RECOVERY OF TALC FROM TALC- CARBONATE SCHIST OF SWAT EMERALD MINES, NWFP, PAKISTAN

Nisar Mohammad[1], Mohammad Mansoor Khan[1]

ABSTRACT

In present research preliminary investigations like petrographic study, grain size evaluation and chemical analysis were undertaken on talc bearing rock of Swat emerald mines, aiming at finding some suitable processing technique to recover talc. A few processing tests using flotation, gravity separation and leaching methods were conducted to see the amenability of talc to enrichment by these techniques. Analysis of seven talcum powder products available in the local market including pharmaceutical grade talc was carried out for comparison with Swat raw- talc under study and to know the level of impurities in it. The results revealed that Swat emerald mines talc rock contains calcite, magnesite, dolomite, muscovite and quartz as impurities. Talc content in the original rock ranges from 60 to 65% and possible to liberate at grind size of 45 microns. Flotation test results revealed that talc upgraded to 85% with 80% recovery using frother as a process aid whereas, upgradation using gravity separation was 82%. The flotation concentrate on leaching further improved and the level of impurities reduced from15 to 8 %.

Key words: *Swat emerald mine, talc, froth flotation, gravity separation, leaching*

INTRODUCTION

The mineral talc is hydrous magnesium silicate with chemical formula $Mg_3 Si_4 O_{10} (OH)_2$. When pure, it contains 63.36% silica, 31.89% magnesia and 4.75 % water of crystallization. Talc is one of the most widely used industrial minerals with more than hundred uses. Industries using talc are ceramics, rubber, paper, plastic, paint, cosmetic and pharmaceutical. The minor uses of talc are in dry fire extinguishing powder, cereal polishing (rice, corn and barley) car and floor polish, bleaching agent, floor wax, water filtration, leather treatment, shoe polish, welding rod coating, printing ink, detergent and washing powder. It is also used as filler in asphalt, in jointing compounds, confectionaries, foam, rubber, putties, automobiles dish boards and bumper trims, sealants and gaskets, textile, refractories, sculpturing, flux, table tops in chemical laboratories, lubricants, anti stick coat on food stuff (chewing gums and confectionaries), animal feed and glues. Each of these industries consumes talc of some particular chemical composition and physical properties[1].

Huge deposits of talc occur in various parts of NWFP as shown in Figure 1. Exact reserves data of talc in NWFP is yet to be confirmed by detailed exploration. However according to rough estimation by Pakistan Mineral Development Corporation, Geological Survey of Pakistan and Directorate of Mines and Minerals, NWFP talc reserves are in the range of 4 to 5 million tons in Kurram agency, 2 to 3 million tons in Sherwan area (Hazara Division) and in Swat area talc reserves are in billion of tons[2].

In Swat area of NWFP emerald deposits occur at different localities like Mingora, Gujar killi, Shamozai, Alpuri. In these deposits talc carbonates and talc silicates host emerald crystals[3]. After recovery of emeralds, the talc bearing host rock is thrown away as a refuse. Being useful talc bearing commodity author felt the need to take research on processing of this waste rock of emerald mines to recover industrial grade talc products through beneficiation so as to save the foreign exchange spent on import of talc and talc products[4].

The fundamental studies through this research would be utilized not only for up gradation of talc deposits of Swat area but also similar deposits exist in Pakistan elsewhere.

EXPERIMENTAL WORK AND DISCUSSION

MATERIALS AND METHODS

Representative samples of talc carbonate rock were collected from different excavation sites of Mingora emerald mine, which were used in the re-

[1]*NWFP University of Engineering and Technology, Peshawar, Pakistan.*

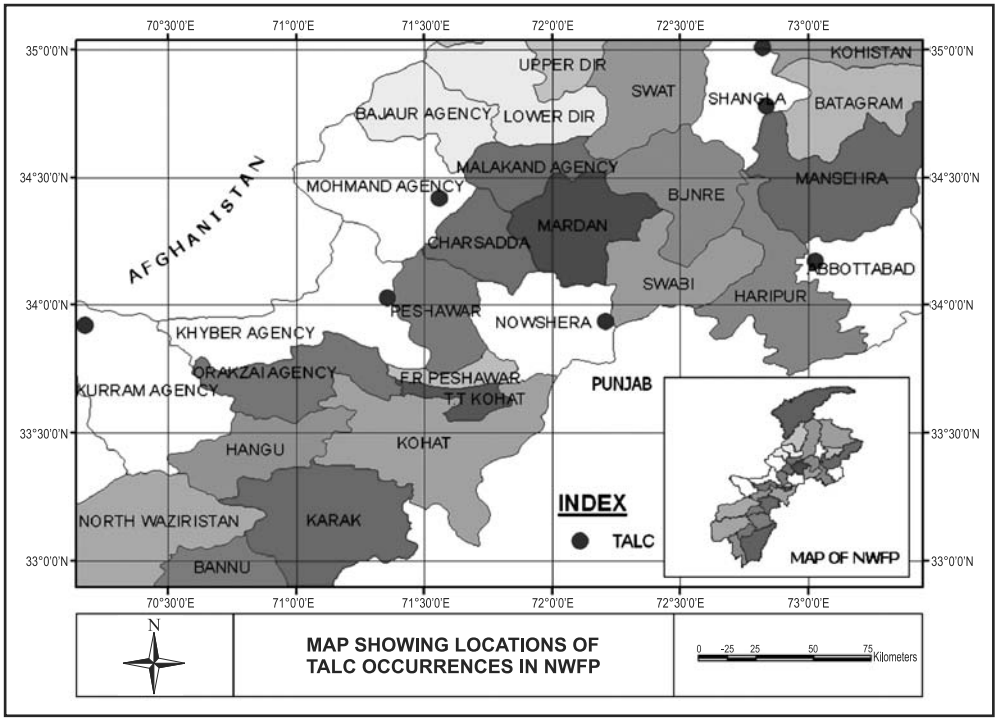

Figure 1: Map Showing Location of Talc Occurrence in NWFP (Source: Directorate of Mines and Minerals, NWFP)

search work. Preliminary investigations were made in Mineral Testing Laboratory (MTL), Hayatabad Peshawar, Mineral Processing Laboratory of Mining Engineering Department, NWFP University of Engineering and Technology, Peshawar, National Centre of Excellence (NCE) in Geology, Peshawar and PCSIR Laboratories Complex, Peshawar. Major equipment and analytical instruments used for the research and its purpose are present in Table1.

In first part of the study preliminary investigations for the chemical and mineralogical composition of talc carbonate rock, mesh size and grindability study were made. In the second part preliminary processing study of the rock was done. The details of these investigations are elaborated under separate headings and tests results are presented in Tables 2 to 9.

A. PRELIMINARY INVESTIGATIONS

1. CHEMICAL ANALYSES OF ORIGINAL REPRESENTATIVE TALC CARBONATE SAMPLE

The bulk sample was ground and subjected to wet screen analysis and the size fractions were analyzed in PCSIR laboratories Peshawar. The metallic elements in the rock i.e. Al, Mn, Pb, were determined by using Flame Atomic Absorption Spectrometer. The other elements i.e MgO, SiO_2, CaO, Na_2O, K_2O and Fe_2O_3 were determined by wet analysis[5]. The analysis results are given in Table 2. The level of impurities to be re-moved from swat talc when compared with chemical analysis of standard cosmetic grade talc as quoted in research paper[6] and websites of talc producing companies is present in Table 3 and illustrated in Figure 2. In this table averaged composition of Swat talc was taken and all the contents except SiO_2 and MgO were determined by difference of the amounts of Swat talc and the standard talc. However, the values of SiO_2 and MgO were calculated as under.

In pure talc the SiO2 and MgO ratio is about 2:1. In Swat talc, SiO_2 content is 29.652 and the MgO content is 35.532. If we compare it with the said ratio of pure talc, the actual MgO of Swat talc is 29.652/2 i.e 14.826% and rest of MgO i.e 35.532 – 14.826 = 20.706 is contributed by the impurities like magnesite, calcite and dolomite etc.

2. MESH OF GRIND

The mesh of liberation of talc grains in the rock was determined in National Centre of Excellence (NCE)

Table 1

S. No	Equipment/Analytical Instrument	Purpose of Use	Laboratory/Organization
1	Flame Atomic Absorption Spectrometer, Model Z-8000, Hitachi, Japan	Chemical analysis (Al, Mn, Pb,)	PCSIR Laboratories Complex, Peshawar.
2	Polarized microscope (Model BX-51) with digital camera (DP-12) Olympus, Japan	Mesh of grind study	National Centre of Excellence (NCE) in Geology, Peshawar.
3	Polarizing Microscope (Microphot-FXA/SA)with Digital Camera (NikonFx 35DX) Nikon, Japan	Mineralogical composition study	Department of Mining Engineering, University of Engineering and Technology, Peshawar.
4	Flotation cell Model No. LF-51-A, KHD Industrieanagen Co. Germany	Flotation test	—Do—
5	Ball Mill Model No. 9-8516, Germany	Grinding of talc rock	—Do—
6	Sieve Shaker Model TG 108 W Macross Corporation Tokyo, Japan	Sieve analysis	—Do—
7	Shaking table (Wilfley Co. England) and Mozley table (Richard Mozley Ltd. England)	Gravity separation	Mineral Testing Laboratory (MTL), Hayatabad Peshawar
8	Petrothin Buehler, Discoplan thin cutting and grinding machines and bonding jig	Thin sections Preparation	—Do—

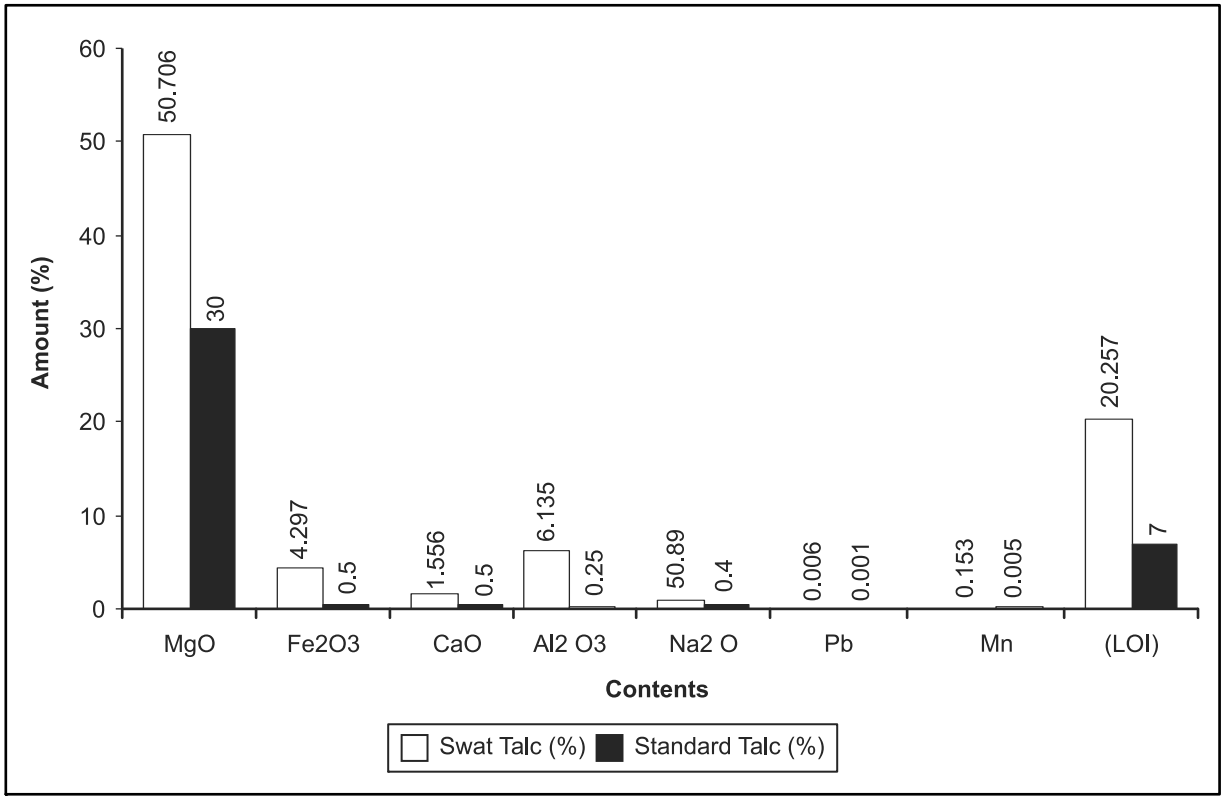

Figure 2. Level of Impurities in Swat Raw Talc

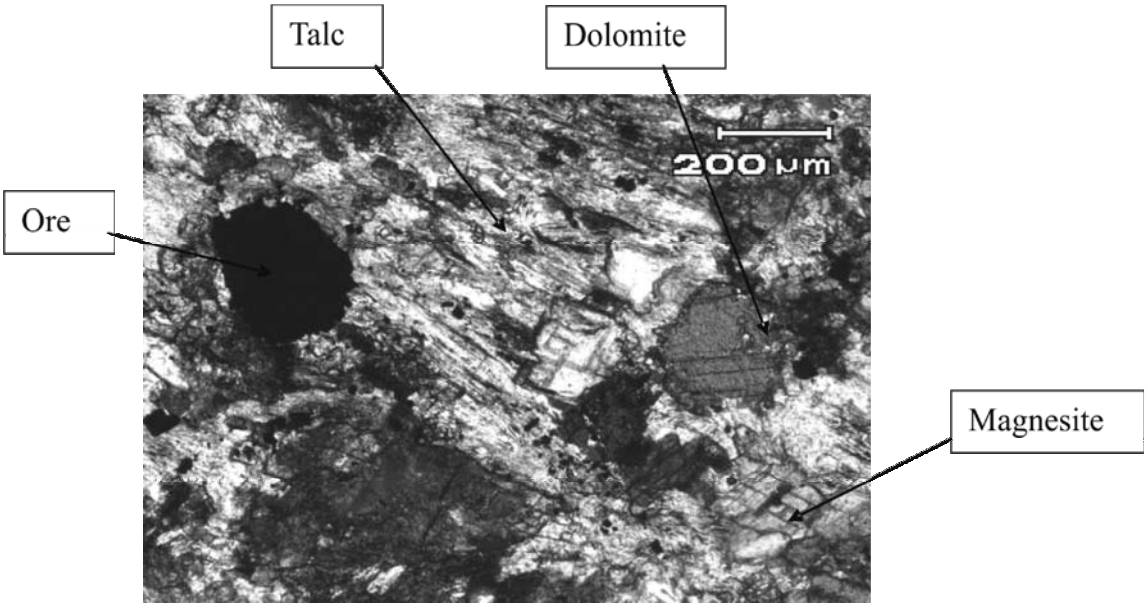

Figure 3. Photomicrograph of talc-carbonate schist for approx. mesh size of talc

in Geology, University of Peshawar. The grain size of the constituent minerals can be seen from the scale on the photomicrograph. Grain size of talc (greenish particles) varied and was measured as below 45 microns as shown in Figure 3.

3. GRINDING OPTIMIZATION

400 grams crushed bulk sample was ground in laboratory size ball mill with the following parameters.

No. of large size balls = 4 (38 mm)

No. of medium size balls = 5 (25mm)

No. of small size balls = 5 (13mm)

Grinding time= 10 minutes

Total charge in the shell = approximately 40% of its volume.

After grinding, homogenizing by coning and quartning and passing through the sample splitter, half the sample was screened dry and half using wet screening. Dry and wet screening was done to compare their efficiency and accuracy. The results are present in Table 4.

4. PETROGRAPHIC STUDY

This study was conducted to know the mineralogical composition and texture of the original rock sample. Knowledge of mineralogical composition and texture is important in selection of processing technique for specific ore. Ten thin sections of talc car-

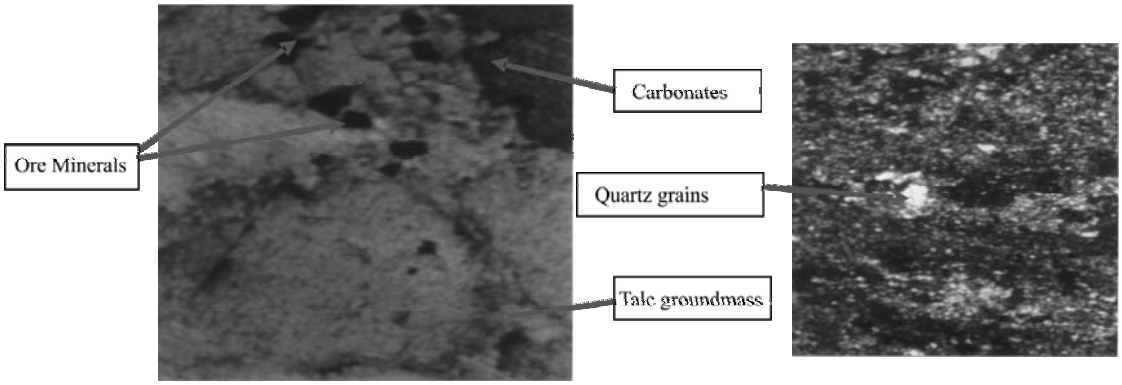

Figure. 4 Photomicrographs of Talc- carbonate Thin Sections

Table2: Chemical Analysis Results of Various Fractions of Wet Screening of Head Sample (Contents are in %)

S. No	Screen Size (Microns)	MgO	SiO_2	Fe_2O_3	Al_2O_3	CaO	Mn	Pb	Na_2O	K_2O	L.O.I
1	+ 150	36.17	19.38	5.16	7.38	1.20	0.18	0.00	0.73	0.23	28.70
2	-150+106	36.05	26.28	3.45	6.37	1.67	0.14	0.004	0.59	0.07	24.03
3	-106+75	33.63	35.08	3.84	7.34	0.54	0.13	0.005	0.31	0.10	17.24
4	-75+53	34.31	33.22	4.65	2.89	2.36	0.18	0.002	1.65	0.55	18.76
5	-53+45	38.98	28.42	4.14	8.41	1.37	0.11	0.009	0.93	0.09	16.81
6	-45	34.05	35.53	4.54	4.42	2.20	0.18	0.009	1.13	0.32	16.00

Table 3: Chemical Composition of Swat Emerald Mines Talc vs. Standard Grade Industrial Talc

Talc of Swat Emerald Mines		Standard Talc	Impurity level
Content	Amount (%)	Amount (%)	Amount by Difference (%)
SiO_2	29.652	60	0.00
MgO	35.532	30	20.706
Fe_2O_3	4.2 97	0.50	3.797
CaO	1.556	0.50	1.056
$Al_2 O_3$	6.135	0.25	5.885
$Na_2 O$	0.890	0.40	0.490
As	———	0.0001	———
Pb	0.006	0.001	0.005
Mn	0.153	0. 005	0.148
Whiteness	———	95	———
Losson Ignition (LOI)	20.257	7.00	13.257

Table 4: Dry and Wet Screening Analysis of Head talc Sample

Screen Size (Microns)	Weight(wt) retained (gms)		% Weight retained (gms)		Cumulative % wt retained (gms)		% Passing	
	Dry Screening	Wet Screening	Dry Screening	Wet Screening	Dry Screening	Wet Screening	Dry Screening	Wet Screening
+ 150	70.5	84.6	35.25	42.3	35.25	42.3	64.75	57.7
–150 + 106	28.4	19.4	14.2	9.7	49.95	52	50.05	48
– 106 + 75	24.1	25.5	12.05	12.75	62	64.75	38	35.25
–75 + 53	69.4	15.7	34.7	7.80%	96.7	72.55	3.3	27.45
–53 + 45	6.1	17.7	3.05	8.85	99.75	81.4	0.25	18.6
-45	1.1	35.1	0.55	17.55	100	100	0	0

Table 5: Mineralogical Composition of Swat Emerald Mine Host Rock Containing Talc

S. No	Mineral	Percentage
1	Carbonates	32-38
2	Talc	60-65
3	Muscovite	4-5
4	Serpentine	1-2
5	Ore minerals	1-1.5

bonate rock samples, collected from different excavations sites of Mingora mine, were prepared in MTL and studied in NCE in Geology, University of Peshawar and Department of Mining Engineering, NWFP University of Engineering and Technology Peshawar. The report of the study is as under.

The Mingora emerald mine talc is medium grained, mostly composed of talc and carbonate minerals with subordinate proportion of ore minerals and quartz grains. Talc is the dominant phase and is mostly recorded in the form of elongated lathlike fibers with parallel orientation to the maximum stress direction. All the flacks of fibrous mass of talc are confined to the groundmass. The carbonate phase is recorded in the form of subhedral to anhedral grains with interlocking boundaries and well-developed rhombohedral cleavages. Ore minerals are recorded in the form of euhedral to subhedral grains as cluster of granules in the groundmass. Quartz is the least observed. The average proportion of the constituent minerals in all the thin sections is given in the Table 5. Photomicrographs of thin sections are annexed below as Figure 4, depicting the constituent minerals.

5. CHEMICAL ANALYSIS OF TALCUM POWDERS AND PHARMACEUTICAL GRADE TALC

Six samples of talcum powders of industrial grades and one sample of pharmaceutical grade talc available in the local market were analyzed in the laboratory to know their composition and compare it with the raw talc under study. The results are given in Table 6.

B. PRELIMINARY PROCESSING STUDIES

1. FLOTATION TEST

A flotation test was conducted using conventional bench scale flotation cell and the following optimum parameters cited in the literature[7,8,9,10] and the results are presented in Table 7 and graphically illustrated in Figure 5.

Optimum Flotation Parameters:

Percent solids = 20 % (200gm/litre), pH of the pulp = 7±0.5, Frother type = Propyl glycol Frother

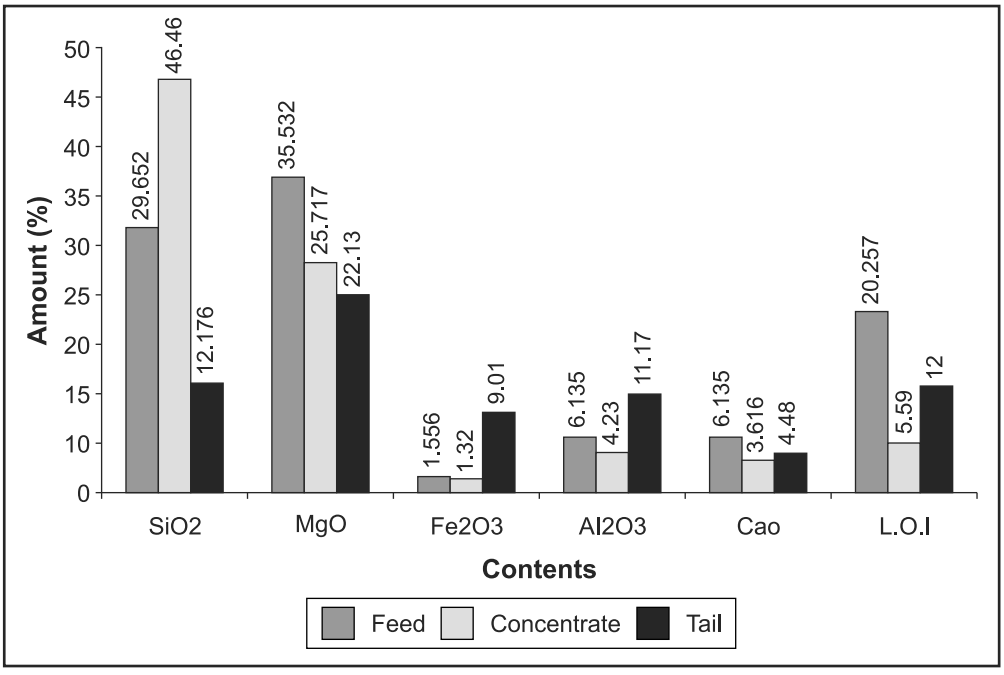

Figure 5. Showing upgradation of Talc by Flotation test

Table 6: Chemical Analysis Results of Talcum Powders Available in Market (Contents are in %)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Mn	Pb	Na_2O	K_2O	Total
1	8.47	46.36	1.28	13.32	5.60	25.21	0.00753	0.00185	0.634	0.00	100.883
2	4.73	50.81	1.10	8.79	3.36	30.38	0.00447	0.00199	1.507	0.597	101.280
3	11.41	45.73	1.10	9.46	7.94	23.55	0.014700	0.00058	1.320	0.470	100.995
4	12.35	50.81	5.24	0.0014	7.61	23.30	0.0088	0.00134	0.603	0.089	100.014
5	17.05	45.33	5.31	0.0015	2.11	28.73	0.00307	0.00	0.885	0.140	99.559
6	7.4	51.55	5.86	0.0015	1.09	33.85	0.00274	0.00	0.863	0.219	100.886
7	3.01	56.56	6.00	0.52	0.00	33.44	0.004	0.0004	0.30	0.05	99.884

1. Touch me Talcum Powder
2. Wild Flower Perfumed Talc
3. Medora Perfumed Talc
4. Dream Flower Talcum powder
5. Cuticura Hygiene Plus Talcum Powder
6. Mother Care Baby Talcum Powder
7. Pharmaceutical grade Talc

Table 7: Results of Flotation Test on Head Sample (Contents are in Percent)

Content	Feed	Concentrate (Weight recovered= 134.70gms)	Tail (Weight recovered= 65.30gms)
SiO_2	29.652	46.46	12.176
MgO	35.532	25.717	22.13
Fe_2O_3	1.556	1.32	9.01
Al_2O_3	6.135	4.23	11.17
CaO	6.135	3.616	4.48
L.O.I	20.257	5.59	12

Table 8: Results of Gravity Separation Tests on Head Samples

Mozley Table Test	**Shaking Table Test**
Weight of feed = 200 grams	Weight of feed = 200 grams
Feed particle size = -53 +45 microns	Feed particle size = -53 +45 microns
Concentrate (light) weight = 173 gms	Concentrate (light) Weight = 171.9 gms
Tail (heavy) weight = 32gms	Tail (heavy) weight = 28.1gms
Talc content (acid insoluble) in concentrate =82 %	Talc content (acid insoluble) in concentrate=68 %
Talc content (acid insoluble) in Tail = 40%	Talc content (acid insoluble) in tail = 45%

Dosage = 0.1 kg/ton, Feed particle size = -53 +45 microns, Impeller speed = 1200rpm Froth collection Time = 10 minutes

2. GRAVITY SEPARATION TEST

Two gravity separation tests were conducted using shaking table and Mozley table each with capacity of 2 to 3 tons/day. Shaking table dimensions is 4.5ft x 2.5f, slope angle is $5^{o,}$ stroke rate is 125 jerks per minute, riffles are of fiber glass and motor of 1hp. Mozley table dimensions is 5x2ft, slope 1.7^{o}, water flow rate 2litres per minute, stroke 3.5 and operation time was kept 3 minutes. The tests parameters and results are given in Table 8.

Table 9: Leaching Tests Result (Contents are in %)

Sample	Leaching	L.O.I.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	K_2O	Pb	Mn	Total
Leach Test 24 hours	HCl	08.70	47.23	02.19	12.05	02.51	26.24	0.0851	0.026	0.0019	0.095	**99.05**
Leach Test 24 hours	—	09.64	48.26	03.13	11.18	01.64	25.17	0.1143	0.078	0.0012	0.0184	**99.23**
Leach Test 48 hours	—	16.90	39.11	03.15	09.48	01.10	29.59	0.0259	0.025	0.00	0.0331	**99.67**
Leach Test 48 hours	—	13.53	39.08	02.26	15.28	01.05	27.16	0.1338	0.0491	0.0010	0.0236	**98.56**
Leach Test 72 hours	—	07.61	46.93	01.27	14.59	02.11	26.84	0.0985	0.129	0.00	0.0172	**99.59**
Leach Test 72 hours	—	08.01	45.96	01.58	15.04	01.55	27.30	0.0800	0.027	0.0016	0.0171	**99.55**
Leach Test 96 hours	Water	18.44	30.89	03.12	12.50	03.82	29.85	0.0735	0.027	0.0021	0.1561	**98.87**
Leach Test 96 hours	—	17.64	32.95	3.85	11.43	2.07	30.81	0.0592	0.017	0.0024	0.1672	**98.99**

***Talc Content Determination:**

Talc content in the test products was determined using acid insoluble technique[11]. The acid used was HCl (30%) and leaching time was kept 20 hours. Since talc is insoluble mineral present in talc bearing rock, dissolving the talc bearing rock in dilute hydrochloric acid will dissolve most of the impurities particularly carbonates and the acid insoluble content left behind can be taken approximately as talc content. Presence of quartz and other silicates and insoluble iron will increase the acid insoluble content of the rock and deduction must be made in the acid insoluble content (talc %) for these minerals. The amount of quartz, other silicates and insoluble iron is obtained from mineralogical study of the talc rock. Same method was followed for talc determination in this research work

3. LEACHING TESTS

With varying leaching time of 24hrs, 48hrs and 72 hrs, leaching tests were conducted using HCl (37%) as leaching agent[12,13]. Tests were repeated for each leaching time to ascertain reproducibility. The tests products were analyzed and the results are presented in Table 9. In separate test water was used as leaching agent for comparison with HCl. The amount of loss in leaching indicates quantity of carbonates dissolved.

CONCLUSIONS

In terms of elemental composition MgO, Fe_2O_3, CaO, Al_2O_3 contents in the rock under study are in excess and level of these elements is required to be maintained in talc in desired limits for its industrial applications. Wet sieving is preferred than the dry sieving of talc carbonate rock, because in case of dry sieving the fine size particles block the openings of the sieves and render the sieving analysis inaccurate. Mesh of liberation of talc is approximately below 45 microns. This was confirmed by mesh of grind study. Grinding and screening studies reveal that the grinding time needs to be increased than taken in the study (10 minutes) to get maximum quantity of desired size material i.e. below 45microns for processing tests.

Petrographic study reveals that talc content in the rock varies from 60 to 65 % and the total carbonate content in the rock varies from 35 to 40 %, which is mostly magnesite. However, other than magnesite, the calcite, dolomite, serpentine, silica and iron bearing minerals are the undesired minerals associated with Swat talc- carbonate rock in small proportion, which need to be removed. The talcum powder prod-

ucts collected from market and analyzed in this research study contain CaO, Fe_2O_3, MgO and Al_2O_3 on higher side than the limits expressed in talc specifications. It needs to be confirmed that the talc sold in the market is adulterated or additions are desired for industrial purpose.

Flotation technique is suitable for talc recovery from talc bearing rock but it cannot upgrade the talc to desired limits alone. Due to great specific gravity difference, most of the metallic impurities associated with talc can be easily separated from talc with gravity separation. Results were better by using Mozley table than the shaking table. Leaching dissolve maximum carbonate content of talc rock. In the original rock the loss on ignition is about 20%, which indicate that Swat talc contains maximum of carbonate impurities. Using HCl (37%) as leaching agent with 72 hours leaching time gives better results in term of carbonates removal from the talc.

Literature survey reveals that combination of froth flotation, gravity separation and leaching techniques should be used to obtain specialized grade talc suitable for cosmetic and pharmaceutical industries.

REFERENCES

1. *Virta, R., 1989. "The Talc Industry - An Overview", Information Circular 9220, U.S Bureau of Mines.*
2. *Zaki Ahmad and Razi Ahmad Siddiqi, 1993. "Minerals and Rocks for Industry, Volume III", Geological Survey of Pakistan.*
3. *Arif, M & Ummar, M. Khattak. 1999. "The Emerald Hosting Magnesite Rich Rocks from Swat, NW Pakistan", Geol. Bull. Univ. Peshawar, Vol 32, 63 – 70.*
4. *Expert Advisory Cell, Ministry of Industries and Production, Govt. of Pakistan, 2004. "Investment Oriented Study on Minerals and Minerals Based Industries, Volume 1".*
5. *Standard Methods of chemical analysis by N.H. Furman and Scott. 6th Edition.*
6. *Robbins, J (Associate Editor), 1985. "U.K Cosmetics - Make up Minerals", Industrial Minerals (London) No. 216, 75-79.*
7. *Al-Wakeel, M.I., 1996. "Geology and Beneficiation of Some Egyptian Talc-Carbonate Rocks". Ph.D Thesis Ain Shams University, Cairo, Egypt.*
8. *Adel Vatandoost., 2001. "How to Reach Pharmaceutical Grade Talc from Iranian Resources", CIM Minespace.*
9. *P.E. Sarquis and M. Gonzalez., 1998. "Technical Note on Limits of the Use of Industrial Talc-The Carbonate Effect". Minerals Engineering Vol. 11, No.7, 657-660.*
10. *Anderws, P. 1986. "Processing Talc in Canada. A Review of Studies at CANMET". Industrial Minerals. 63-69.*
11. *Andrew, P.R., 1985. "A Laboratory Study of The Flotation Circuit at Baker Talc Inc. High Water, Quebec", Industrial Minerals, CIM Bulletin, 78, No. 884.*
12. *Unal Akdemir, Taki Guler and Guvengez Yildiztekin, 2005. "Flotation and Entrainment Behavior of Minerals in Talc–Calcite Separation" Scandanavian journal of Metallurgy, Vol, 34, issue 4, 241-244.*
13. *Mahmoud M Ahmad, Galal A Ibrahim, Mahamed M.A. Hassan, 2007. "Improvement of Egyptian Talc Quality for Industrial Use by Flotation Process and Leaching" International journal of Mineral processing 83, 132-145*