	-0.03797
0	150	0.188	0.16272	0.02528
2	150	0.17	0.150982	0.019018
4	150	0.155	0.138347	0.016653
6	150	0.14	0.12546	0.01454
8	150	0.128	0.112979	0.015021
0	250	0.205	0.150803	0.054197
2	250	0.188	0.134872	0.053128
4	250	0.171	0.118249	0.052751
6	250	0.153	0.101559	0.051441
8	250	0.14	0.085474	0.054526

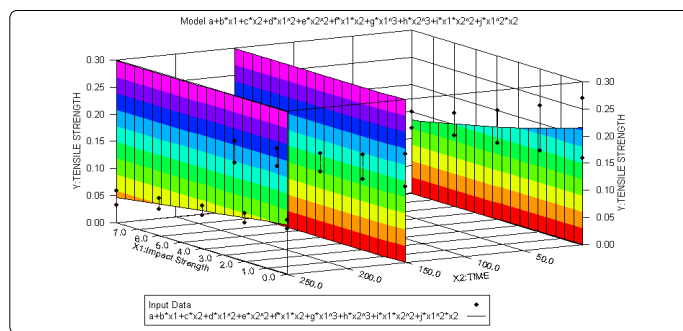


Figure 7. Indicate the model fitted data for impact strength property for both Iraqi and Foreign (RHDPE) due to best fit property tensile strength.

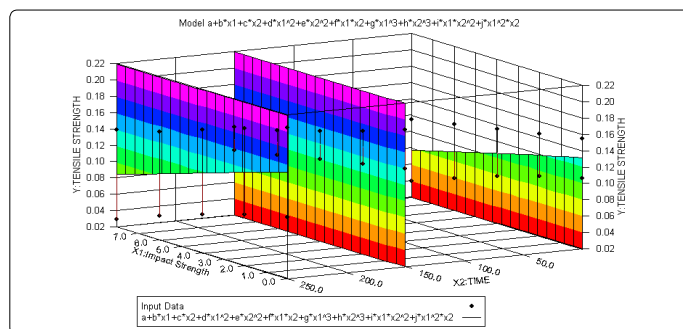


Figure 8. The Fit model for Recycling LDPE of both sources Iraqi and Foreign at constant optimum temperature (50°C) with respect to base fitting tensile strength

**Thermo-mechanical modulus of elasticity Property**

The experimental data for both PE wastes (RHDPE and RLDPE) stated that an increasing of contaminates concentration was caused an increasing in values of above modulus property for different a range of aging exposure time (0, 150, 250) hr, with a little deviation in values from both sources Iraqi and Foreign at higher level of aging 250 hr for RHDPE and the normalized results for RLDPE wastes, as shown in (Figures 9, 10). Also the experimental data shows high values of modulus for Foreign RHDPE and Iraqi RLDPE wastes.

Then an introducing of these data were achieved in order to optimize an suitable modeling software program function that would give a high quality best fitting results (correction factor, deviation, and coefficients), also to examine if the analyzed property was a basic one for others (Thermo-mechanical property), then a best fitting occurred for the applied data above as shown in (Figures 11, 12). And tables 7, 8, 9 show the results of this fitting.

Table 7. The coefficients of best fit model from both PE wastes.

Coefficient	Value	
	RHDPE	RLDPE
a	62.12	65.328
b	7.836	2.464
c	-4.358*10 <sup>11</sup>	5*10 <sup>11</sup>
d	0.396	0.734
e	4.649*10 <sup>9</sup>	-5.335*10 <sup>9</sup>
f	-0.012	4.96*10 <sup>-2</sup>
g	-1.753	1.749*10 <sup>-3</sup>
h	-1.162*10 <sup>7</sup>	1.333*10 <sup>7</sup>
i	2.5*10 <sup>-5</sup>	-9.801*10 <sup>-5</sup>
j	-7.84*10 <sup>-4</sup>	-2.988*10 <sup>-3</sup>
R <sup>2</sup>	0.93164	0.98177
V (%)	93.164	98.177

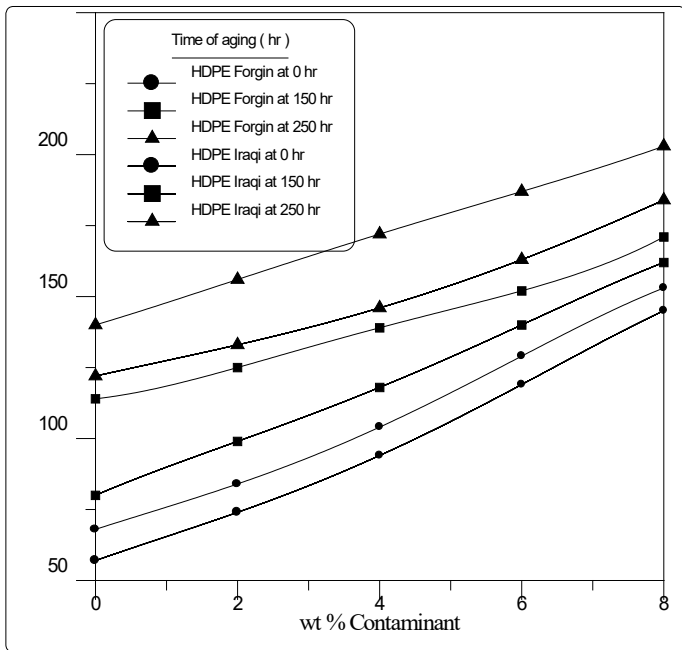


Figure 9. Indicate the Experimental available data for both Iraqi and Foreign RHDPE wastes

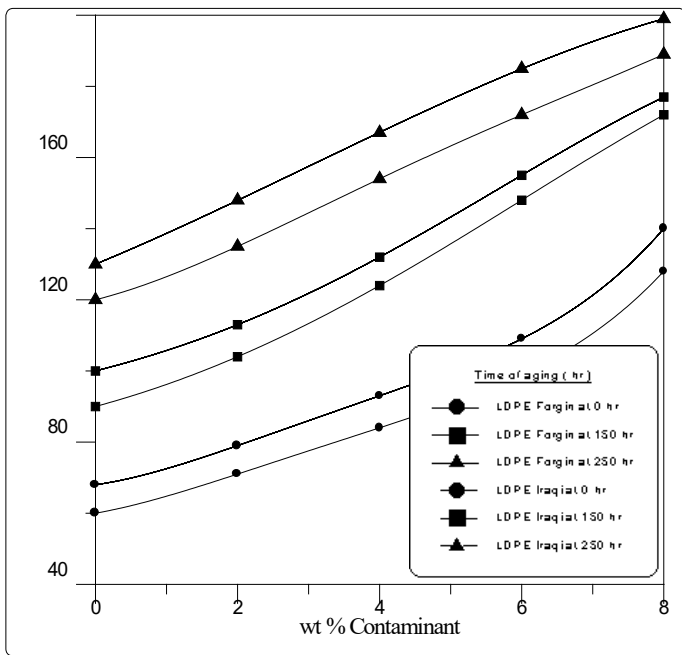


Figure 10. Shows the Experimental Data for both source Iraqi and Foreign of RLDPE.

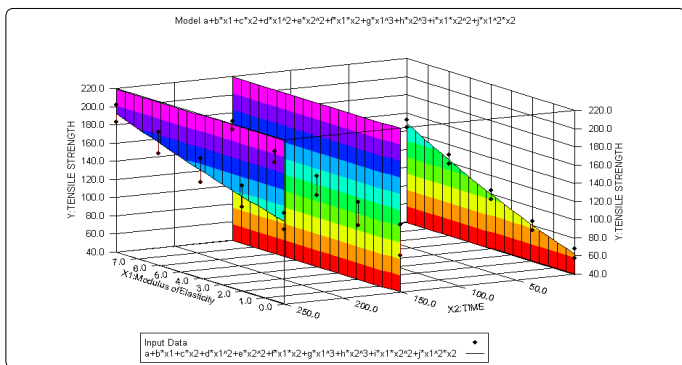


Figure 11. Indicate the Model Data for Modulus of Elasticity property for both source Iraqi and Foreign wastes for (RHDPE) due to base Tensile Strength property.

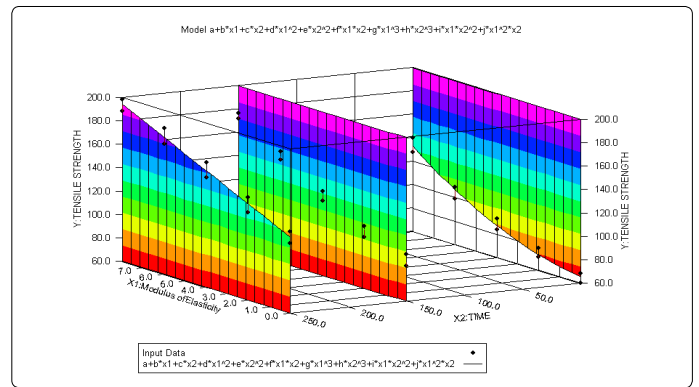


Figure 12. Indicate the results model for both source Iraqi and Foreign RLDPE for Modulus property due to base Tensile Strength property.

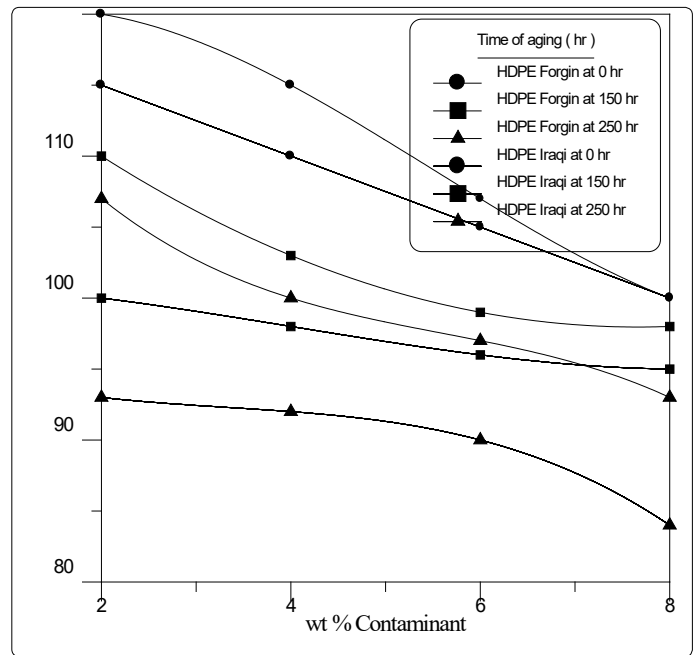


Figure 13. Indicate the Experimental Data for RHDPE

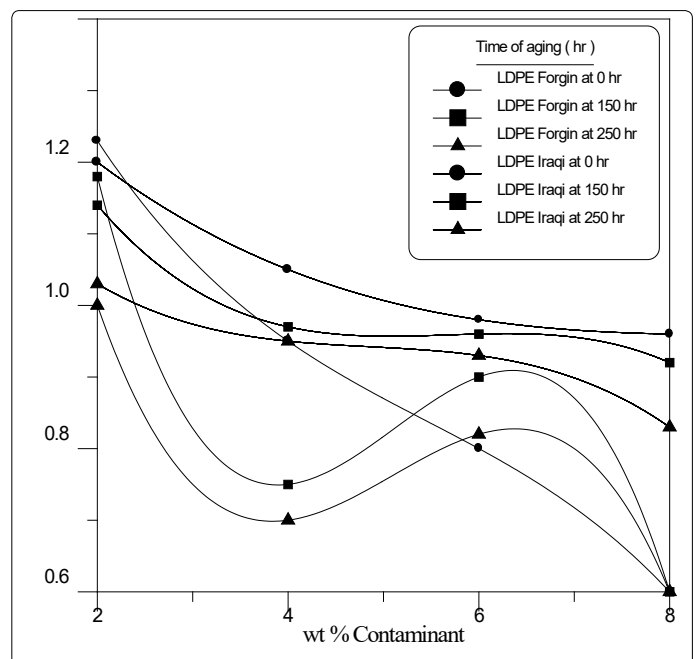


Figure 14. Indicate the Experimental Data for RLDPE

Table 8. Shows the results of fitting data for RHDPE model modulus property.

$x_1$	$x_2$	$Y_{prop.}$	$Y_{cal.}$	Res.
0	0	68	62.12031	5.87969
2	0	84	79.36443	4.635568
4	0	104	99.69621	4.303786
6	0	129	123.0315	5.968523
8	0	153	149.286	3.713955
0	150	114	97.48047	16.51953
2	150	125	111.6364	13.36364
4	150	139	127.9383	11.0617
6	150	152	146.3023	5.697703
8	150	171	166.6463	4.353671
0	250	140	130.9531	9.046875
2	250	156	144.2989	11.70106
4	250	172	159.1626	12.83742
6	250	187	175.4659	11.53408
8	250	203	193.1191	9.88088
0	0	57	62.12031	-5.12031
2	0	74	79.36443	-5.36443
4	0	94	99.69621	-5.69621
6	0	119	123.0315	-4.03148
8	0	145	149.286	-4.28604
0	150	80	97.48047	-17.4805
2	150	99	111.6364	-12.6364
4	150	118	127.9383	-9.9383
6	150	140	146.3023	-6.3023
8	150	162	166.6463	-4.64633
0	250	122	130.9531	-8.95313
2	250	133	144.2989	-11.2989
4	250	146	159.1626	-13.1626
6	250	163	175.4659	-12.4659
8	250	184	193.1191	-9.11912

Table 9. Shows the results of fitting data for RLDPE model Modulus property.

$x_1$	$x_2$	$Y_{prop.}$	$Y_{cal.}$	Res.
0	0	60	65.32862	-5.32862
2	0	71	73.21115	-2.21115
4	0	84	87.05481	-3.05481
6	0	99	106.9436	-7.9436
8	0	128	132.9615	-4.96151
0	150	90	93.54297	-3.54297
2	150	104	110.1046	-6.10463
4	150	124	129.042	-5.04205
6	150	148	150.4382	-2.43823
8	150	172	174.3772	-2.37715
0	250	120	124.9492	-4.94922
2	250	135	142.3997	-7.39971
4	250	154	159.8342	-5.8342
6	250	172	177.3347	-5.33473
8	250	189	194.9833	-5.98332
0	0	68	65.32862	2.671377
2	0	79	73.21115	5.788852
4	0	93	87.05481	5.945188
6	0	109	106.9436	2.056398
8	0	140	132.9615	7.038495
0	150	100	93.54297	6.457031
2	150	113	110.1046	2.895369
4	150	132	129.042	2.957952
6	150	155	150.4382	4.561772
8	150	177	174.3772	2.622846
0	250	130	124.9492	5.050781
2	250	148	142.3997	5.600294
4	250	167	159.8342	7.165801
6	250	185	177.3347	7.665272
8	250	199	194.9833	4.016676

### Thermo-Mechanical Elongation Property

The experimental data for PE wastes (RHDPE and RLDPE) showed that a decreasing in elongation at increasing both weathering variables (concentration of contaminants and time of aging) with preference for Foreign RHDPE values and Iraqi RLDPE wastes as shown in (Figures 13, 14).

Afterward the application of different software model were achieved for both wastes (RHDPE and RLDPE) from both sources (Iraqi and Foreign), then the results was given an optimum high quality multi-polynomial model with preference for Iraqi RLDPE of less residual and high correction factor quality (82%), as shown in (Figures 15, 16). The results of produced fitting model were shown in (Tables 10, 11, 12).

Table 10. The Coefficients of Fitting model for both PE wastes types and sources.

Coefficient	Value	
	RHDPE	RLDPE
a	-0.875	124.834
b	21.527	-3.744
c	$3.301 \times 10^{11}$	$3.796 \times 10^{10}$
d	-78.546	0.164
e	$-3.521 \times 10^9$	$-4.049 \times 10^{-8}$
f	$-5.918 \times 10^{-3}$	$1.731 \times 10^{-2}$
g	87.751	$-1.015 \times 10^{-2}$
h	$8.803 \times 10^6$	$1.012 \times 10^{-6}$
i	$-7.081 \times 10^{-6}$	$-5.749 \times 10^{-5}$
j	$9.301 \times 10^{-3}$	$1.463 \times 10^{-4}$
R <sup>2</sup>	0.67989	0.82523
V (%)	67.989	82.523

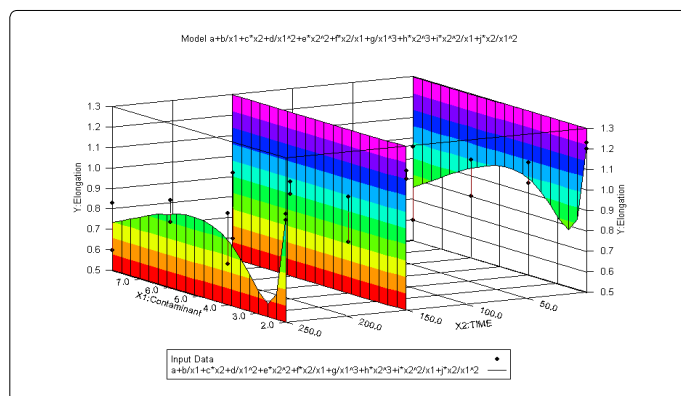


Figure 15. Model data for RHDPE of both two type of sources Iraqi and Foreign for Elongation property.

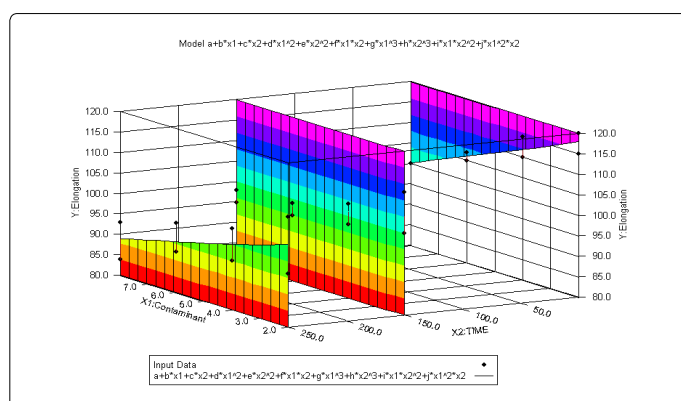


Figure 16. Shows the Model structure for RLDPE from both sources Iraqi and Foreign wastes for Elongation property.

Table 11. Shows the Data results for fitting model for RHDPE waste for Elongation property.

$x_1$	$x_2$	$Y_{prop.}$	$Y_{cal.}$	Res.
2	0	1.23	1.220713	0.009287
4	0	0.95	0.968525	-0.01852
6	0	0.8	0.937039	-0.13704
8	0	0.6	0.759763	-0.15976
2	150	1.18	1.14999	0.03001
4	150	0.75	0.897463	-0.14746
6	150	0.9	0.905266	-0.00527
8	150	0.6	0.753836	-0.15384
2	250	1	1.020187	-0.02019
4	250	0.7	0.815933	-0.11593
6	250	0.82	0.863872	-0.04387
8	250	0.6	0.734914	-0.13491
2	0	1.2	1.220713	-0.02071
4	0	1.05	0.968525	0.081475
6	0	0.98	0.937039	0.042961
8	0	0.96	0.759763	0.200237
2	150	1.14	1.14999	-0.00999
4	150	0.97	0.897463	0.072537
6	150	0.96	0.905266	0.054734
8	150	0.92	0.753836	0.166164
2	250	1.03	1.020187	0.009813
4	250	0.95	0.815933	0.134067
6	250	0.93	0.863872	0.066128
8	250	0.83	0.734914	0.095086

Table 12. Shows the data results for fitting model for RLDPE waste for Elongation property.

$x_1$	$x_2$	$Y_{prop.}$	$Y_{cal.}$	Res.
2	0	120	117.9193	2.080704
4	0	115	111.8292	3.170813
6	0	107	106.0766	0.923363
8	0	100	100.1743	-0.1743
2	150	110	104.3148	5.685235
4	150	103	101.0944	1.905566
6	150	99	98.38711	0.612895
8	150	98	95.70584	2.294162
2	250	107	100.2643	6.735727
4	250	100	96.0823	3.917703
6	250	97	92.53049	4.46951
8	250	93	89.12155	3.878453
2	0	115	117.9193	-2.9193
4	0	110	111.8292	-1.82919
6	0	105	106.0766	-1.07664
8	0	100	100.1743	-0.1743
2	150	100	104.3148	-4.31476
4	150	98	101.0944	-3.09443
6	150	96	98.38711	-2.38711
8	150	95	95.70584	-0.70584
2	250	93	100.2643	-7.26427
4	250	92	96.0823	-4.0823
6	250	90	92.53049	-2.53049
8	250	84	89.12155	-5.12155

## Chemical Properties

### Permeability / Length of Spectra Property

The experimental data for both PE wastes (RHDPE and RLDPE) from both sources (Iraqi and Foreign) were shown an increasing in permeability values with increasing both concentration of contaminants and temperature of exposure with preference of Iraqi wastes (RHDPE and RLDPE), as shown in (Figures 17, 18). Then applied the available experimental data in a different software programs and the results of this modeling was shown in (Figures 19, 20). The result of this optimum fitting

such as coefficients correction factor and deviation were shown in (Tables 13, 14, 15). The optimum multi-polynomial result model have high quality of fitting 96-97% and similar residual functions and deviations (30, 34) for both waste.

Table 13. Shows the Coefficients of fitting model for both types of PE wastes.

Coefficient	Value	
	RHDPE	RLDPE
a	$-3.566 \times 10^7$	$6.389 \times 10^{12}$
b	$4.744 \times 10^9$	$7.829 \times 10^6$
c	$-1.421 \times 10^{13}$	$-8.611 \times 10^8$
d	$-8.328 \times 10^{-7}$	$6.696 \times 10^{-7}$
e	$6.720 \times 10^{12}$	$-4.446 \times 10^9$
f	$-2.242 \times 10^9$	$-2.348 \times 10^5$
g	$7.857 \times 10^{-12}$	$3.646 \times 10^{-11}$
h	$-7.891 \times 10^{11}$	$3.816 \times 10^7$
i	$2.633 \times 10^8$	156.589
j	$1.681 \times 10^{-7}$	$-1.446 \times 10^{-8}$
R <sup>2</sup>	0.9797	0.9649
V (%)	97.97	96.49

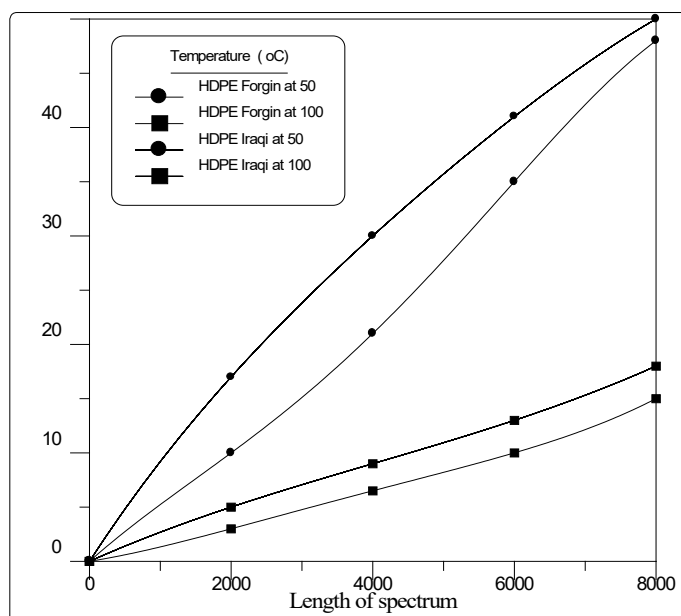


Figure 17. Shows the Experimental results for permeability/Length of spectrum for RHDPE.

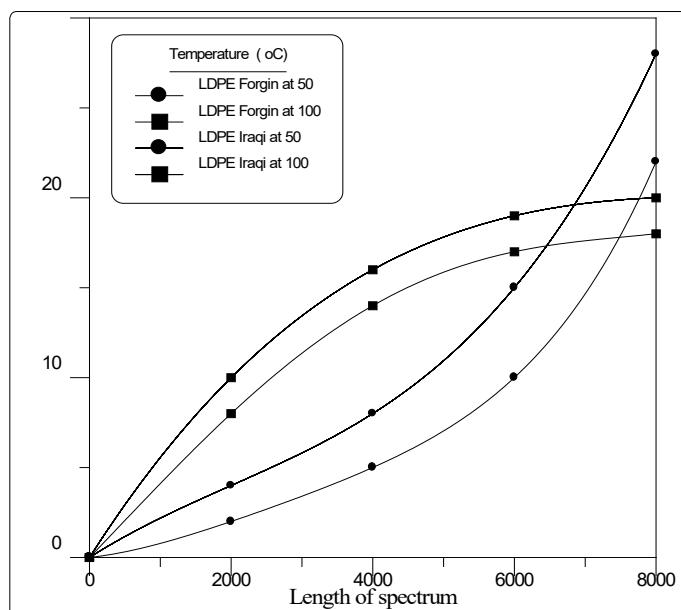


Figure 18. Shows the Experimental Results for permeability/Length of spectrum for RLDPE waste.



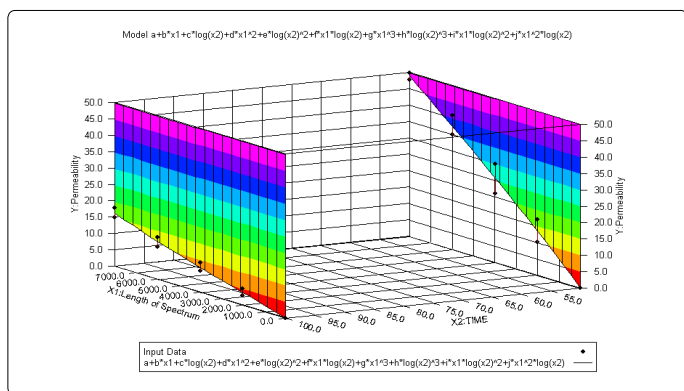


Figure 19. Models Data Profile for Permeability / Length of spectrum for RHDPE.

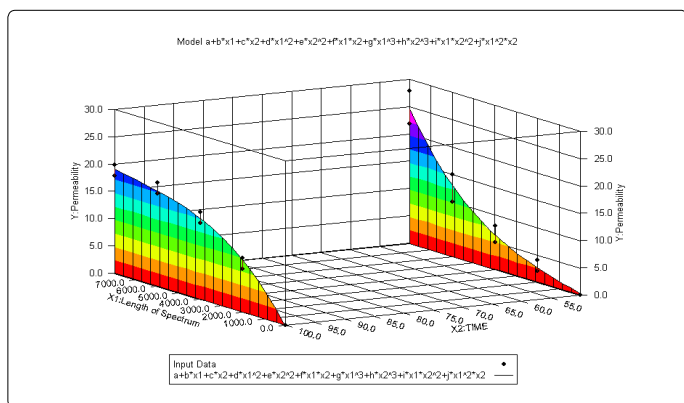


Figure 20. Shows the Model Data Profile for Permeability / Length of spectrum property for RLDPE from both wastes Iraqi and Foreign.

Table 14. Shows the data fit table model for RHDPE for Permeability/Length of spectrum property.

X <sub>1</sub>	X <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
0	50	0	-0.02051	0.020508
2000	50	10	13.4236	-3.4236
4000	50	21	25.84529	-4.84529
6000	50	35	37.62248	-2.62248
8000	50	48	49.13164	-1.13164
0	100	0	0.060547	-0.06055
2000	100	3	3.905017	-0.90502
4000	100	6.5	7.662062	-1.16206
6000	100	10	11.70229	-1.70229
8000	100	15	16.41192	-1.41192
0	50	0	-0.02051	0.020508
2000	50	17	13.4236	3.576398
4000	50	30	25.84529	4.154713
6000	50	41	37.62248	3.377523
8000	50	50	49.13164	0.868363
0	100	0	0.060547	-0.06055
2000	100	5	3.905017	1.094983
4000	100	9	7.662062	1.337938
6000	100	13	11.70229	1.297714
8000	100	18	16.41192	1.58808

Table 15. Shows the Data Fit Table Model for RLDPE for Permeability / Length of spectrum property.

X <sub>1</sub>	X <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
0	50	0	0.221436	-0.22144
2000	50	2	2.614418	-0.61442
4000	50	5	6.328735	-1.32873
6000	50	10	13.11433	-3.11433

8000	50	22	24.72149	-2.72149
0	100	0	-0.26416	0.26416
2000	100	8	9.556869	-1.55687
4000	100	14	14.91437	-0.91437
6000	100	17	17.55687	-0.55687
8000	100	18	19.23535	-1.23535
0	50	0	0.221436	-0.22144
2000	50	4	2.614418	1.385582
4000	50	8	6.328735	1.671265
6000	50	15	13.11433	1.885674
8000	50	28	24.72149	3.278505
0	100	0	-0.26416	0.26416
2000	100	10	9.556869	0.443131
4000	100	16	14.91437	1.085633
6000	100	19	17.55687	1.443131
8000	100	20	19.23535	0.764653

**Permeability / Thickness Property**

The experimental data for both wastes of PE (RHDPE and RLDPE) were shown a decreasing in permeability values with increasing both thickness of specimen and length of spectra for optimum samples from both type of wastes RHDPE and RLDPE with preference for short length of spectra at 400 A for both type of wastes, see (Figure 21).

The application of these optimum result data from both type of wastes on the different software modeling programs were shown different type of model system and number of coefficients as shown in equations and tables (16, 17, 18), also the 3D histogram appearance of models were shown in (Figures 22, 23).

And the results of RHDPE gave a best fit than RLDPE for most of checked analysis properties (thermo-mechanical and chemical properties), and all were fitted the mathematical software model below:

$$Y_{model} = a + b_1 + c_2 + d_1^2 + e_2^2 + f_1x_2 + g_3 + h_3 + i_2^2 + j_1^2x_2 \quad (1)$$

Where:

a, b, c ...j = coefficient of the best fit model.

x<sub>1</sub> = concentration of contaminants.

x<sub>2</sub> = time of aging.

$$Y_{RHDPEP} = a + \frac{b}{x_1} + \frac{c}{x_2} + \frac{d}{x_2^2} \quad (2)$$

$$Y_{RLDPEP} = a + b \log x_1 + \frac{c}{x_2} + \frac{d}{x_2^2} + \frac{e}{x_2^3} \quad (3)$$

Table 16. Shows the Coefficients of fitting model for both types of PE wastes.

	Value	
	RHDPE	RLDPE
a	-1.784*10 <sup>16</sup>	-3.401*10 <sup>16</sup>
b	1.943*10 <sup>6</sup>	-83.049
c	2.14*10 <sup>19</sup>	2.199*10 <sup>19</sup>
d	-5.711*10 <sup>21</sup>	1.17*10 <sup>22</sup>
e		-6.023*10 <sup>24</sup>
R <sup>2</sup>	0.9858	0.9604
V (%)	98.58	96.04

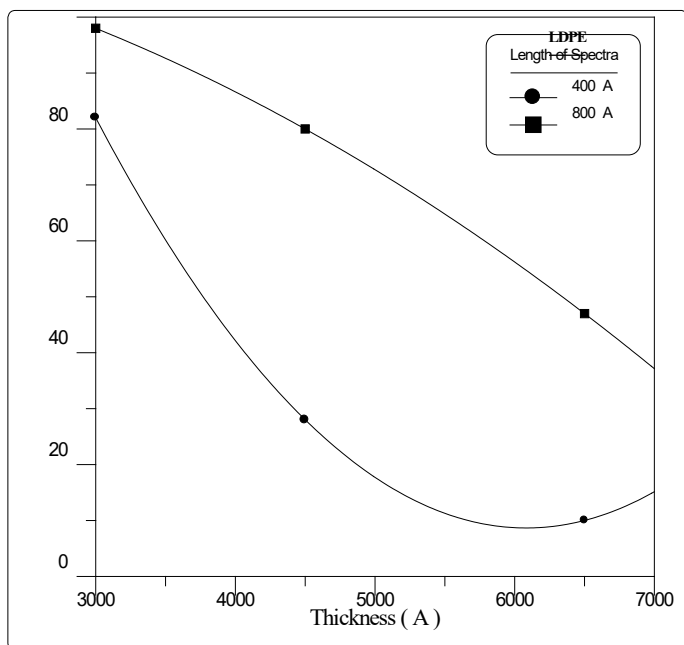


Figure 21. Shows the Experimental Data for Permeability / Thickness property for RLDPE waste.

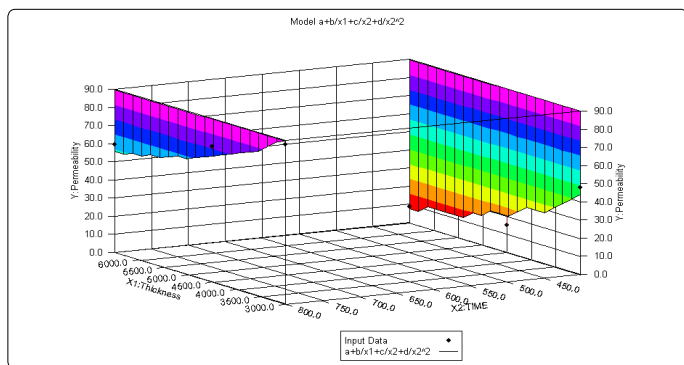


Figure 22. Shows the Model Fitting Data of Permeability / Thickness property for RHDPE wastes.

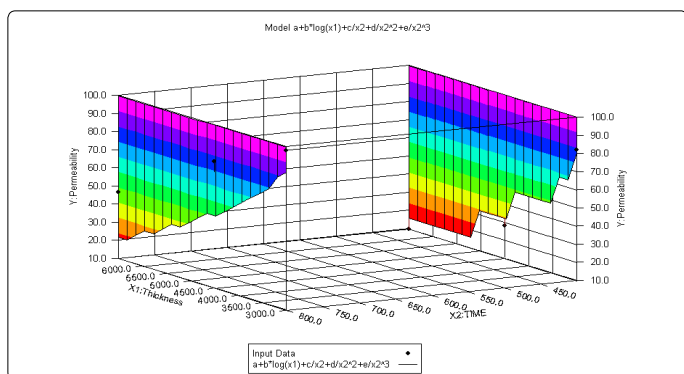


Figure 23. Shows the Model Fitting data of Permeability / Thickness property for RLDPE wastes.

Table 17. Shows the data table model that will fitted at Permeability / thickness property for RHDPE wastes.

X <sub>1</sub>	X <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
3000	400	48	44	4
4500	400	15	20	-5
6500	400	9	8	1
3000	800	88	93	-5
4500	800	75	73	2
6500	800	60	59	1

Table 18. Shows the data table model that will fitted at Permeability / thickness property for RLDPE wastes.

X <sub>1</sub>	X <sub>2</sub>	Y <sub>prop.</sub>	Y <sub>cal.</sub>	Res.
3000	400	82	80	2
4500	400	28	32	-4
6500	400	10	16	-6
3000	800	98	110	-12
4500	800	80	74	6
6500	800	47	46	1

## Conclusions

From the above theoretical – software were model studied on the both types of PE wastes (RHDPE and RLDPE) and sources (Iraqi and Foreign), it could concluded that:

1. The Thermo-mechanical properties such as tensile strength, modulus elasticity were the basic specify properties.
2. The chemical properties of both permeability / length and permeability / thickness were the basic specify properties too.
3. The optimum fitting models for all comparison properties Thermo-mechanical and chemical properties is a multi-polynomial model function except of permeability / thickness property of log-polynomial model, see equations (1, 2, 3).
4. The optimum fitting model was fitted all sorting and characterization properties except of permeability / thickness due to input other weathering variables for both sources (Iraqi and Foreign) wastes and both types (RHDPE and RLDPE), and this was an advanced studied now.
5. The optimum weathering variables for comparison were concentration of contaminates and time of aging, also the optimum basic property for comparison was tensile strength, modulus of elasticity and permeability.

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