Use of Diatomaceous Earth Wastes and Plant derived Binders in Water Purification Systems

Sr Mary Taabu Simiyu, HHCJ

Supervisors

Prof. Francis Nyongesa
Prof. Bernard Aduda
Dr. Zephania Birech

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Mary Taabu Simiyu[1], Francis Nyongesa[1], Bernard Aduda[1] Zephania Birech[1], Godwin Mwebaze[2]
[1]University of Nairobi (Department of Physics, Kenya)
[2]Makerere University (Department of Physics, Kenya)
Corresponding author: marytaabu@students.uonbi.ac.ke

Abstract

The outbreaks of water-borne diseases are a common occurrence in developing countries and have claimed millions of lives in the recent years despite the many water purification approaches in use. This is because most of these water purification systems are unaffordable to the poor of developing world and are inefficient in removal of viruses from drinking water. Furthermore, the DE wastes have not found direct application in science. Thus, the wastes pose a challenge to DE industries. In this work, the nanomaterials of diatomaceous earth (DE) wastes and charcoal are employed in the design of efficient and effective water filtration membranes capable of eliminating pathogens and viruses from water. The DE waste and charcoal raw materials were ground to the range of 86.0 nm to 200.0 nm. The DE wastes were characterized in terms of chemical analysis. They were found to contain 89% silica and a total flux content of 11.0% (4.14% of Al_2O_3, 3.88 of CaO, 0.85% of K_2O, 0.19% of MgO and 5.10% of Na_2O) making it a suitable material for water filter membranes. The samples for the filter membranes were fabricated from a mixture of DE and charcoal in various ratios and fired at 900 ºC. The pore size of the finished filter was in the range of 22.0 nm – 150 nm. The mechanical strength of the filter membranes was enhanced by use of plant derived binders ("Mrenda") thereby increasing the filter flow rate without compromising on its structural reliability.

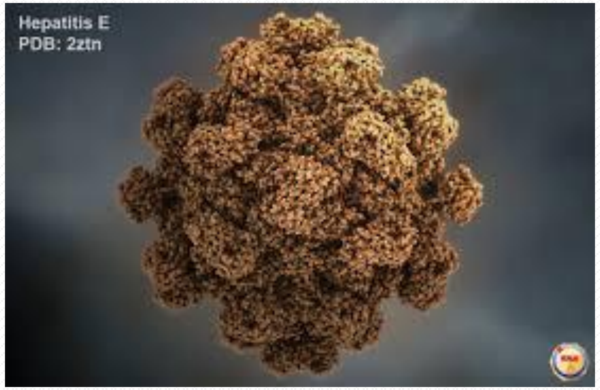
1. Introduction

Globally safe water and good sanitation are basic needs to all humans, research show that around a third of the world's population lack these basic needs [1]. Among these population, 90% is from the developing world [1]. The most vulnerable are women, infants and

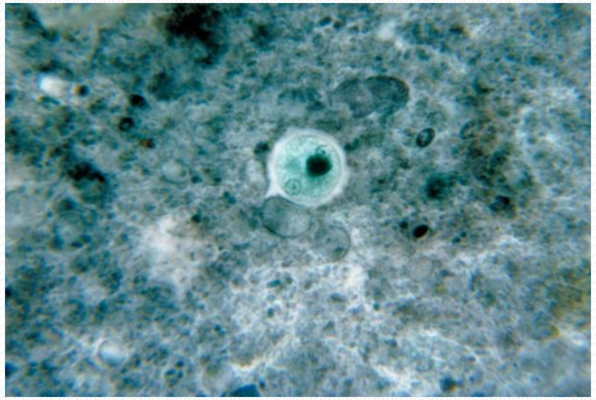
reported that drinking water filters made from DE can remove up to 90% - 99.999% of the viruses [6] the cost of these filters are unfordable for developing world. However, diatomaceous earth waste can equally be porous and effective as they are made of 80% diatoms and can considerable lower the cost of diatomaceous

What are pathogens

Bacteria E. coli and Vibrio cholerae



HEV and Entameoba hystolitica



Purification methods

- ❑ Chemicals
- ❑ Filters
  - RO
  - UF
  - Clay ceramics
- ❑ UV light

Chemicals such as chlorine leaves byproducts which also contaminate water

Disadvantages of conventional filters

Expensive, low flow rates, eliminates important ions Lacks shelf life alerts, ineffective in salty water and virus elimination

Problem Statement

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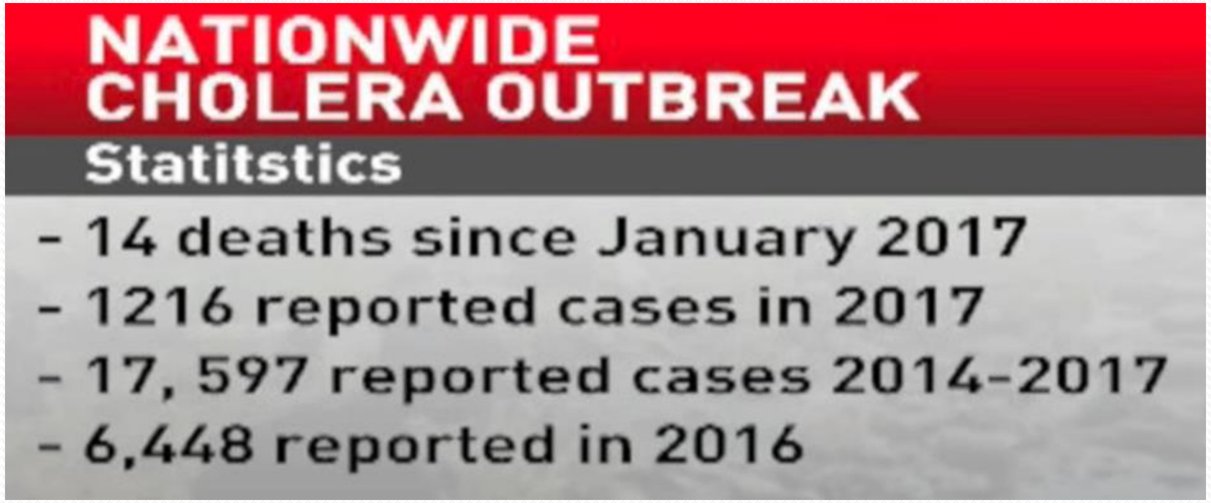
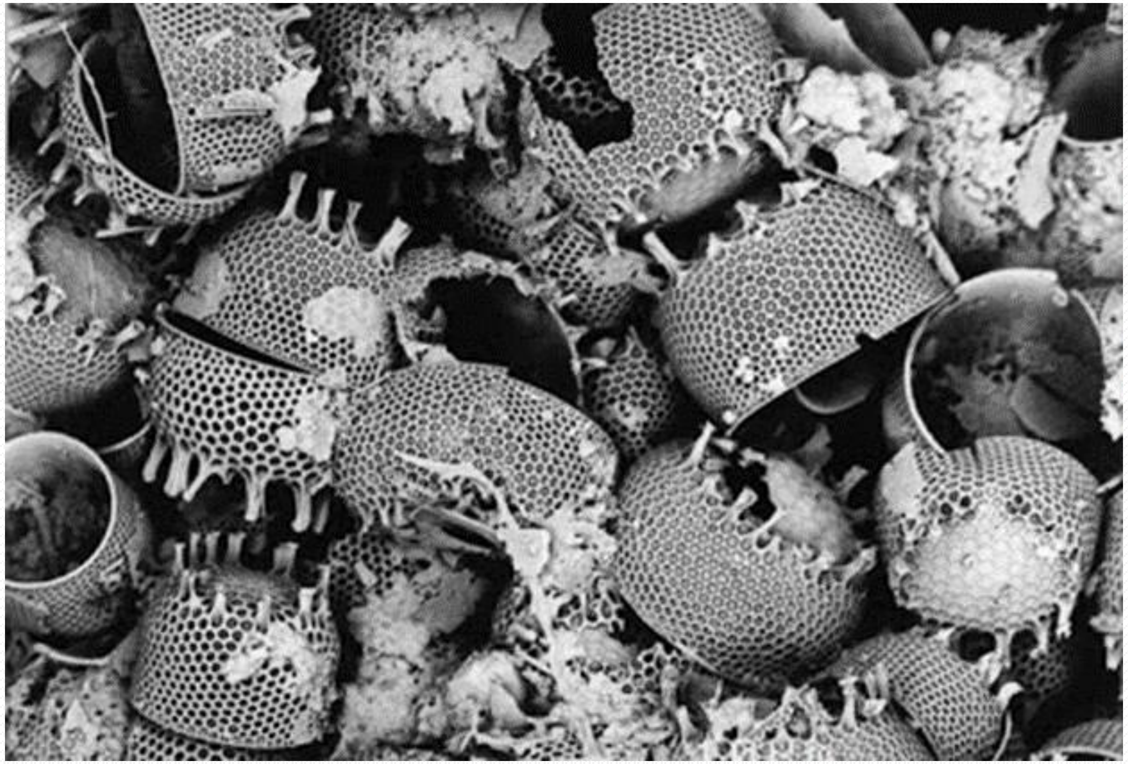


Loss of both human and animal lives

Develop a cheap, highly porous, fast potable, virus sensitive and effective POU CWF

Proposed Composite Filter

Composite filter



Advantages of the composite method

Diatoms

Uniform pores, High porosity, removes most pathogens, easily available and cheap

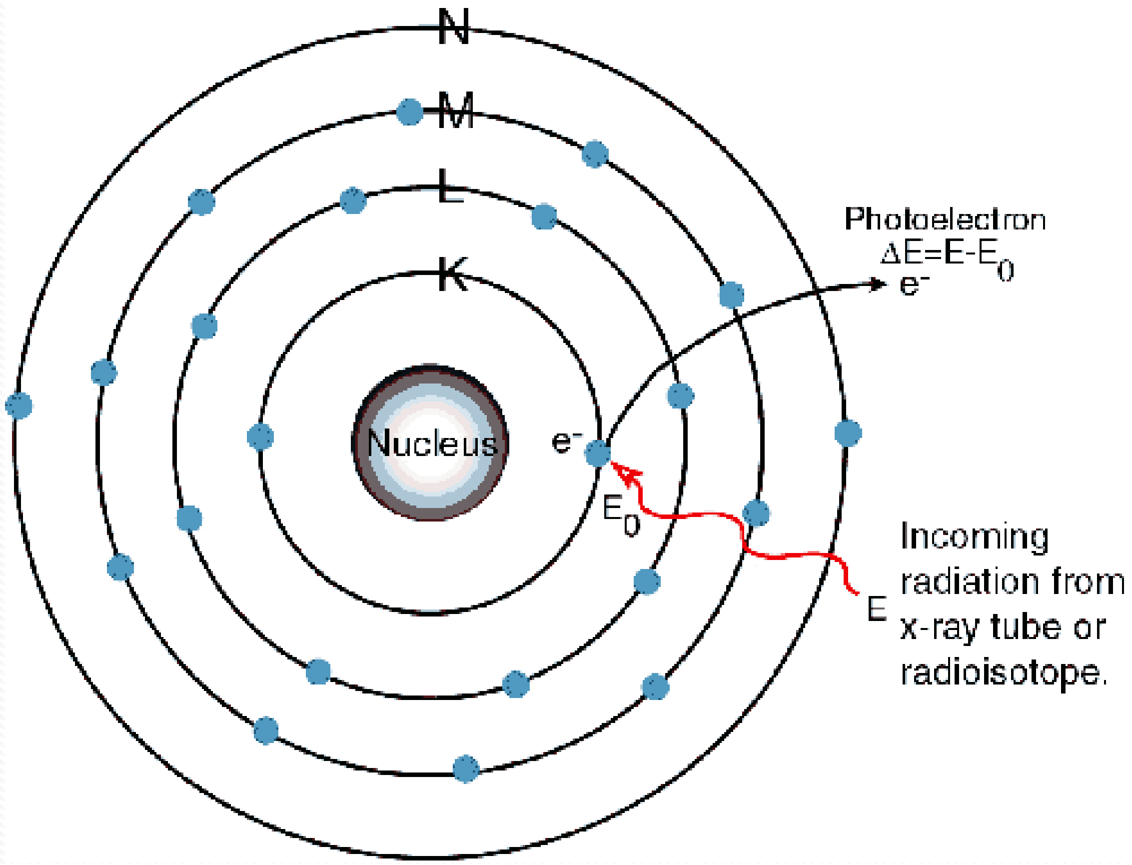
Charcoal

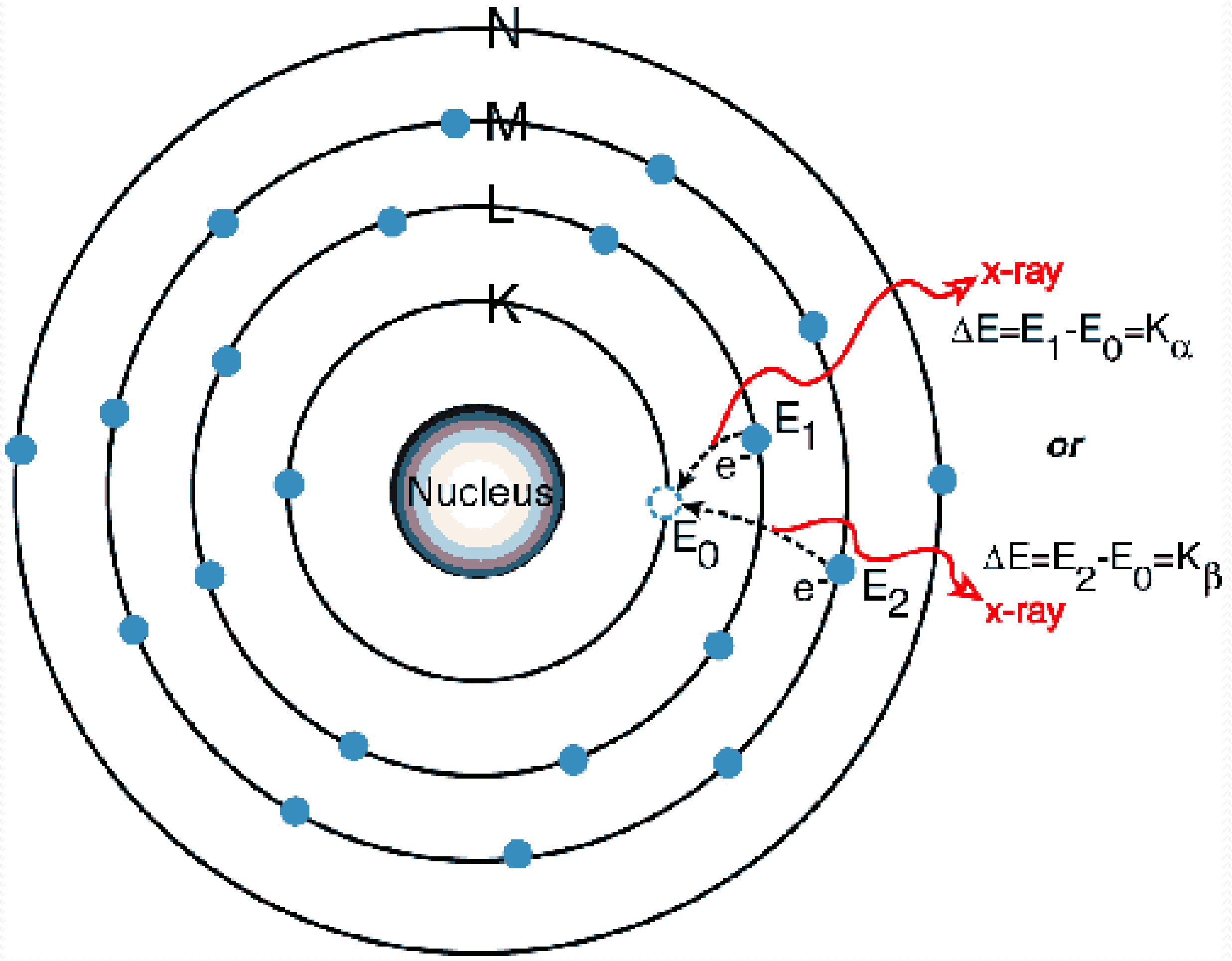
Cheap, be made locally and is highly porous

Organic binder

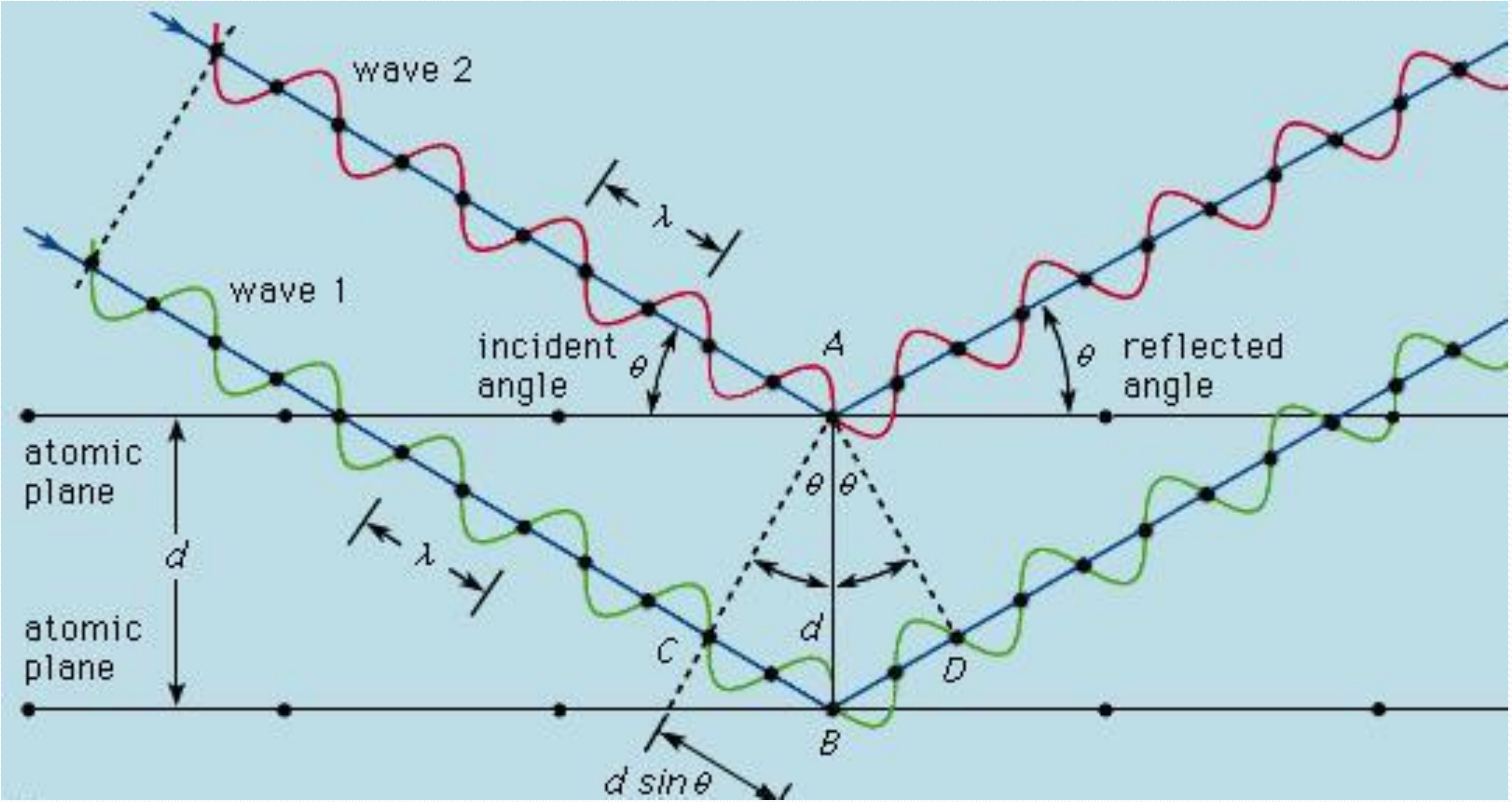
Mechanical enhancing and makes the smooth green and dried wares

X-Ray Fluorescence Process





X-Ray Diffraction Process



Materials and methods

Materials and methods

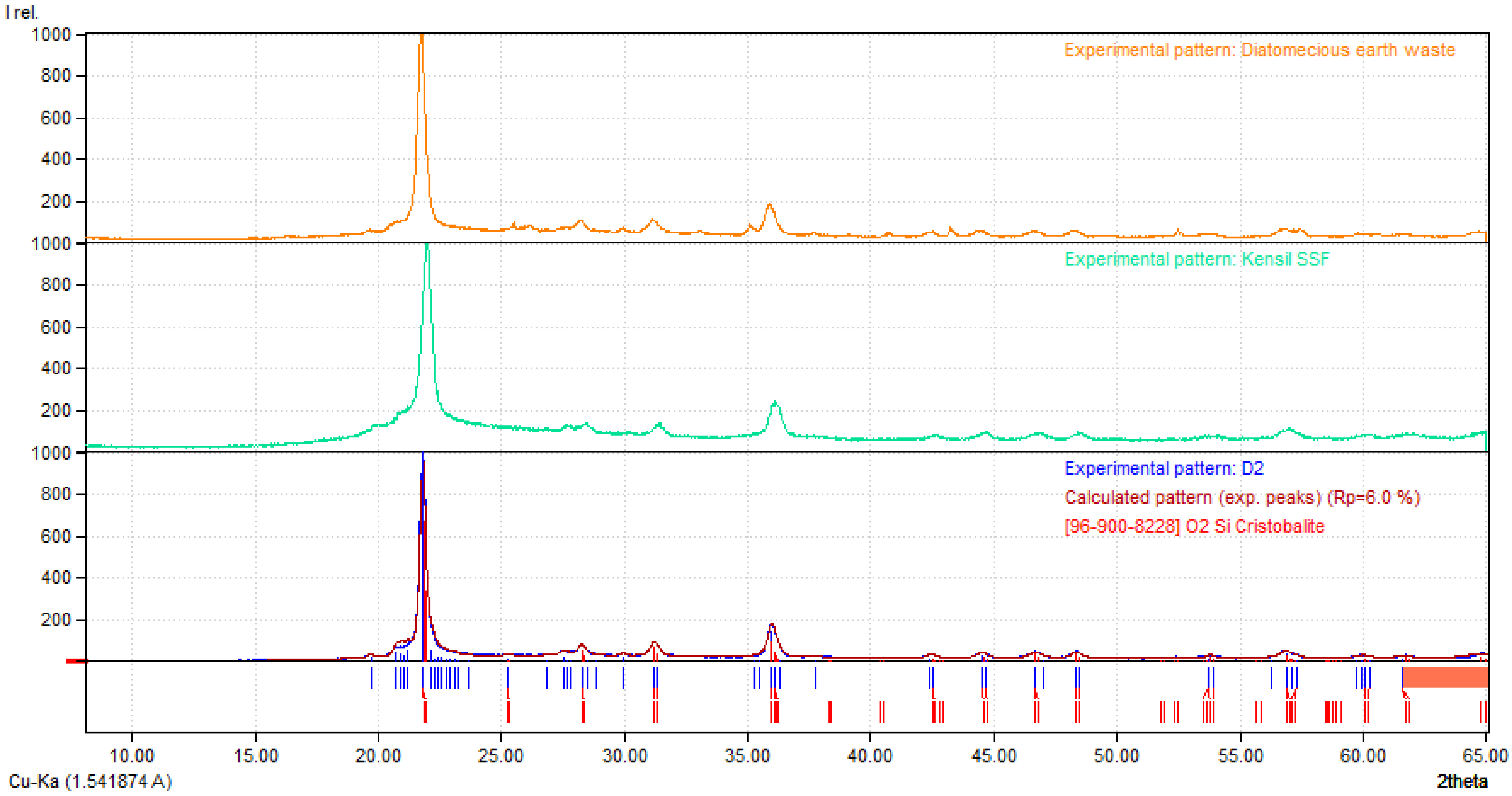
Elemental Analysis

Sample Name	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	K_2O (%)	Na_2O (%)	P_2O_5 (%)	TiO_2 (%)	MnO (%)	Cr_2O_3 (%)
Waste	79.021	7.686	2.849	3.738	0.174	0.013	0.852	5.56	0.051	0.471	0.059	0.046
Kensil SSF	89.579	4.030	2.300	1.220	0.097	0.003	0.781	1.87	0.025	0.315	0.046	0.011
Kensil 90	87.495	2.934	2.090	2.578	0.098	0.006	0.711	4.21	0.025	0.308	0.046	0.01
Diatomacious earth from [9]	84.170	4.010	2.960	0.240	0.110	-	0.75	0.610	0.040	0.170	0.040	-

Elemental Analysis of Binder

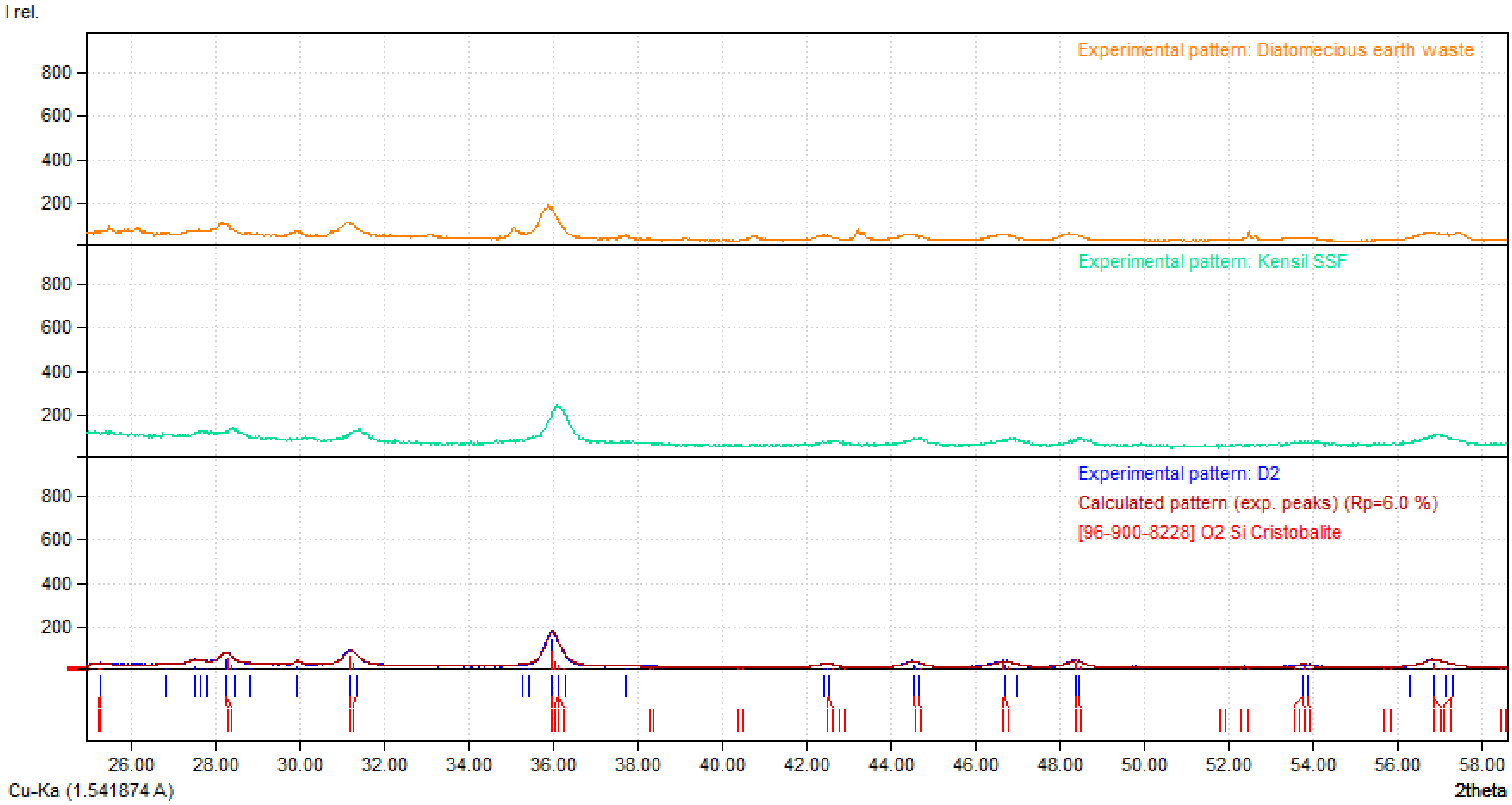
Ions present	ppm
Al_2O_3	3910
P_2O_5	341
K_2O	3320
Fe_2O	152
CuO	14.8
ZnO	11.4

XRD

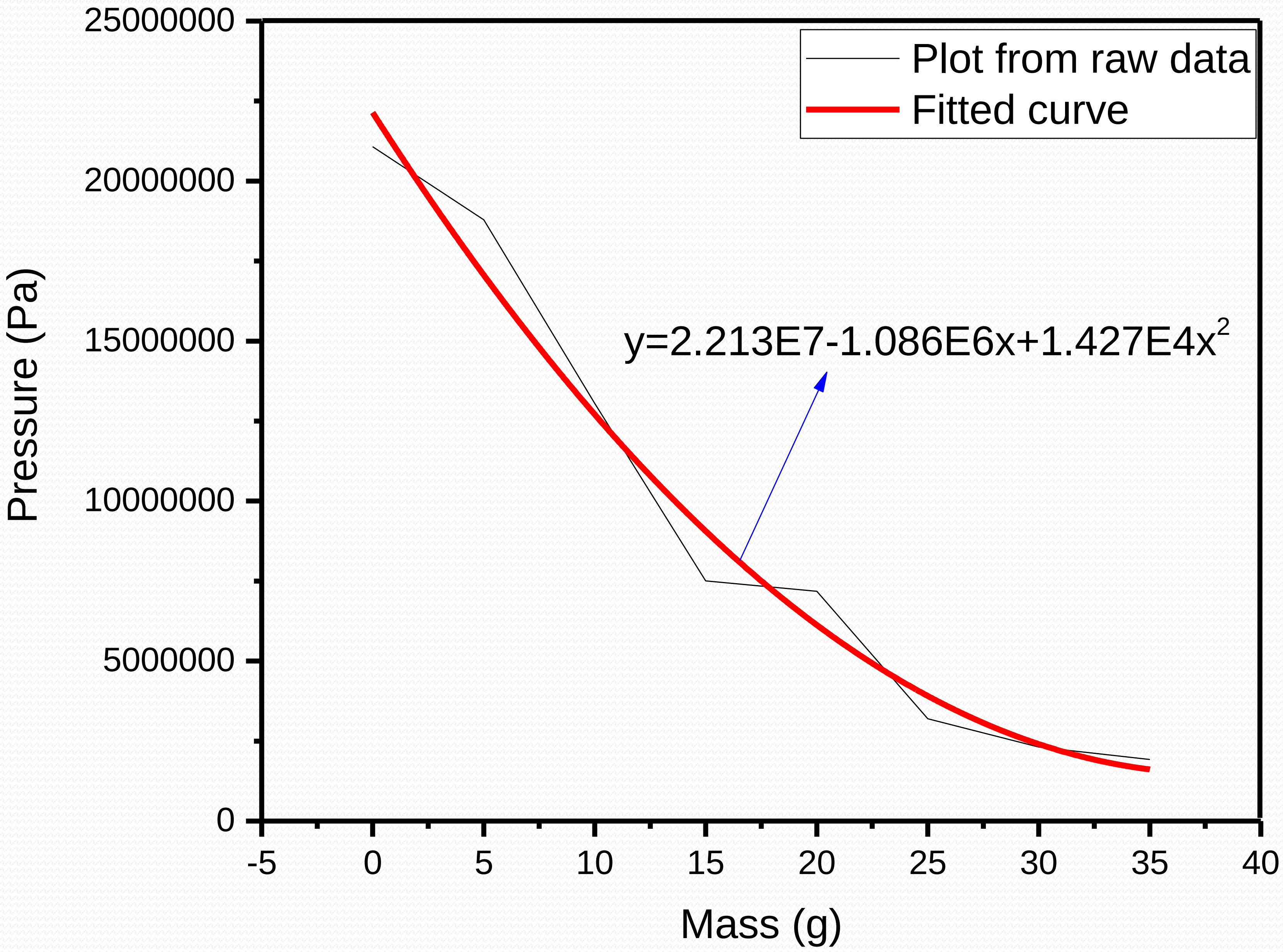


I rel.
1000
800
600
400
200
Experimental pattern: Diatomecious earth waste
Experimental pattern: Kensil SSF
Experimental pattern: D2
Calculated pattern (exp. peaks) (Rp=6.0 %)
[96-900-8228] O2 Si Cristobalite
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
Cu-Ka (1.541874 A)
2theta

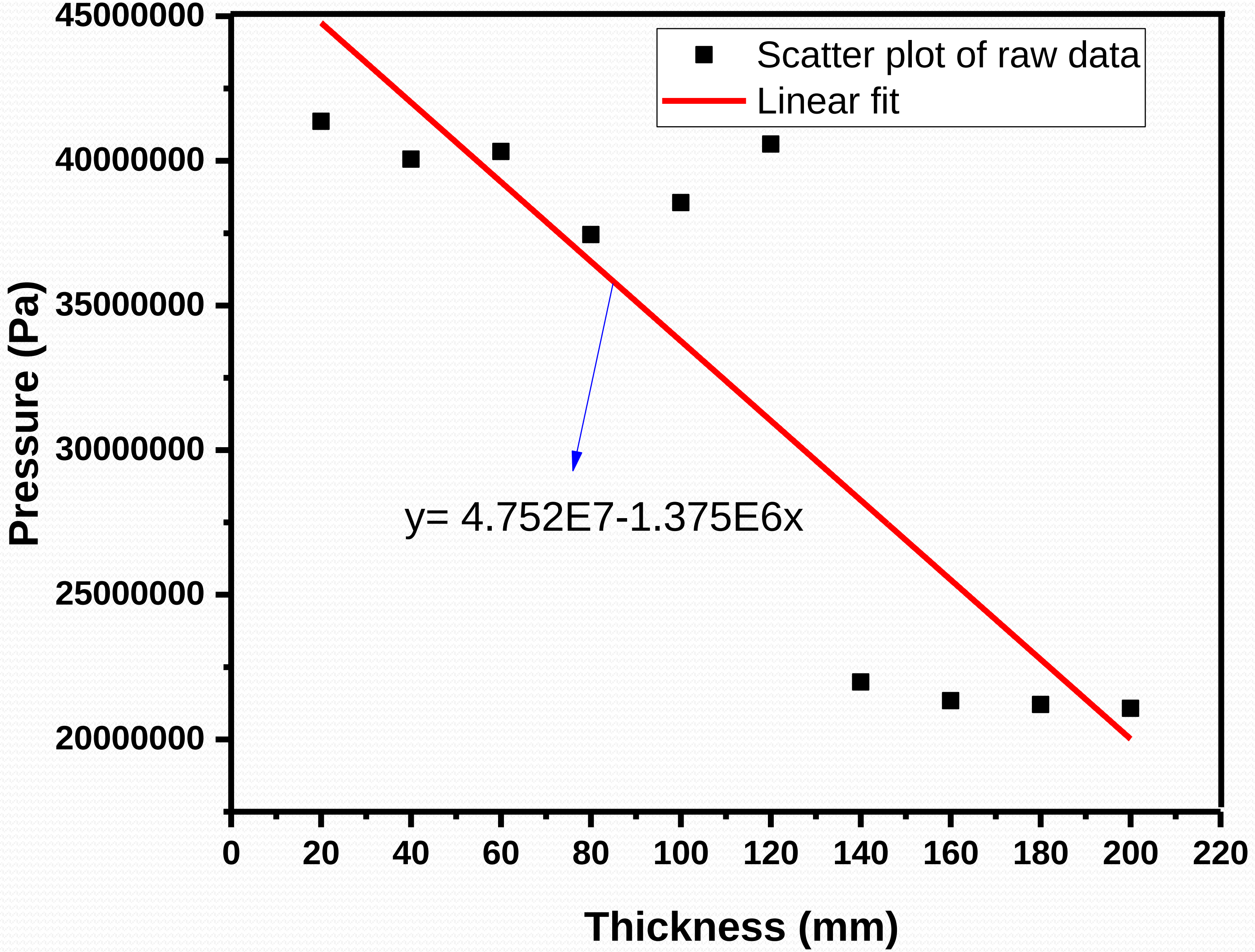
XRD


I rel.
800
600
400
200
Experimental pattern: Diatomecious earth waste
Experimental pattern: Kensil SSF
Experimental pattern: D2
Calculated pattern (exp. peaks) (Rp=6.0 %)
[96-900-8228] O2 Si Cristobalite
26.00
28.00
30.00
32.00
34.00
36.00
38.00
40.00
42.00
44.00
46.00
48.00
50.00
52.00
54.00
56.00
58.00
Cu-Ka (1.541874 A)
2theta

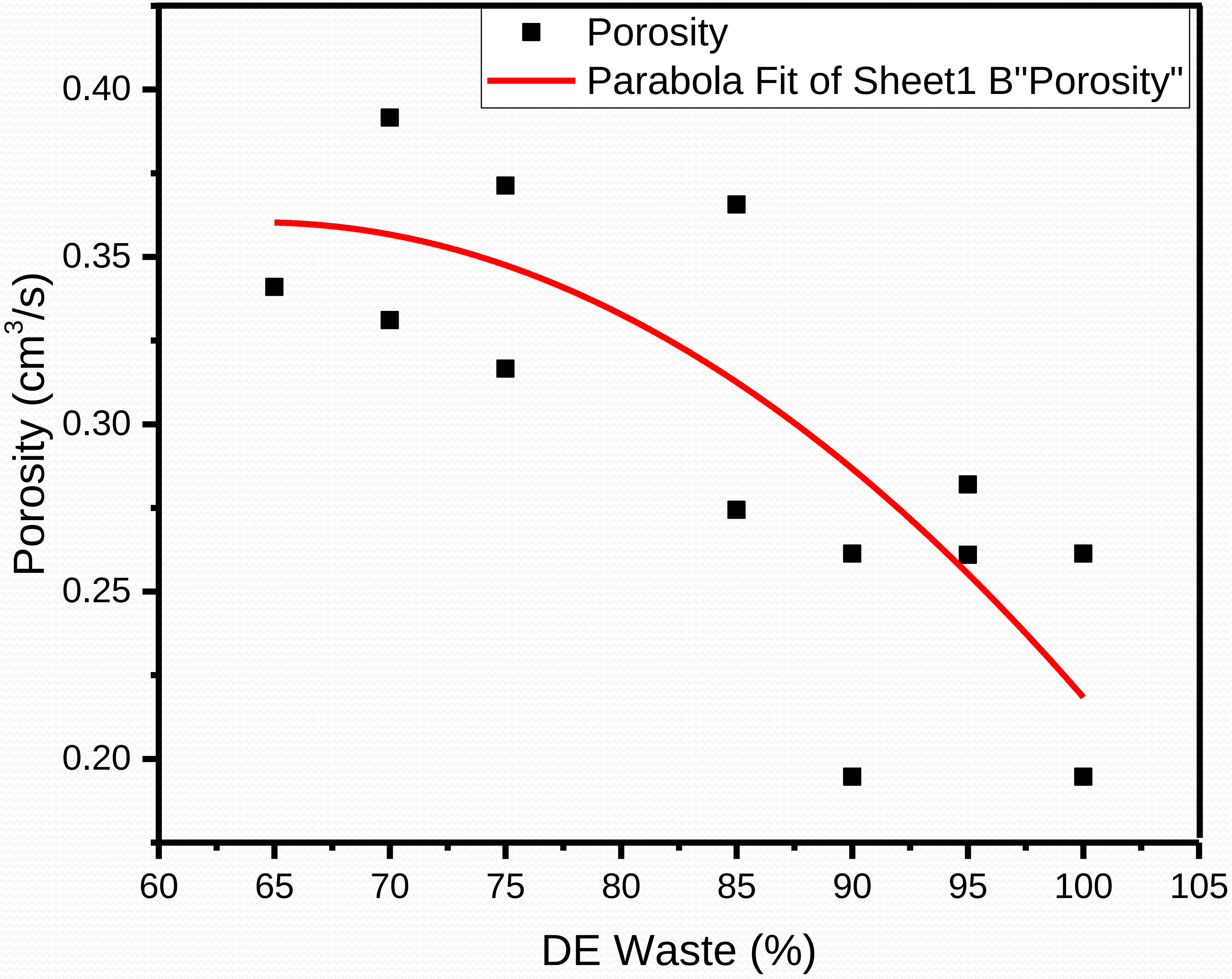
Compression test



Compression test



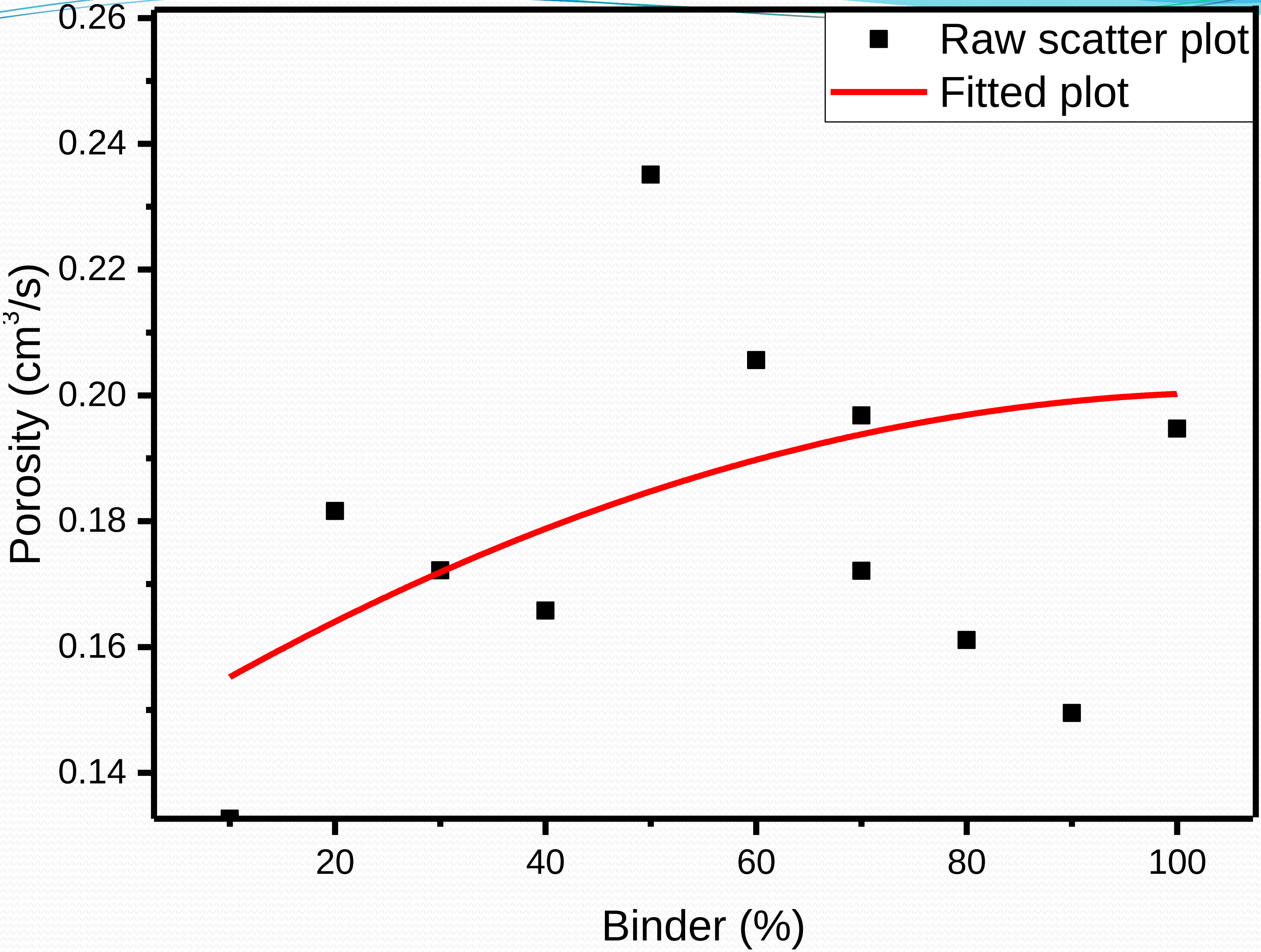
Porosity against Mass of DE waste



Porosity DE waste

Sample Name; D6 Measurement of Porosity											
D6 %	mass B4	mass afte	Mass diff.	density	volume	Porosity		Nmass	Nporosity	Nporosity	Nporosity
%	(g)	(g)		(g/cm3)	cm3/10 s	(cm3/s)		g	(cm3/s)	(cm3/h)	(cm3/day)
100	9.583	12.196	2.613	1	2.613	0.2613		0.27267	0.027267	98.16133	2355.872
100	6.234	8.181	1.947	1	1.947	0.1947		0.31232	0.031232	112.435	2698.441
90	7.012	8.507	1.495	1	1.495	0.1495		0.213206	0.021321	76.75414	1842.099
80	7.014	8.625	1.611	1	1.611	0.1611		0.229683	0.022968	82.68606	1984.465
70	7.832	9.8	1.968	1	1.968	0.1968		0.251277	0.025128	90.45965	2171.032
70	6.938	8.659	1.721	1	1.721	0.1721		0.248054	0.024805	89.29951	2143.188
60	8.074	10.13	2.056	1	2.056	0.2056		0.254645	0.025464	91.67203	2200.129
50	8.199	10.55	2.351	1	2.351	0.2351		0.286742	0.028674	103.2272	2477.453
40	6.652	8.31	1.658	1	1.658	0.1658		0.249248	0.024925	89.7294	2153.506
30	7.088	8.81	1.722	1	1.722	0.1722		0.242946	0.024295	87.4605	2099.052
20	7.088	8.904	1.816	1	1.816	0.1816		0.256208	0.025621	92.23476	2213.634
10	5.658	6.985	1.327	1	1.327	0.1327		0.234535	0.023454	84.43266	2026.384

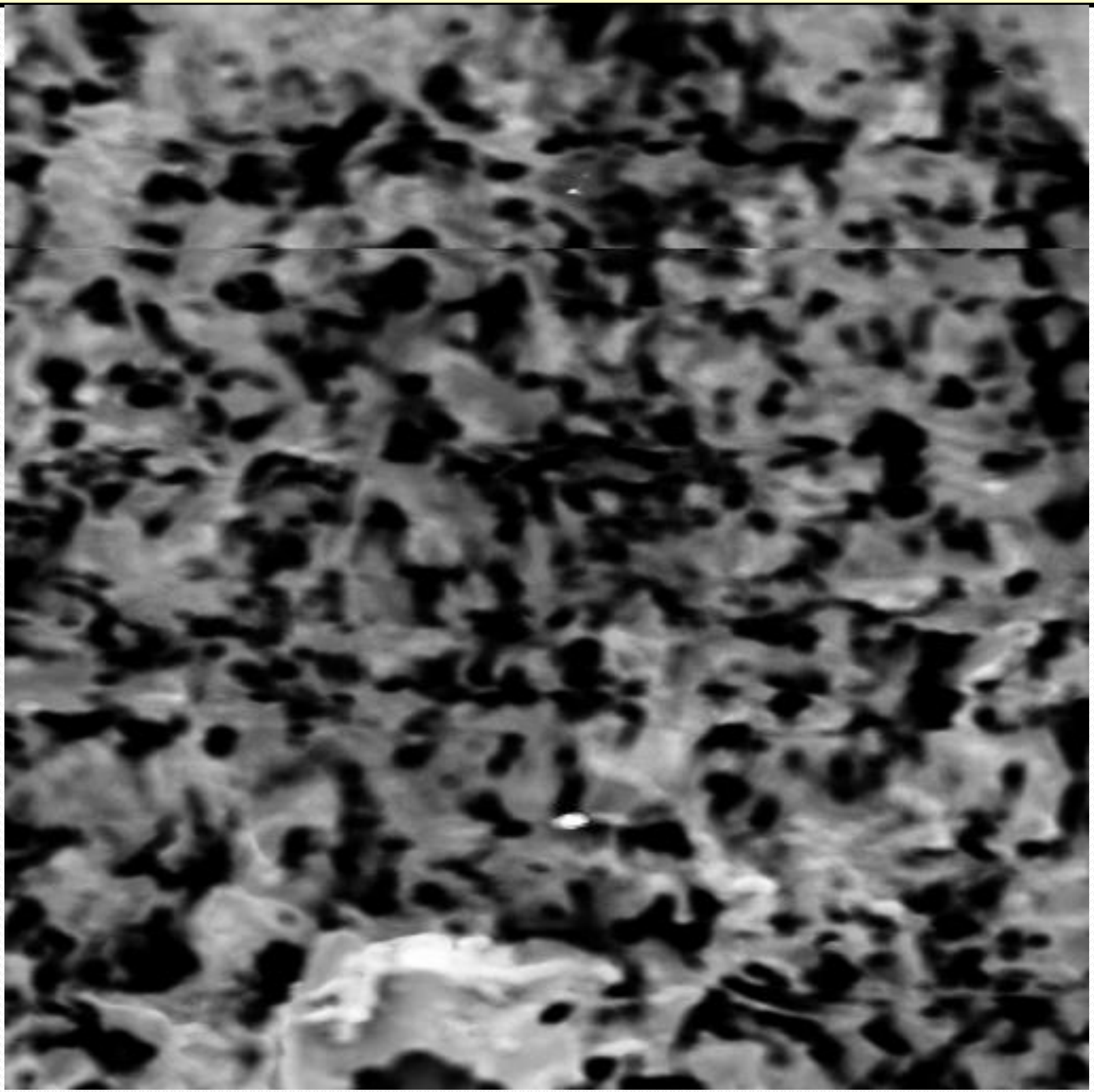
Porosity DE waste



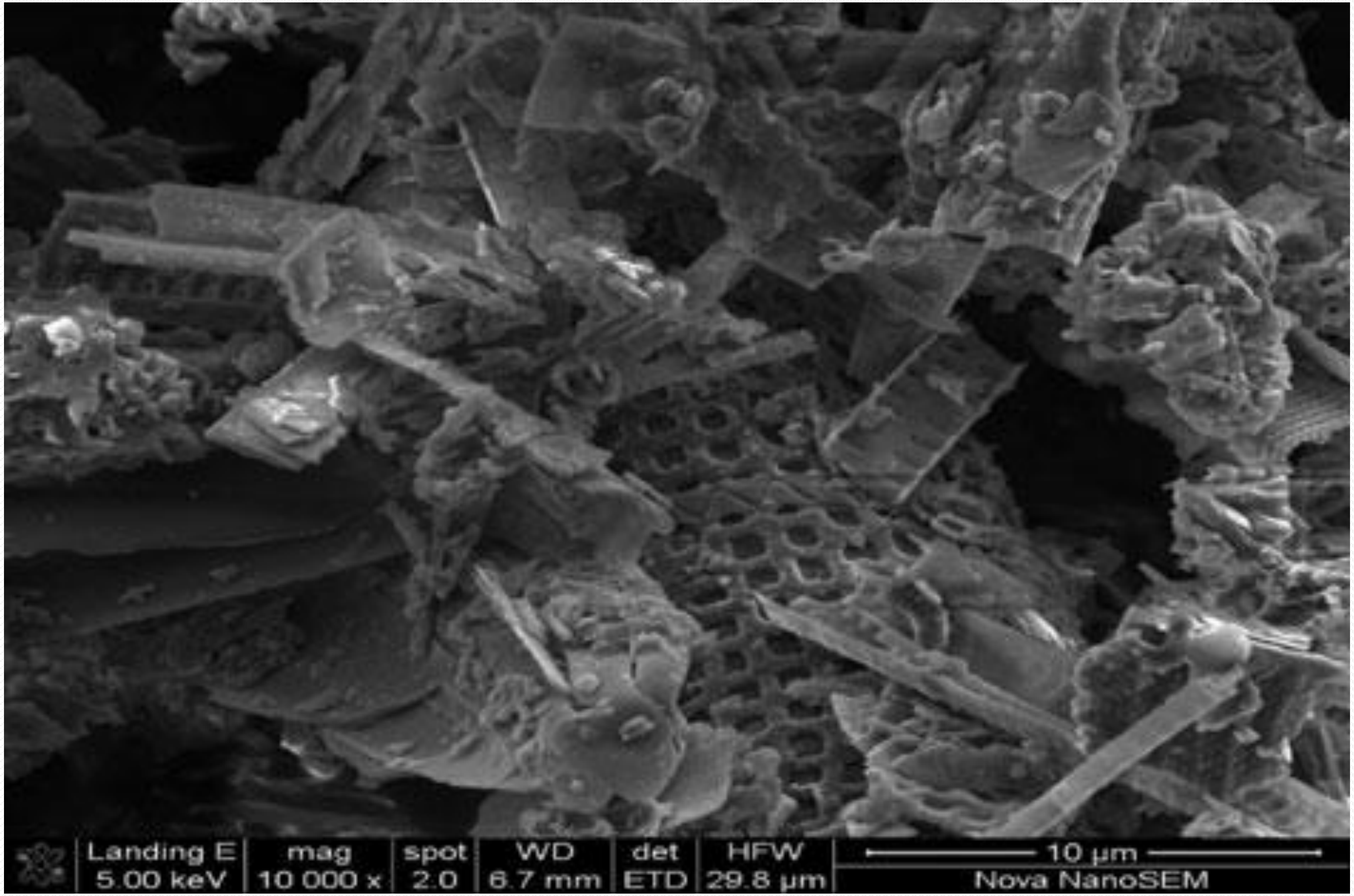
Porosity DE waste with Charcoal

Sample Name; D6 Measurement of Porosity											
D6 %	mass B4	mass afte	Mass diff.	density	volume	Porosity		Nmass	Nporosity	Nporosity	Nporosity
%	(g)	(g)		(g/cm3)	cm3/10 s	(cm3/s)		g	(cm3/s)	(cm3/h)	(cm3/day)
100	9.583	12.196	2.613	1	2.613	0.2613		0.27267	0.027267	98.16133	2355.872
100	6.234	8.181	1.947	1	1.947	0.1947		0.31232	0.031232	112.435	2698.441
95	8.565	11.385	2.82	1	2.82	0.282		0.329247	0.032925	118.5289	2844.694
95	7.915	10.525	2.61	1	2.61	0.261		0.329754	0.032975	118.7113	2849.071
90	6.234	8.181	1.947	1	1.947	0.1947		0.31232	0.031232	112.435	2698.441
90	9.583	12.196	2.613	1	2.613	0.2613		0.27267	0.027267	98.16133	2355.872
85	7.083	10.739	3.656	1	3.656	0.3656		0.516165	0.051617	185.8196	4459.67
85	5.886	8.63	2.744	1	2.744	0.2744		0.466191	0.046619	167.8287	4027.89
80	6.656	10.666	4.01	1	4.01	0.401		0.602464	0.060246	216.887	5205.288
75	5.767	9.48	3.713	1	3.713	0.3713		0.643836	0.064384	231.7808	5562.74
75	5.144	8.31	3.166	1	3.166	0.3166		0.615474	0.061547	221.5708	5317.698
70	5.694	9.005	3.311	1	3.311	0.3311		0.581489	0.058149	209.3361	5024.067
70	5.5	9.416	3.916	1	3.916	0.3916		0.712	0.0712	256.32	6151.68
65	4.448	7.858	3.41	1	3.41	0.341		0.766637	0.076664	275.9892	6623.741

SEM Image at 3000 magnification



SEM Image From Literature



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