

Supplementary Information for

**Optimizing leaching of rare earth elements from red mud and spent fluorescent lamp
phosphors using levulinic acid**

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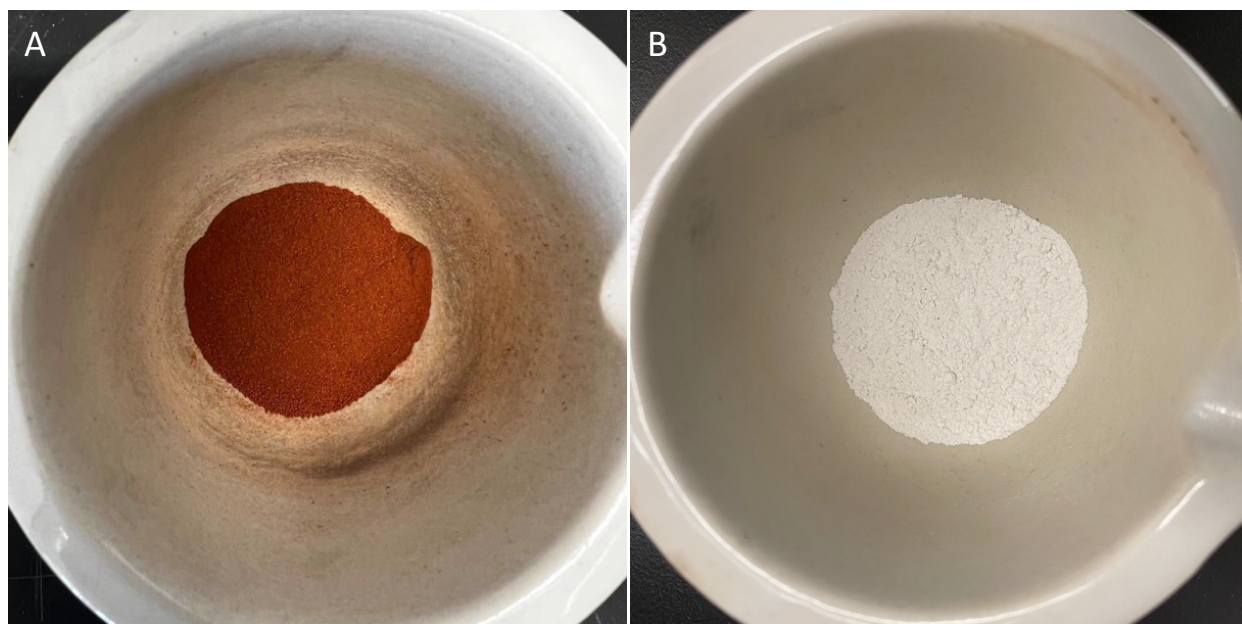


Figure S1. Processed red mud (A; < 125 μm) and florescent phosphors (B; < 63 μm).

Table S1. Design matrix and results for screening of organic acids and DES. The stirring speed was 500 rpm for all tests.

Test No.	DES or acids	REOs	L/S (L/kg)	Conditions	Dissolution (%)
1	ChCl-UA, 1:2	La_2O_3	20	24h 50 °C; then 48h 80 °C	20
2	ChCl-UA, 1:2	CeO_2	20	24h 50 °C; then 48h 80 °C	20
3	ChCl-UA, 1:2	Gd_2O_3	20	24h 50 °C; then 48h 80 °C	60
4	ChCl-UA, 1:2	Y_2O_3	20	24h 50 °C; then 48h 80 °C	40
5	ChCl-EG, 1:2	La_2O_3	20	24h 50 °C; then 48h 80 °C	20
6	ChCl-EG, 1:2	CeO_2	20	24h 50 °C; then 48h 80 °C	20
7	ChCl-EG, 1:2	Gd_2O_3	20	24h 50 °C; then 48h 80 °C	80
8	ChCl-EG, 1:2	Y_2O_3	20	24h 50 °C; then 48h 80 °C	20
9	ChCl-MA, 1:1	La_2O_3	20	48 h 80 °C	20
10	ChCl-MA, 1:1	CeO_2	20	48 h 80 °C	20
11	ChCl-MA, 1:1	Gd_2O_3	20	48 h 80 °C	40
12	ChCl-MA, 1:1	Y_2O_3	20	48 h 80 °C	20
13	ChCl-OA, 1:1	Gd_2O_3	20	48 h 80 °C	40
14	ChCl-OA, 1:1	CeO_2	10	48 h 80 °C	20
15	ChCl-CA, 1:1	Y_2O_3	20	48 h 80 °C	40
16	EG-CA, 4:1	La_2O_3	20	48 h 80 °C	20

17	EG-CA, 4:1	CeO ₂	20	48 h 80 °C	20
18	EG-CA, 4:1	Gd ₂ O ₃	20	48 h 80 °C	40
19	EG-CA, 4:1	Y ₂ O ₃	20	48 h 80 °C	20
20	EG-MA, 4:1	La ₂ O ₃	20	48 h 80 °C	20
21	EG-MA, 4:1	CeO ₂	20	48 h 80 °C	20
22	EG-MA, 4:1	Gd ₂ O ₃	20	48 h 80 °C	80
23	EG-MA, 4:1	Y ₂ O ₃	20	48 h 80 °C	40
24	ChCl-LevA, 1:2	La ₂ O ₃	20	48 h 80 °C	20
25	ChCl-LevA, 1:2	CeO ₂	20	48 h 80 °C	20
26	ChCl-LevA, 1:2	Gd ₂ O ₃	20	48 h 80 °C	20
27	ChCl-LevA, 1:2	Y ₂ O ₃	20	48 h 80 °C	20
28	LevA, 30% H ₂ O	La ₂ O ₃	6.67	48 h 80 °C	100
29	LevA, 30% H ₂ O	CeO ₂	20	48 h 80 °C	40
30	LevA, 30% H ₂ O	Gd ₂ O ₃	6.67	48 h 80 °C	100
31	LevA, 30% H ₂ O	Y ₂ O ₃	20	48 h 80 °C	100
32	LevA, 30% H ₂ O	Gd ₂ O ₃	6.67	24 h 50 °C	100
33	LevA, 30% H ₂ O	La ₂ O ₃	6.67	72 h 50 °C	80
34	LevA, 30% H ₂ O	CeO ₂	20	72 h 50 °C	20
35	LevA, 30% H ₂ O	Y ₂ O ₃	20	72 h 50 °C	100
36	SA, saturated	La ₂ O ₃	20	48 h 80 °C	40
37	SA, saturated	CeO ₂	20	48 h 80 °C	20
38	SA, saturated	Gd ₂ O ₃	20	48 h 80 °C	80
39	SA, saturated	Y ₂ O ₃	20	48 h 80 °C	20
40	LacA, 30% H ₂ O	La ₂ O ₃	20	48 h 80 °C	20
41	LacA, 30% H ₂ O	CeO ₂	20	48 h 80 °C	20
42	LacA, 30% H ₂ O	Gd ₂ O ₃	20	48 h 80 °C	20
43	LacA, 30% H ₂ O	Y ₂ O ₃	20	48 h 80 °C	20
44	AceA, 30% H ₂ O	La ₂ O ₃	20	48 h 80 °C	80
45	AceA, 30% H ₂ O	CeO ₂	20	48 h 80 °C	20
46	AceA, 30% H ₂ O	Gd ₂ O ₃	20	48 h 80 °C	100
47	AceA, 30% H ₂ O	Y ₂ O ₃	20	48 h 80 °C	60
48	ForA, 30% H ₂ O	La ₂ O ₃	20	48 h 80 °C	20
49	ForA, 30% H ₂ O	CeO ₂	20	48 h 80 °C	20
50	ForA, 30% H ₂ O	Gd ₂ O ₃	20	48 h 80 °C	40
51	ForA, 30% H ₂ O	Y ₂ O ₃	20	48 h 80 °C	40
52	CA, saturated	La ₂ O ₃	20	48 h 80 °C	80
53	CA, saturated	CeO ₂	20	48 h 80 °C	20
54	CA, saturated	Gd ₂ O ₃	20	48 h 80 °C	100
55	CA, saturated	Y ₂ O ₃	20	48 h 80 °C	80
56	MA, saturated	La ₂ O ₃	20	48 h 80 °C	80
57	MA, saturated	CeO ₂	20	48 h 80 °C	40
58	MA, saturated	Gd ₂ O ₃	20	48 h 80 °C	80
59	MA, saturated	Y ₂ O ₃	20	48 h 80 °C	100
60	MA, saturated	La ₂ O ₃	20	72 h 50 °C	60

61	MA, saturated	CeO ₂	20	72 h 50 °C	20
62	MA, saturated	Gd ₂ O ₃	20	72 h 50 °C	80
63	MA, saturated	Y ₂ O ₃	20	72 h 50 °C	60
64	Control, water	La ₂ O ₃	20	48 h 80 °C	0
65	Control, water	CeO ₂	20	48 h 80 °C	0
66	Control, water	Gd ₂ O ₃	20	48 h 80 °C	0
67	Control, water	Y ₂ O ₃	20	48 h 80 °C	0

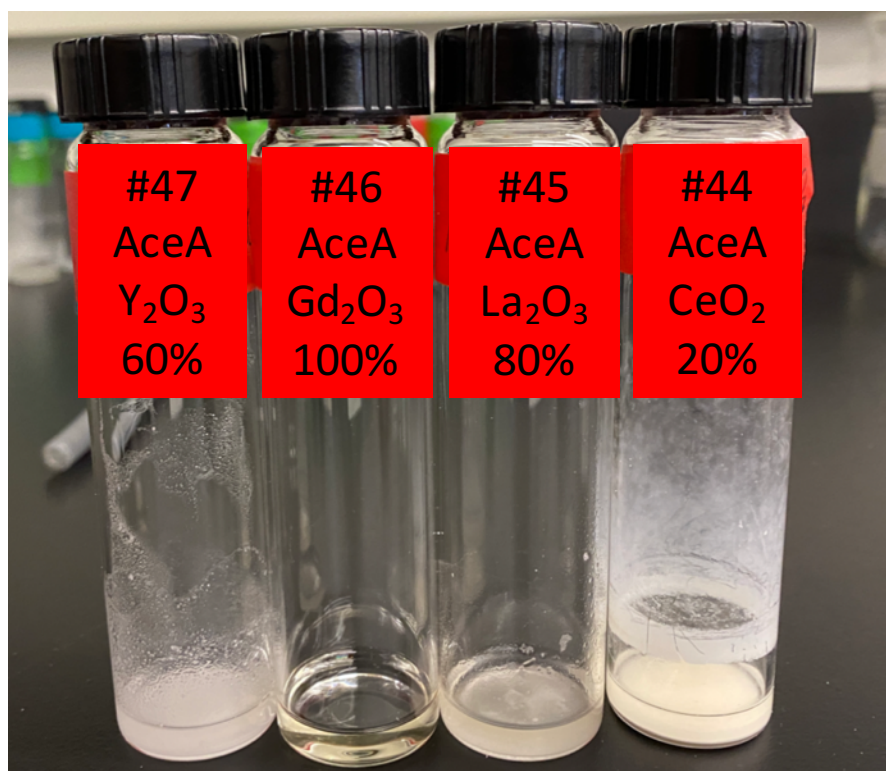


Figure S2. An example of the classification of dissolution by direct observation. The denoted sample numbers are the same with those in Table S1. The dissolution from left to right: 60%, 100%, 80%, and 20%.

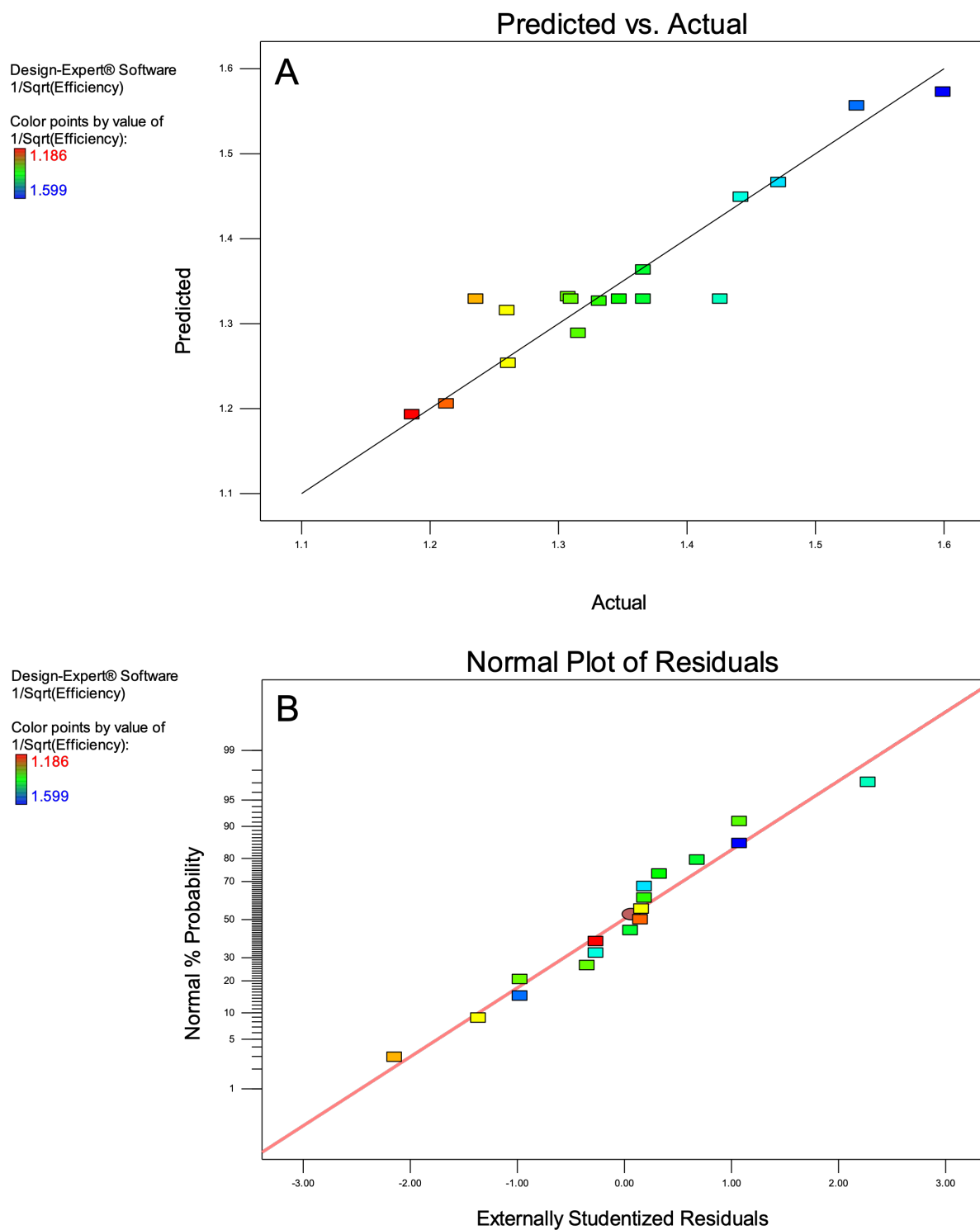


Figure S3. Predicted against actual plot (A) and normal plot of residuals (B) of the developed model for red mud.

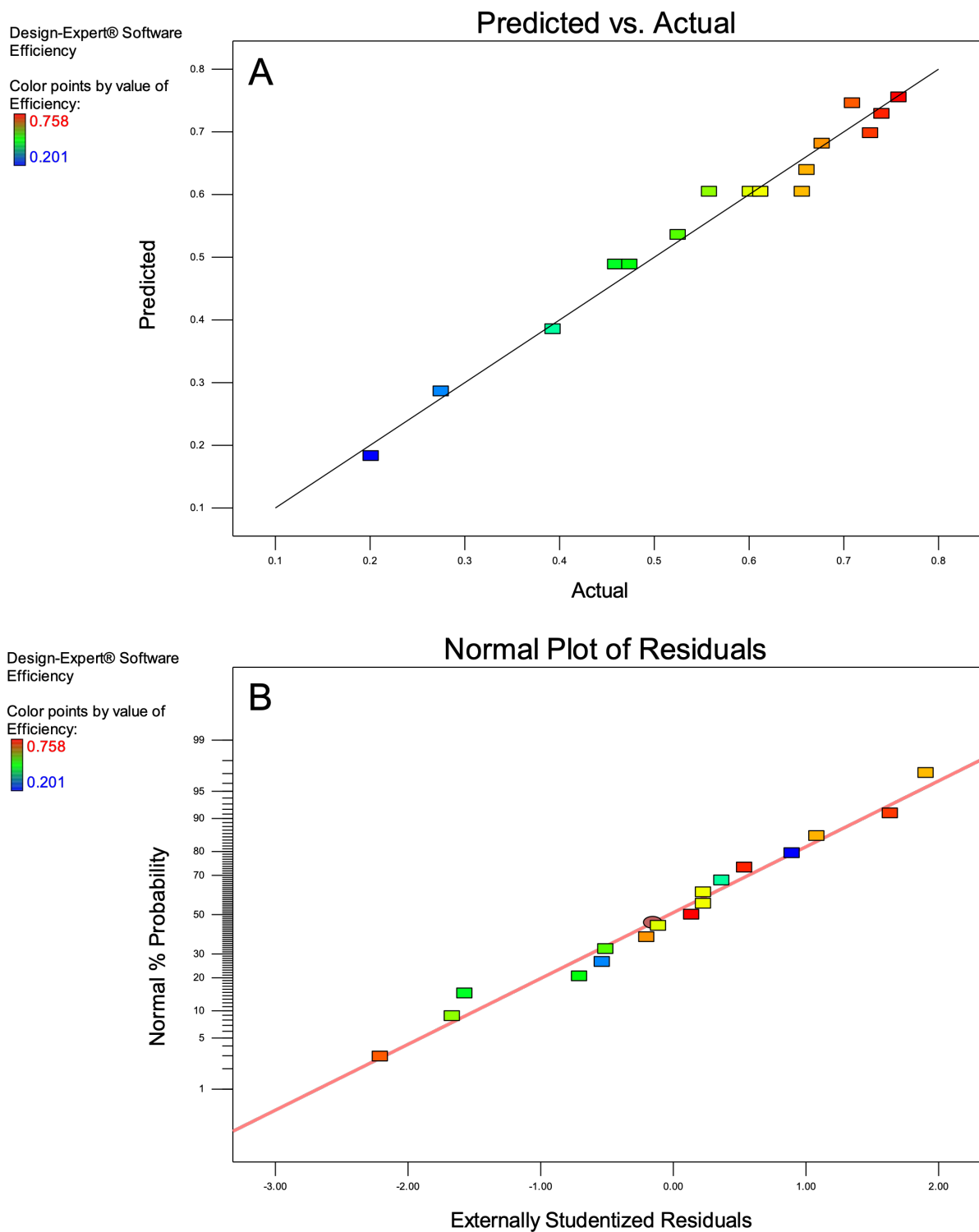


Figure S4. Predicted against actual plot (A) and normal plot of residuals (B) of the developed model for florescent phosphors.

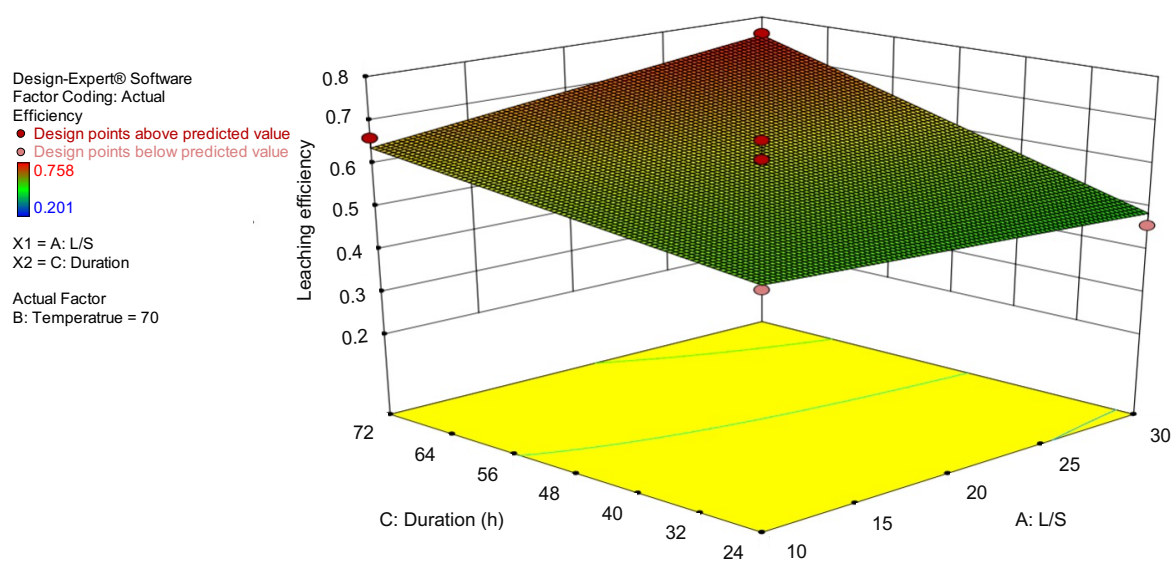


Figure S5. Three-dimensional response surface plots of total efficiency as a function of different variables for florescent phosphors with a fixed temperature at 70 °C.